KNOWLEDGE AND SKILLS IN THE GLOBAL ECONOMY: THE CASE OF THE EUROPEAN BIOTECHNOLOGY INDUSTRY

SALLY HAYWARD

A thesis submitted in fulfilment of the requirements of
The Nottingham Trent University for the Degree of Doctor of Philosophy

This research programme was carried out in collaboration with the
Commission of the European Communities COMETT II University Enterprise Training
Partnership, BEMET

1997

In loving memory of my dear Father
and to Molly

‘The empirical basis of objective science has thus nothing ‘absolute’ about it. Science does not rest upon solid bedrock. The bold structure of its theories rises, as it were, above a swamp. It is like a building erected on piles. The piles are driven down from above into the swamp, but not down to any natural or ‘given’ base; and if we stop driving the piles deeper, it is not because we have reached firm ground. We simply stop when we are satisfied that the piles are firm enough to carry the structure, at least for the time being ‘

- Karl Popper, The Logic of Scientific Discovery, 1968, p.106

ABSTRACT

This thesis examines the suggestion that the Western economies are witnessing the globalisation of markets, production, finance and knowledge which has placed severe limits on the economic role of national governments, and that effective public policy is now restricted to the promotion of education and training which is the chief determinant of national competitiveness in the new global, knowledge-intensive economy. In practice, governments have become heavy supporters of knowledge-intensive industries through policies aimed mainly at upgrading human capital. This view of the role of economic policy amounts to a new academic and policy orthodoxy and is subject to critical examination in this thesis. This thesis contends that some convergence of economic systems has occurred with national economic development enmeshed in a global economy in which some positions are more rewarding than others. At the same time, the nation-state remains central to shaping industrial activity. Nowhere is this argument more true than in 'high technology or 'knowledge-intensive' sectors where increasing returns apply and where government policies continue to play a critical role in determining industrial development. These arguments are examined through a case study of skills and training issues in European biotechnology - purportedly a sector exposed to processes of globalisation. The study reveals the explanatory limits of the new orthodoxy. It reveals a picture of biotechnology in which economic development is far more complex than originally assumed at the beginning of the skill shortage study. The economic validity of the argument that investments in skills and training are a panacea to improving productivity in a knowledge-intensive industries and are thus the key to the economic prosperity of nations is criticised. It is shown how popular assumptions in relation to the scientific labour market are misplaced and inappropriate. The development of the sector is shown to have been heavily influenced by the operation of national structures and the ways in which these have structured the level and nature of demand for the industry's products and the availability of investment finance for new technologies. Significant changes in the dimensions of national biotechnology industries are acknowledged to have occurred through the globalisation of capital and markets, but the role of the national environment and of the strategic choices of governments in developing the sector are seen to have been highly influential in shaping the dynamics of the industry. Although the failure of the European biotechnology industry to develop at the pace originally envisaged has been attributed to skill shortages, it is argued that the pace of economic development in this sector has been influenced also by the power of national and transnational social groups, differential access to knowledge and finance - in short by the combination of the institutional characteristics of national societies and the emerging power of transnational movements.

CONTENTS

ACKNOWLEDGEMENTS

There are a number of people who I should like to thank for the preparation of this thesis and for persuading me that I could, in fact, undertake the task of completing a Ph.D.

To begin, I should like to thank all my colleagues in the Centre for Urban and Regional Development Studies at Newcastle University for their advice, support and for giving me the opportunity to continue with my research in a pleasant and often comforting environment. In particular, I would like to give my special thanks and gratitude to John Tomaney for reading again and again several draft manuscripts, for unprecedented levels of patience and for spending far too long discussing ideas with me in Cafe Pani.

Beyond CURDS, others assisted me greatly in the conduct of my research. A special thanks is extended to Tony Payne for his unerring support in my endeavours in theory and his continual belief in my abilities. During the course of the fieldwork and questionnaire preparation I received wide help, advice and support from members of the biotechnology community: Martin Griffin at Nottingham Trent University, for helping me to appreciate the differences between the natural and social sciences and for his significant and important contribution to the preparation of the empirical research in chapter seven; the BEMET steering committee, particularly Tony Godfrey, Neil Barnes and Louis Da Gama for taking an interest in the study and providing important information and advice which greatly helped in the preparation of chapters five and six;

and to Neville Davies for his forbearance for teaching a non-statistician. I am also grateful to the support and assistance received from the BEMET secretariat at The Biochemical Society, Annie Walshe especially, and from the secretariat at Nottingham Trent University efficiently organised by Joanne Curtis. I also express my gratitude to Martin Griffin and Chris Farrands for their comments on my penultimate draft.

My friends and family have offered me much support over the period and have always encouraged my endeavours and I am deeply grateful to Jez Tatman for his constant support in 'the early days'; to Alisun Brennan for never letting my ire weaken even in the face of what seemed total adversity and her oodles of friendship; to Simon Rood for putting up with my tantrums; to Penny, Paul, Sophie and Emma for offering me a warm environment in which to retreat and to Molly for her unerring belief in her daughter's capabilities!

The research on which this thesis is based was conducted whilst working as an Research Assistant for the University Enterprise Training Partnership BEMET in the Department of Life Sciences at The Nottingham Trent University and while in receipt of an EC COMETT funded scholarship.

FIGURES

TABLES

CHAPTER ONE

INTRODUCTION

1. Preamble

1.1 Globalisation and the politics and economics of education and training

In the United States, the work of political economists Robert Reich and Lester Thurrow (Reich, 1991; Thurrow, 1992) address some of the key problems which currently face Western capitalist economies. Both commentators have been highly influential in the Clinton Administration in the US and with this enhanced credibility their ideas have more recently began to be taken up with enthusiasm by European politicians. In both Reich and Thurrow's work clear messages are sent: globalisation characterises the international system, the nation-state has become a less important entity in it and the external competitiveness of a country is now the main determinant of economic prosperity. However, it is the work of Reich that is of particular interest for this enquiry given the significance that he attaches to the skilled labour market in contemporary economic development. In *The Work of Nations* published in 1991, Reich offers an assessment of the United States in the contemporary global economy whereby national economies and products are obsolete and each nation's primary assets are its citizens' skills and insights. Specifically, Reich argues that traditional classifications of work have become anachronistic in the global economy and that an assessment of the competitive positions of Americans in the global economy requires new categories of work. For Reich, there are three new categories of work emerging, corresponding to three different competitive positions in which Americans find themselves. These are categorised as routine production services, entailing '...the kinds of repetitive tasks performed by the old foot soldiers of American capitalism in the high-volume enterprise' (1991, p.174). In the contemporary knowledge society, Reich locates many information processing activities in this category. The second category is in-person services. This type of work centres on the function of hours worked or amount of work performed. These services are person-to-person and thus not sold world-wide. Included in this category are retail sales workers, house-cleaners and any form of employment where '..in-person servers are in direct contact with the ultimate beneficiaries'(1991, p.176). The final category, and the object of specific interest for this enquiry is the symbolic-analytic services. Like routine production services, symbolic analytic services can be traded world-wide and thus 'must compete with foreign providers even in the American market.' (1991, p.177). The point about this category of work is that symbolic analysts do enter world commerce as standardised items and only occupy a very small proportion of the overall labour market. Highly skilled, these workers trade instead the manipulations of symbols - data, words, oral and visual representations. Reich explains:

> '..symbolic analysts sit before computer terminals - examining words and numbers, moving them, altering them..formulating and testing hypotheses, designing or strategizing...Most symbolic analysts have graduated from four-year colleges or universities; many have graduate degrees aswell. The vast majority are white males, but the proportion of white females is growing ... symbolic analysis current accounts for no more than 20 percent of American jobs' (Reich, 1991, p.179).

To summarise Reich's overall thesis, superior human resources are central to the wealth of nations. This argument is centred around an widely held belief that industrial production has undergone some form of transformation. He explains:

> '[S]uccessful businesses in advanced nations..... are moving to a higher ground based on specifically tailored products and services. The new barrier to entry is not volume or price; it is skill in finding the right fit between particular technologies and markets. Core corporations no longer focus on products as such, their business strategies increasingly center on specialised knowledge' (Reich 1991, p.84).

Changes in technology now enable the instant addition of intellectual and financial capital to the process of production which create 'global webs' - the threads of these webs being computers, facsimile machines, satellites, high resolution monitors and modems, '..linking designers, engineers, contractors, licensees and dealer's world wide' (Reich, 1991, p.111). But more important than these artefacts of technology are the bearers of intellectual and financial capital - the highly educated problem-solvers, -identifiers and -brokers, or symbolic analysts that form the 'partnerships' that are the essential ingredient to these global webs. As he describes it, the global enterprise is:

> '....evolving into an international partnership of skilled people whose insights are combined with one another and who contract with unskilled workers from around the world for whatever must be standardised and produced in high-volume' (Reich, 1991, p.132).

Reich's view creates an image of a world of 'stateless' companies bonded in an international division of labour whereby competitiveness depends on the functions that labour perform. The economic prosperity of a region will depend on the quantity and quality of symbolic analysts there. And, in order to obtain this labour, stateless enterprises are prepared to 'spin' global webs by searching world-wide for high-paid, high-value symbolic analysts and lower paid, lower-value routine producers. Based on this explanation of the organisation of states, firms and markets, Reich infers that the enterprises that create employment are comparatively unimportant. Hence central location has become irrelevant. As he comments:

> '....in the emerging high-value economy, which does not depend on large scale production fewer products have distinct nationalities .. [q]uantities can be produced efficiently in many different locations to be combined with all sort of ways to serve customer needs in many places. Intellectual and financial capital can come from anywhere and be added instantly' (Reich, 1991 p.112).

For Reich, the policy prescription based on this analysis is that the prime role for national government is to upgrade the skills of the domestic workforce and increase the quantity and quality of its potential symbolic analysts. A secondary role for government is within limits provide some inducements to enterprises of whatever national origin to attract inward investment. This specific policy judgement and the analysis on which it is based is of specific interest to this enquiry. As regards the analysis this more extreme version of the globalisation thesis adopted by Reich pictures the global economy where the nation-state no longer functions as a legal entity within its own borders or within its international affairs. The concept of national differences in innovative capabilities determining national performance is challenged on the grounds that transnational corporations (TNCs) are changing the face of economic activity in the direction of globalisation. Thus in the world economy, only two forces actually matter, global market forces and transnational companies, neither of which are subject to effective global governance. The implication of this perspective is that the global system is governed by the logic of global market competition, and public policy will be at best secondary, since no governmental agencies (local or national) can match the scale of market forces. Following this analysis, the extreme globalisers argue that national policies are futile, since economic outcomes are determined wholly by macroeconomic forces such as global financial and knowledge flows and by the internal decisions of transnational companies. In this sense, national governments are subordinated to the level of municipality in the global system: their economies, are no longer 'national' in any significant extent and they can only be effective as governments if they accept their reduced role of providing locally the public services that the global economy requires of them.

This analysis has important implications for understanding state policy-making. The idea that the national environment is less important for sustaining competitiveness as a consequence of powerful, global macroeconomic forces has begun to pervade debates in Europe, especially in Britain. Based on this analysis of the international system, the industrial policy debate has shifted toward how to improve the supply-base of national (and regional) economies, particularly in countries and peripheral regions in Europe that have began to rely on the attraction of direct foreign investment as a source of its economic development, for example, in Scotland, Wales and Ireland. Crucially, the implications of this analysis for state policy-making are clear: interventionist industrial policies matter less because governments can only ensure that investments are made in the quality and quantity of its people and in improving the supply-base of its economy more generally.

What is particularly interesting about this argument is how it resonates with traditional and conservative assumptions about the economy, despite, for example in the case of Reich, to have emerged from a body of ideas that sought to challenge these very assumptions. Investments in education and training are perceived to be the most important dimension of industrial policy. And in tandem with the more extreme version of the globalisation thesis, there has been a re-assertion of the orthodox economics assumption that investments in human capital improve productivity leading to a political attractiveness to such arguments in a period where most industrialised societies are faced with growing unemployment levels. This has elevated the politics of education and training to a 'new growth theory' in many political circles (Hutton, 1996) and the emergence of a 'new policy orthodoxy' in relation to government, the national environment and industrial development.

There are numerous examples of this trend of thinking in Britain. In the British political ether there now seems to be very little difference between the ideas of the Right and the patois of the New Left. For example, across the spectrum, the British political parties throughout the late 1980s and early 1990s have emphasised the role of supply-side policies as the basis for upgrading industrial and human capital. Skills shortages are a perennial concern in the British economy. Rarely a month passes without the publication of some survey pointing towards the existence of a problem with respect to the skills base of the British economy. Anecdotal evidence of the existence of skills shortages at organisation or industry level gains even more frequent exposure. Indeed, it is not difficult to find statements of almost religious belief about the value of employee training in policy documents concerned with improving UK competitiveness. From the Government's second Competitiveness White Paper entitled *Forging Ahead* comes this: '[t]o compete internationally the UK [needs] employers who see the importance of developing the skills of their workforce'(1993, p.78). Similar sentiments are expressed in the Labour Party's statement on industrial policy *Winning for Britain,* (1996) arguing repeatedly that it is the quality of the workforce which is now the essential determinant of international competitiveness. This is a continuing theme throughout the Labour Party literature. In 1993, in *Labour's Economic Approach*, it is stated that '..capital is more than ever a global commodity, highly skilled labour is now finally acknowledged to be the critical resource' and that 'to enhance the value of labour [is] a policy objective which is the key...to a successful economy.'(1993, p.9). Again, the point was forcefully made in a recent Fabian phamplet by the Shadow Chancellor, Gordon Brown. As he put it, 'in the modern global economy, where capital, raw materials and technology are internationally mobile and tradable world-wide, it is people - their education and skills- that are necessarily the most important determinant of economic growth' (1994, p1). The policy corollary of this is that there should be a substantial increase in investment in education and training and to that end small businesses should be 'obliged to invest a minimum amount on training their workforce', or 'make a contribution to the local and national training effort' in a effort to prevent 'free riders' poaching the products of the training investments of others (The Labour Party, 1992, p.13).

It is clear that there is much which is laudable in these arguments - investments in education and training are a worthwhile pursuit for any government aiming for the widening of educational opportunities and the general development of skills within the population to help reduce wage inequalities in some growing sectors. The argument runs that a shortage of skills throughout the British workforce may contribute towards a lower level of productivity and a lower rate of productivity growth in the British economy when compared with other advanced industrialised societies. Research by the National Institute of Economic and Social Research has placed heavy emphasis on the under-skilling of the British workforce in explaining the lag in productivity levels in a number of British industries when compared with their German counterparts (Prais, 1981; 1990). Recent research by the National Institute in a study of the chemical industries in the two countries found the same skills gap as in industries previously studied, but without this gap having the same adverse impact on relative Britain's productivity (Mason and Wagner, 1994). This cast considerable doubt upon how far the Institute's earlier findings could be generalised to other industries and, more importantly, the relevance of this strategy for supporting certain sectors in seeking to enhance competitiveness within them. As this study will show, skill shortages are a slippery concept, ill-defined and measured in a variety of ways. Moreover, there is a reluctance to go beyond the headlines proclaiming that *x* per cent of firms are complaining about skill shortages according to the latest survey, to ask exactly what are the implications for economic performance, if any, of the existence of any given level of reported skills shortages.

The main concern of this thesis is to explore and test the validity of the argument that investments in skills and training are a panacea to the economic competitiveness of firms (and the overall prosperity of nations). Despite the significance attached to education and training, there has been little analysis of knowledge and skills in the global economy. As I show, where the labour market has been discussed, it has primarily been driven by neo-classical theories (the human capital model) which imply that investments made in human capital lead to increased firms' competitiveness. In practice, governments have become heavy supporters of knowledge-intensive industries through policies aimed at mainly upgrading human capital. This is subject to critical review in this thesis.

1.2 Claims to Originality in the Thesis

The thesis advanced is that an industrial strategy premised on the benefits derived from investments in human capital neglects the complexity of the production system of which skills and training constitutes but one dimension. Whilst some form of economic convergence has occurred in national economies, at the same time the nation-state still remains central to shaping industrial activity.

In so arguing, a number of alternative perspectives are taken as important explanations of the way in which markets function. For example, British and increasingly European mainstream economic theory is almost derivative of orthodox neo-classical work in the United States. Krugman states that as early as the mid-1980s the concept of rational expectations in macroeconomics, for example, had been exposed as a fallacy, although not everyone in conventional economics could conceive of an alternative, so powerful has been the orthodoxy (Krugman, 1994). However, neo-classical theories continue to be the mainstream way of thinking about economics in European universities. And, exponents of an alternative perspective in economics have, generally, been side-lined. Following in this alternative tradition, I argue that new methodological theories are necessary to understand the overall relationship between knowledge and skills and the economic development of global, high-technology sectors such as biotechnology. As this study of the European biotechnology industry shows, the assumption that investments in human capital can improve the competitiveness of firms is an oversimplification of the development of this sector and fails to account and explain other related factors beyond that of increasing the supply of skilled workers that have impeded biotechnology economic development in Europe. For example, the disorganised nature of the science and technology co-ordination between European member states, cultural barriers within Europe which prevent the free movement of personnel, the problems facing small firms for recruiting outside the nation-state, the lack of financial incentives to attract the right personnel, an under-developed demand structure for biotechnology-related products in certain countries as a consequence of powerful social forces and problems related to financing small firm R&D in Europe because of the lack of financial structures for new innovations. In turn this raises important challenges to conventional wisdom as regards the relationship between the national environment and industrial development in knowledge based sectors such as biotechnology. In particular, the thesis argues that instabilities and weaknesses in the skilled labour market for knowledge intensive industries as biotechnology can be accounted for through a model of 'institutional failure' rather than through a 'skills shortage' model. The specific features of what are summed up here as 'institutional failure' are explored in chapter seven in a case study of skills and training needs in the biotechnology industry. The ramifications for industrial policy making and economic development of the 'knowledge economy' are discussed in detail in the last main chapter of the thesis.

This thesis is also original in that it is based on a report of work undertaken under the aegis of a European Community funded project completed through the Department of Life Sciences at Nottingham Trent University. While much of the survey work was conducted jointly with project management, the author had a role in survey design and largely conducted the surveys alone. The analysis is also original and conducted by the author. This original empirical work is the basis of the testing of the distinctive arguments developed in the theoretical critique in this thesis. It forms a distinctive if modest advance in the analysis of knowledge based industries in the global economy of the 1990s.

1.3 Case Study: The European Biotechnology Sector

Biotechnology is a particularly useful case-study to explore this argument for three reasons. First, the potential of biotechnology to be an important 'revolutionary' technology in the next century has attracted wide-spread political interest during the last decade. Like information technology, it is pervasive with considerable potential for transforming production processes in many traditional manufacturing sectors. This has already begun in the healthcare sector with new delivery mechanisms for the production of certain diagnostic kits and biotherapeutics. In this respect, biotechnology processes and products represent in Reich's terminology 'high-value' activities in globalised markets. In addition, Europe, traditionally strong in pharmaceuticals and chemicals, has nominated biotechnology as key strategic sector in the future competitiveness of European countries. In April 1991, the European Commission put forward an important communication indicating how they perceived biotechnology as a major force in Europe's economic expansion, stating:

> 'The recent increase in biotechnology products is only a beginning. It is clear biotechnology will have a strategic significance in dealing with some of the major challenges facing the developed and developing world, such as food, health, environment and population growth through new vaccines,...drought resistant plants.., and making certain plants unattractive to traditional predators thus reducing the need for pesticides..'(CEC, 1991, p.1).

The second reason for using biotechnology as a case-study for this study is the direct relationship between the economic development of biotechnology and knowledge and skills. More than any other knowledge-intensive activity, biotechnology depends on the quality of the science base, and the quality of advanced scientists and technologists for harnessing new techniques and developing them. As the discussion of the European COMETT funded programme, Biotechnology in Europe, Manpower, Education and Training (BEMET) shows, this has led to the widely held perception that investments in human capital, in the longer term, determine improvements the competitive position of biotechnology firms in world markets. The general consensus about the biotechnology labour market according to previous studies and among policy-makers, interest groups and industrialists from the onset of project BEMET was that the real problem in the labour market was a mismatch between the supply and demand for scientists and technologists. This general assumption about biotechnology and its dependence on technological innovations and human capital is widely reflected in European debates on biotechnology growth and competitiveness (for example, the European Commission White Paper, *Employment, Growth and Competitiveness* published in 1993 and the relationship between innovation and skills was also re-iterarted by the European Commission Green Paper on Innovation, see Bangemann, 1995). Through an empirical investigation of firms' perceptions of skills and training requirements, it is argued that such general assumptions underpinning the scientific labour market in this sector are misplaced and inappropriate.

The third reason for using biotechnology as a case-study relates to my own work as a Research Assistant on a Commission of the European Communities University Enterprise

Training Partnership (UETP BEMET 1990-1994). This is described in more detail in chapter seven. One of the aims of my position was to gather information through a Europe-wide study of the personnel and training requirements of biotechnology firms. The project was especially focused on the needs of small biotech businesses. Furthermore, I was employed to disseminate through the organisation of meetings a regular newsletter with information on labour market issues to members and interested parties. The primary objective of BEMET, therefore, was to take up the issue of skill shortages in the sector and to identify more closely specific skills and training requirements within European biotechnology firms. This information would then be filtered to policy makers at the European and national level to contribute to the training debate in the Life Sciences. This position gave me a useful platform on the whole debate at the European level as regards perceptions around the labour market in biotechnology.

The research reported in this study reveals that the perceptions of firms were more mixed than originally thought at the onset of the research investigation. Although, methodologically, the research only offers a 'snap-shot' view of the biotechnology labour market according to firms, the study has offered a broad overview of a relatively under-researched area, despite its centrality to contemporary debates on the future prosperity of European states. In terms of supporting the thesis advanced here, the study demonstrates that despite the global characteristics of the biotechnology sector, the 'quantity' of labour was generally adequate, but the main challenge for firms was finding suitable workers to fill highly specific posts in the firm. In this sense then, skills-shortages were highly selective and closer examination revealed an imperfect labour market, where contrary to Reich's ideas that high-technology firms now spun 'global webs' seeking the necessary personnel, that recruitment was sourced from personal contacts or the national labour market. This was further impeded by the heterogeneous scientific and educational infrastructure across the European Union which served as a barrier to Europe-wide recruitment policies for small firms and by the very imperfect market of information in Europe about biotechnology skills and opportunities.

Understanding these findings can be more usefully explained by examining the industrial structure of the biotechnology sector in Europe, its historical trajectory and the emergence of a heterogeneous scientific infrastructure across Europe. In terms of understanding biotechnology development therefore, complementary research to the BEMET survey of skills and training requirements of biotechnology small firms helps to create a new picture of the biotechnology industry where the labour market can not be disassociated from the overall production system for the European biotechnology industry. Following this line of analysis, it is argued that public policy targeted at investments in human capital as a strategy for supporting the economic development of this sector are generally one-sided if policies are not, equally, created to target other obstacles to biotechnology economic development, such as public perception levels and securing finance for the industry.

The significance for theory of this research lies in how it raises questions about the way in which the relationship between investments in human capital and GDP are understood in high technology sectors. Neo-classical labour market theories using a human capital model, the orthodox approach, inadequately conceptualise labour markets in the European biotechnology sector. My research findings suggest that a more sophisticated theoretical explanation is required which is not offered by neo-classical theories. For example, theories are required that address labour markets as linked into the overall global structures of power, institutions and the macro-economic environment. Understanding this complexity in biotechnology is rendered more complicated by the lack of literature that addresses the identified problems in this study. Unlike other high technology sectors such as information technology, where a rich literature exists on labour process changes and the restructuring of the labour market exists, radical political economy perspectives of scientific labour markets which link labour market activity to the wider science policy debate has received very little attention to date. This thesis is not primarily aimed at filling this specific gap, but it is hoped that it opens up an intellectual space within which future debate can take place.

A more useful analysis of the relationship between labour and the economic development of biotechnology begins with institutional economics where the market itself is taken as an institution, comprised of a host of subsidiary institutions which interact with other institutional complexes in society. In short, the economy is more than the market mechanism: it includes the institutions which form, structure and operate through, or channel the operations of the market. Thus it is not the market, but the organisational structure of the larger economy which effectively allocates resources including the institutional arrangements of a society, the organisation of the industry, the relationship between the firms and governments and the legal framework within firms and workers operate. Thus the *relevance of the social organisation of production and the structure of the industry is taken to have an important bearing on the choices that firms make.* What is still missing in this approach however, are studies of high technology labour markets in globalised sectors. In this respect, the role of labour and more broadly defined, 'knowledge' requires examination, especially in terms of what the impact on the nation state has been, as a consequence of structural transformation in the world economy. To do this, a discussion of academic theories on the nature of the global production system and the role of knowledge is equally necessary.

From this theoretical position the thesis addresses three specific research questions:

1) To what extent are claims about the importance of investments in education and training as a panacea to problems of international competitiveness in the knowledge based economy justified?
2) To what extent are European biotechnology labour markets characterised by a shortfall of skilled workers which can be explained by conventional thinking about labour market functions?
3) What are the broader implications of this case-study for understanding state intervention and national competitiveness in the global economy? What are the

implications for academic theories seeking to explain industrial policy in the global industrial system?

This is discussed in eight chapters. The organisation of these chapters is outlined below.

2. STRUCTURE OF THE STUDY

The structure of the study follows the broad argument through a number of stages. Chapter two begins with an analysis of recent theoretical literature concerned with knowledge and skills in the accumulation process (flexible specialisation, international political economy, new trade theories and national system of innovation debates). The chapter offers a critical assessment of these different schools, all of which advance the proposition that knowledge is central to the process of economic development.

Perhaps the most popular among these conceptualisations of change are debates in economic geography on the rise of regional agglomerations - Marshallian industrial districts and flexible production - flexible specialisation. What is important from these debates is the centrality of 'embedded' skills and knowledge to this form of industrial organisation. Whilst there are a number of other important issues raised by flexible specialisation and the industrial districts paradigm, it is skills and knowledge issues that are of specific interest here. This is intimately linked to the way in which these debates have addressed certain transformations taking place in industrial organisation, emphasising the territorial and local organisation of skills, knowledge and networking activities. The strength of the flexible specialisation thesis is that it directly invokes the crucial role of skills and knowledge in the industrial process. However it is limited by its over emphasis on *territorially*-bound production systems and the underpinning of these arguments are focused on a conventional (neo-classical) understanding of the way in which markets function.

For these reasons - the neglect of other powerful macroeconomic structural changes and its narrow assumptions about the operation of the economy following the neo-classical tradition, other debates in political economy offering important insights on contemporary capitalism are used. Theorisations in international political economy (IPE) have attempted to bridge the conceptual gap between *agency* and *structure* and create an organising framework for understanding the relationship between the 'domestic' and 'international'. The work of Susan Strange (1988) is of value to the concerns of this study because her theories of the organisation of states and markets provide an analytical framework whereby power is intimately linked to economics and the *inter*-national system in its historical specificity (globalisation), rather than a system comprising of individual and atomistic nation-state actors. However, these IPE theorisations fail adequately to address the 'embedded' nature of skills and skill formation and technology. In addition, there is a tendency towards overgeneralisation and a lack of attention to the variety of competing approaches in capitalism that are directly linked to the organisation of states and markets and the role of government policy-making.

While IPE theorisations offer important contributions on how to conceptualise the macroeconomic environment, other debates focus specifically on how governments ought to respond to fundamental changes taking place in the world economy. Debates within and around the 'new trade theories', 'national systems of innovation' and management studies (i.e. Porter, 1990) have made important contributions on how to understand this. These sets of debates have attempted to draw together the main themes that are raised in the last two previous sections on flexible specialisation and IPE. Specifically, these contributions attempt to understand the complexities of the contemporary organisation of markets and states by drawing on new thinking in economics. The 'new trade theories', in particular, are based on the concept of 'increasing returns' which sets down a few guidelines for the conduct of an interventionist industrial strategy, albeit of a different kind to the traditional ones. Along with the overall recognition of knowledge in the accumulation process, this literature connects with Reich's argument cited earlier concerning the role of national governments and the national context in contemporary 'globalisation' (although Reich shows very little awareness of the existence of such a theory). These schools of thought give powerful justification for state intervention in the economy, both in general and through industrial policy. Empirical research using new trade theory and national systems of innovation convincingly shows that some nations are more apt to develop in particular sectors as a consequence of adopting a sensible strategy in industries where increasing returns apply.

Chapter two develops the view that states and markets are more complex than traditional theories imply as a consequence of the centrality of knowledge and skills in the production process. However, the conceptualisation of contemporary economic phenomenon has remained relatively unchallenged, particularly in policy circles. Through this discussion of these theories, the limitations of methodological individualism are challenged and a number of propositions taken from these debates to create 'building blocks' from which to examine labour market behaviour in knowledge-intensive industries. The aim of this chapter then is to provide an analytical framework in relation to the changing environment and the necessity to adopt new tools for analysis for understanding issue-areas.

Drawing on the strengths of the literature review of knowledge and skills in the global economy, chapter two concludes with an outline of an alternative framework. This conceptualisation can be broadly understood by drawing on the work of radical political economy. A major contention of this alternative approach is that the more strong version of globalisation theory is based on an analysis that is misguided thus the policy judgements formed from this base inaccurate.

This is related to a number of propositions. First, the role of the state in economic affairs has not diminished, instead it has been 'modified' as a result of transformations in world structures. Second, traditional analytical 'tools' of political realism and conventional economics in relation to 'nation-states' and the national 'economy' are no longer adequate. The weakening of realism requires giving priority once again to the interactive processes of a unified world economy rather than to the internal workings of the state. The market is more complex than a market for exchange - the market itself is identified as an institution, comprised of a host of subsidiary institutions which interact with other institutional complexes in society. These institutional complexes are both national and transnational. In short, the economy is more than the market mechanism: it includes the institutions which form, structure and operate through or channel the operations of the market. In this respect, it is not the market but the organisational structure of the larger economy which effectively allocates resources (Samuels, 1989).

Third, firms' and governments' choices are articulated through a complex negotiation process that represents both economic and political imperatives. Economic imperatives drive the change in the structure of production and financial markets and affect the international division of labour. Equally so, political imperatives are those choices faced by states, either solely or in alliance with others. Additionally, world structures have a direct bearing on the decisions that these (and other non-state actors) 'agents' take. Rather than diminish the role of governments (as neoliberal theories tend to suggest), structural changes have created both new possibilities for creating wealth and new dilemmas for governments on how to balance the conflicting demands of their domestic and international agendas.

The fourth proposition addresses methodology. Following the arguments of a number of scholars, there is a need to develop theorisations that are capable of taking into account the rapidity of global transformations and major structural shifts. The stress on institutions and political economy leads to the proposition individual choice is constrained through the power structure of the organisation of capital and the social organisation of the market. This argument is the guiding principle of chapter three. The chapter begins by examining the various attempts of the 'new orthodoxy' to account for the benefits to be gained from the economics of investments in skills and training for the competitiveness of firms. Particular attention is paid to the human capital model developed by the classical economist Gary Becker. It is with orthodox labour market economics that many of the contemporary *assumptions* in relation to education and training policies and debates, and their relationship with the economy begin. This chapter (three) examines labour market economics at a broad conceptual level, and assesses what new principles, if any, underlie these approaches, and whether the analytical reasoning described amounts to a useful understanding of labour markets in terms of their functions. The argument advanced is that the human capital model is underdeveloped and fails satisfactorily to explain the consistent and pervasive discrimination in wages, jobs advancement and segregation faced by some sections of the workforce such as women and ethnic groups. The most restrictive assumption underlying this analysis is that it has very little to say both about the nature of skills which individuals acquire and about the nature of the training activity itself. The human capital model offers no attempt to explain why some individuals have access to training and others do not. Similarly, human capital theory has very little to say about the demand side of the labour market. For example, why do some firms offer more training than others, and what determines the types of training that they offer? The concept of the firm as an institutional entity is irrelevant as it is assumed that individuals spend most of their working life taking active decisions unfettered by their social position to learn technical skills, with the result that they become more productive workers (Brown, 1993).

Specifically, the neo-classical approach fails to conceptualise labour market behaviour in industries such as biotechnology where the demand side of the labour market plays an important factor in determining why some firms offer more training than others and in explaining the type of training that they offer. The notion that investments in training result in more productive workers is also highly speculative and depends on the tasks involved and the range of other influences that can affect the productivity of workers including working conditions, psychological factors, a worker's motivation and overall levels of investment. At the root of these problems is the assumption of a competitive labour market comprised of satisfaction/profit maximising individuals and firms which *will be* efficient as long as the following conditions apply: all workers have access to capital at the social rate of interest; job changing is costless; there are a large number of firms demanding the particular skills concerned; and there are no other externalities. There is much evidence that none of these contributions treat knowledge based industries (see chapter three). As a result it is doubtful that a model based on such a restrictive set of assumptions can have any real value in explaining what happens in the real world, especially in a high technology sector. Thus, the chapter shows that, individual investments in education and training may lend to slower pay offs within the economy than assumed by the new orthodoxy. Equally, unless investments in education and training are embedded in a wider array of policies to improve the overall production system, the results of investing in 'human capital' tend to be variable.

Chapter Four attempts to illuminate the foregoing themes through a case study of the development of an industry based on 'new biotechnologies'. This case study is informed by the alternative theoretical framework outlined at the end of chapter two and three. This suggests that globalisation is more complex and diverse than the simpler versions of this process leads us to believe and that the national environment is highly relevant to economic development. This view is illustrated through the case of the biotechnology sector, which can be seen as a highly globalised sector, where firms' markets are global but also specialised and simultaneously where biotechnological advances and the process of commercialisation is highly dependent on national institutions and social organisation. This contributes to the overall discussion of the production system for biotechnology. For example, biotechnology is characterised by a number of specific factors. These are that the technology is knowledge-based, demand plays an integral role in its development and that financing biotechnology activities is a major determinator of its success.

The argument advanced in chapter three was that despite the centrality of the labour market to the current debate on raising levels of GDP, the labour market is but one dimension of the overall production system. Chapter four charts the evolution of biotechnology as a science into a knowledge-based industry with important economic and social implications. The case study shows the dependence of biotechnology on the public sector for its economic development, the structure of the industry, the pervasive nature of the technology and limited development to date, and the dominance of United States' small firms in the sector. The important point made in chapter four relates to the specific characteristics of this knowledge-intensive activity, along with the industrial structure of the sector, meaning that its competitiveness is firmly bound not only into the global industrial system but, equally, in the territorial structure of production.

Chapter five considers the differences between the development of biotechnology in Europe compared to the United States. Drawing on the theoretical propositions advanced in chapter two concerning the national societal systems in the context of globalisation, it is shown how the economic development of a European biotechnology industry has been constrained by national-societal factors, by an underdeveloped structure of demand, and the lack of necessary financial institutions to support start-up businesses. In addition, this is also related to the earlier theoretical argument proposed in chapter two as regards state intervention to support firms in sectors characterised by increasing returns. As I demonstrate, it is clear that proactive industrial strategies in the United States to support new companies to get new technologies and new products to market as rapidly possible has conferred leadership on US firms in biotechnology knowledge and production. This has given the United States structural advantages in the sector. In contrast, the European states have been less successful in biotechnology, and there remain a number of questions related to the overall long-term development of the sector more generally. In terms of active policy to date, European strategies have mainly focused on improving the supply base of the region. Relating to the theoretical argument in chapter three concerning the role of demand in understanding economic activities, it is clear that in the case of developing competitiveness in the European biotechnology industry, supply-side policies are likely to be ineffectual if other issues - such as demand, finance and political arrangements such as co-operation at a supra-regional levels, are left unaddressed. Furthermore, the organisation of the firm, their capacity to communicate and to absorb innovations internally and their networking possibilities will have important bearing on the overall competitiveness of the firm.

Chapter six turns to the specific issue of skills, training and labour supply. The aim of this chapter is to critically review labour market knowledge and the perceptions developed hitherto in Britain and at the European level. What is significant about these labour market studies is how they demonstrate that the labour market for biotechnology is inadequately explained by aggregate levels of supply and demand. Moreover, it is argued that they pinpoint towards the need for closer evaluation of the labour market within the overall context of the system of production for biotechnology. This therefore raises questions concerning contemporary thinking on the politics and economics of education and training as a focal point of economic strategy for high-technology industry.

The next chapter (seven) takes these analytical starting points for understanding the labour market for biotechnology which have been developed so far in this thesis and now turns to a direct case-study of a European funded evaluation of biotechnology labour markets according to the perceived needs of firms operating in the biotech sector. With respect to the overall argument advanced in this study, chapters seven shows how biotech related labour market issues have gained salience in European policy circles during the late 1980s and early 1990s. Taking a specific case-study of European firms, it is shown that the labour market for this sector is more complex than conventional thinking implies. The empirical evidence suggests that a range of institutional factors underpin the functioning of this labour market, in conjunction with broader production and knowledge structures that underpin the global political economy. The aim of this chapter is to empirically support my thesis that the relationship between skills and training and the economic performance of firms and overall GNP is a more complex relationship than the one implied by the argument increasing the supply of highly skilled workers and increasing the investments in education and training will *inevitably* improve the competitiveness of firms and nations in a global economy. This chapter specifically discusses the perceptions that have been formed in relation to the role of scientific labour and the economic development of the biotechnology industry. The empirical case-study of biotechnology firms calls into question the validity of the argument that increasing the supply of highly skilled labour will increase the competitiveness of biotechnology firms. As I show, such a policy is based on a false illusion of the sector and will not resolve some of the inherent structural problems within the *imperfect* labour market for biotechnology workers which are more adequately explained by the structure of firms, demand conditions and the macro economic environment that has direct bearing on the range of choices available to firms in their recruitment and training strategies.

Following this discussion of the empirical research on the biotechnology sector, chapter eight considers the wider ramifications of these findings for academic debate and for policy making. It is concluded that at a conceptual level, this study of biotechnology demonstrates the complexity of knowledge-based activities and the role of government in the global industrial system. In this sense, it is suggested that markets in knowledge based industries are more complex, diverse and fragmented than conventional theory would suggest. And, as these markets 'mature' they do not become more homogenous, as neo-classical theory would suggest. The predictions of globalisation theory are seen to be inadequate and misdirected and policy recommendations based on it are misguided. Three particular issues are pursued in this context: the claim that the nation state has lost authority and power, the assumption that investment in skills and training determine improvements in competitiveness, and the prominence of training issues in policy proposals in the UK, especially the policy agenda of the Labour Party. Both theory and policy, it is concluded, need to take a more sophisticated view of the complexity of institutional factors which constrain and shape the growth of knowledge based industries including the specific conditions which shape their distinctive labour markets.

CHAPTER TWO

A REVIEW OF KNOWLEDGE AND SKILLS IN THE GLOBAL ECONOMY

'We are living through a transformation that will rearrange the politics and economics of the coming century. There will be no national products or technologies..There will no longer be national economies...All that will remain rooted within national borders are the people who comprise a nation. Each nation's primary assets will be its citizens' skills and insights. Each nation's primary task will be to cope with the centrifugal forces of the global economy which tear at the ties binding citizens together-bestowing ever greater wealth on the most skilled and insightful, while consigning the less skilled to a declining standard of living. As borders become ever more meaningless in economic terms, those citizens best positioned to thrive in the world market are tempted to slip the bonds of national allegiance, and by so doing disengage themselves from their less favored fellows'

(Robert Reich, The Work of Nations. 1991, p.3).

1. INTRODUCTION

The last chapter noted the current interest in education and training and the political and economic salience of education and training as a bedrock policy area. Underpinning this interest is the idea that the better trained the workforce, the better the performance of the economy as a whole and increased GNP. This notion has gained momentum in tandem with the contemporary interest in the idea of *globalisation.* Conventional wisdom implies that as a result of the increasingly global character of production and exchange, governments are less able to establish and implement autonomous macro-economic polices. In chapter one, this more extreme versions of globalisation was discussed particularly in relation to the ideas of Robert Reich, whose thesis suggests that in a world where the national barriers that inhibit firms and capital from moving are falling, nations now depend on the creativity, skills and productivity of their labour force. While politically expedient, the current emphasis attached to skills and knowledge and its relationship to economic performance has elevated education and training to 'growth theory' status. Whilst laudable, policies based on the business of delivering a supply-side revolution require greater analysis. To this end, chapter three will discuss the main tenets that underpin the argument that investments in 'human capital' will (inevitably) improve productivity.

This chapter, however, has another task to perform. The argument advanced here is that states and markets are changing and are thus more complex than traditional theories, but in addition do not necessarily conform to the conventional understanding of globalisation theory. It is widely believed that in the past there existed cohesion among different groups within a nation-state and the nation-state coexisted in an 'anarchical society' (Bull, 1977). This is no longer the case, and despite the tendency for economic systems to become more internationalised through the transnationalisation of certain activities such as technology, and given the increasing interdependence of political systems, it is necessary to re-conceptualise the global political economy by identifying the various agents and structures of change and reassess the implications that these changes have for policy. There are a number of reasons attributed to this particular change taking place in the economic relations between nation-states which are beyond the direct concerns of this thesis. The interest here lies with the salience of knowledge and skills within the global economy. One of the reasons for the growing complexity of relations between states and firms is that knowledge and skills have become ever more central to the production process in advanced, industrialised countries. Thus factor inputs such as knowledge and skilled labour have become more important than the value of space and territory. This necessarily has implications for the political order. The scarcity of space and the security of territory has, historically, formed the foundations for international law and sovereignty - the origin of the modern nation. In this sense then, a profoundly different situation confronts international relations. However, the conceptualisation of contemporary economic activities has remained relatively unchallenged in western policy circles. One of the problems for understanding economic outcomes in a global economy is related to the available academic 'tools for analysis'. This argument is explored through the following organisation.

1.1 Organisation of Chapter

By drawing on a number of important theorisations, the role of knowledge and labour in economic activities are looked at from a number of competing conceptual approaches that have different views of the world. These are: flexible specialisation and the related industrial district paradigm; international political economy; new trade theories and its related strategic trade policy and system of innovation debates. The reason for choosing these diverse sets of literature is that all have a number of 'common' themes underpinning them. First, all acknowledge that the process of structural transformation in the macro-economy has created either new opportunities and/or new challenges (some are more optimistic than others) for public policy-making and for improving economic competitiveness. Second, all debates recognise that through the quickening pace of technological change, the salience of 'knowledge' and 'knowledge-based activities' is now a crucial factor underpinning the competitiveness of firms and thus the long-term security interest of the state. Third, the different literatures (albeit some more explicitly than others) recognise that there is an increased role for public-private linkages and that traditional divisions between 'the state' and 'industry' are often unhelpful. The fourth common theme lies in how these debates perceive the changing relationship between the state (structural agency) and the firm (actor). Significantly, and despite the increasingly recognised global character of production, exchange, and knowledge, only IPE/GPE is directly concerned with methodological questions concerning the relationship between government power, wealth and production in the broader *global* political economy.

The first section discusses an important debate that has cut across industrial economics, economic sociology, economic geography and politics concerned with how the territorial production system has transformed from one based on mass production to one based on flexible specialisation (FS). The relevance of the FS thesis and the related industrial district paradigm is how they focus on 'external economies' of which local skilled labour markets are an important, if not essential dimension. It is argued that the key limitation of both FS and the industrial district paradigm however, is the geographical boundaries that are assumed because both paradigms are based on sub-national territorial systems of production. This results in the exclusion of certain phenomenon taking place around the rise of the interdependent world system. As a consequence of this general neglect, the second section introduces another literature in social science that has begun to address the relationship between the 'international' and 'domestic' spheres. In contrast to territorial-bounded production, 'new' IPE (alternatively, global political economy GPE) is particularly useful for the concerns of this thesis for understanding activities that transcend the traditional geographical analytical categories of the 'region' and the 'state'. Notably, new IPE has moved beyond the confines of territorial boundaries and the narrow focus on the state as the primary unit of analysis for understanding social change.. Such ideas have grown to challenge the powerful orthodoxy of the realist paradigm of international relations (see Tooze, 1988). (On realism see Morgenthau, 1948; Northedge, 1976; Bull, 1977; Keohane, 1984). Developments in the literature now view international relations not as the affairs of states alone. Implict in new IPE is that the process of globalisation has radically altered the meaning of state sovereignty and the conception of the state as the primary actor in international affairs and attempts to develop theories which give weight to both '*structure*' and '*agency*' rather than subsuming one under the other. (On epistemology in IPE see Murphy and Tooze, 1991) A 'new' IPE community has begun to emerge whereby these themes are taken as a starting point for debate (see Stubbs and Underhill, 1994; Gill, 1993; Amin et al, 1994). Susan Strange's 'knowledge structure' is particularly relevant for this (Strange, 1988). An attempt to reconcile the structure-agency problematic however is generally neglected in her analysis. Equally, it will be argued that the IPE theories are generally imprecise, overgeneralise and can only offer an organising framework to understand meso level theories in the global system. In this respect, they offer very limited policy recommendations.

The third section discusses developments in trade theory. Underpinning new trade theory is the argument that in the world economy, trade has changed as a consequence of knowledge activities and can no longer be adequately explained by neo-classical individualism. From this theoretical basis, these theories give legitimacy to government intervention and to industrial policies designed to strategically promote certain sectors. These themes are also inherent in the systems of innovation debates which are discussed next. The final section summarises the main arguments in this discussion leading to the conclusion that a systemic approach is a necessary starting point from which social change, wealth distribution and economic outcomes in the global economy can be related to the specific character of knowledge based industries. On the basis of this discussion of the literature, the chapter concludes that there is a need to construct a heterodox theoretical approach for understanding contemporary economic phenomena in the global system. This forms the basis of a research agenda that has a number of 'building-block' assumptions for the subsequent analysis of skills and its relationship with the overall economic development of European biotechnology. In brief, these include that although the nation-state has been 'modified', it is still a relevant entity in international relations. econd, that national/foreign firms and government choices are articulated through a complex negotiation process that represents both economic and political imperatives

(Stopford and Strange, 1991). Third, these choices are articulated through 'structural power' through which the 'knowledge structure' exerts influential power on the shaping of social and economic outcomes. Fourth, implicit in this approach is the interaction between 'structure' and 'agency' which necessitates new methodological categories from which contemporary social change can be addressed.

2. FLEXIBLE SPECIALISATION

A number of debates across the social sciences including economic geography, industrial economics, economic sociology and political economy have been concerned with the rise of regional agglomerations, or as they are more commonly referred to, Marshallian industrial districts and flexible production - flexible specialisation (FS). The flexible specialisation thesis and the related industrial district paradigm has made a powerful impact on practitioners and academic debates concerned with whether they constitute a blue print for the regeneration of local and regional economies. In addition, these theorisations have made an important contribution to the broader discussion concerning contemporary transformations in the industrial organisation of production and markets. (A full treatment of the main debates in relation to the flexible specialisation thesis beyond the scope of the intentions here, see Amin, 1994a). However, the focus for the purposes here relate to what flexible specialisation has to contribute to our understanding of skills.

The conceptualisation of industrial districts has been subject to wide-debate (see Harrison, 1991 for a review of the literature). Marshall's (1890) seminal work on 'externality', 'agglomeration' and 'localisation' recognises that 'external economies' benefit individual plants or firms from the growth pools of common factors of production - land, labour, capital, energy, sewage and transportation. The external benefit for the user firms, wrote Marshall, are that in the long run, each individual's user's unit production costs will be lower in the presence of such infrastructural and specialised pools of labour and capital than if that producer has to create such factor availability for itself. Drawing from Marshall's observations (and later developed by the growth pole theorists such as Perroux, 1955), were the essential 'commons' - the pool of infrastructural and other services and know-how from which each individual firm in the district might draw. Scitovsky (1963) followed Marshall with another type of 'external economy' - investments made in plant and equipment which enhance the profitability of other companies' existing operations, the latter gaining a benefit without the full cost. Such an example could include a new facility that attracted new customers with whom other firms in the locality may trade. Another possibility is that private investment may encourage (on the differences between Scitovsky and Marshall see Harrison, 1991). 'Agglomeration' invokes the image of the clustering in a geographic space of direct producers (firms, plants and shops) pools of labour and finance capital, and physical as well as social infrastructure. According to this perspective therefore, it could be said that agglomeration has conferred on them a variety of external economies associated with location, including access to a highly skilled pool of labour, however a wide debate exists on why some locales are dynamic and others are not (for example on growth pole theories see Perroux, 1955; Chinitz, 1961).

Developments in the literature led to a widening of growth theories to look at how industries adjust to changing structural conditions in global competition (see Womack et al, 1990; Saxenian, 1990). This has important bearing on this overall discussion of skills and knowledge in the global system because of what the flexible specialisation thesis has to say about the role of locally embedded knowledge. Piore and Sabel (1984) are most closely associated with flexible specialisation thesis (also see Sabel, 1982; 1989; Sabel and Zeitlin, 1985 and Hirst and Zeitlin, 1989; 1991) who argue that as a consequence of a crisis of mass production: mass markets have become saturated and consumers are now demanding specialised and differentiated goods to which the mass production system cannot respond. In this scenario, firms are increasingly dependent on the accumulation of local knowledge-assets such as local skilled labour markets and accessible information to respond to rapidly changing consumer demand. The role of highly skilled workers is therefore pivotal to this organisation of production. It is argued that flexible organisations significantly reduce waste and therefore enhance productivity by reversing the logic of Taylorism by integrating thinking and doing at all levels of operation within an organisation (see Taylor, 1911) The idea is that this process eliminates waste thorough better management and organisation of work by overcoming the under-utilisation of knowledge, creativity and human capabilities that tends to characterise Taylorist forms. In this sense, it is argued that this industrial organisation combines the advantages of craftwork and Fordist/Taylorist mass production without the drawbacks of either (see Association for Manufacturing Excellence, 1990; Piore and Sabel, 1984; Wood, 1989).

Piore and Sabel (1984) suggest that this form of industrial organisation has spatial implications with emphasis on the importance of industrial and social networks pointing to the 'learning advantages of network systems as industrial organisation' (Sabel, 1989, p.30-31). The role of locally 'embedded' knowledge resources in the FS thesis is particularly important to this discussion of knowledge and skills. For Sabel, the proliferation of industrial districts could produce a new form of inter-regional collaboration. One result would be that 'flexible' regions will evolve to share knowledge and resources and create an expansive net of solidarity. Sabel states:

> 'If the pooling of knowledge succeeds, it can easily become the political metaphor and matrix for the pooling of other resources as well. The more knowledge available to each industrial district, the less the probability of being tripped up by costly ignorance; the greater number of prosperous industrial districts, the more likely that each can draw on the resources of the other in moments of distress' (Sabel, 1989, p.58).

Scott and Storper (1987) continue this theme of the concentration of knowledge-activities in a regional agglomeration, adding to it the French Regulation school of political economy (see; Lipietz, 1987; Boyer, 1986). In comparison to Piore and Sabel, the strength of Scott and Storper lies in the way they attempt to use the Regulationist theories to locate industrial districts within a wider transformation of the late Fordist 'regime of accumulation', characterised by branch plant development and decentralisation of production to peripheral regions (also see Boyer, 1986; Hirst and Zeitlin, 1991; Jessop, 1992). In terms of high-technology development, Scott and Storper acknowledge that flexible production has also manifested itself as an industrial paradigm in high-technology sectors where mass production has eclipsed for example the resilient high technology agglomerations as Silicon Valley over the last two decades (see Saxenian, 1990). As the study of biotechnology shows, the role of the local and national context is highly significant in creating the necessary knowledge-base for developing this technology.

2.1 Limitations

There is a rich literature that challenges both the industrial districts and flexible specialisation approach (for example, see Elam, 1994; Asheim, 1992; Solo, 1985; Frankel, 1987; Williams et al, 1987; Sayer, 1989; 1990; Smith, 1989; Amin and Robins, 1990; Pollert, 1991; Jessop, 1992; Lebourne and Liepietz, 1992; Harrison, 1994). The lack of empirical evidence for a broad transition to flexible specialisation has been noted (Harrison and Bluestone, 1990, Wood, 1987, Rubery, 1987; Pollert, 1988), along with criticisms against Piore and Sabel's assumptions that flexible specialisation is beneficial to labour (see Leborgne and Lipietz, 1990; Wood, 1989). However, the interest for this thesis, lies with criticisms relating to first the conceptual underpinnings of the FS thesis and the general limitations of neo-classical theorising, and second, the flexible specialisation thesis does not attempt to locate the rise of 'flexible' production in a broader political economy of contemporary capitalist development and transformation. This is discussed in detail below.

2.1.1 Conceptual Issues

In terms of understanding markets, FS does not recognise the chaotic organisation of markets and economies because it is predicated on micro-economic concerns (Markusen et al 1993). This theme is taken up and discussed in more detail in the following chapter on labour market theory. For example, the FS thesis infers that competition among firms assures efficient allocation of resources and diffusion of technologies. Product and factor markets resume their proper disciplinary roles and group provision of ancillary services such as finance, marketing, insurance, transportation, research and purchasing is provided at low unit cost. However important to the concerns of this thesis is Howes and Markusen (1993) point, who argue that there is an anomaly in this description in relation to the labour market. They argue that, since the flexible production system is seen as fertile environment for learning, there is some endogenous growth implicit in the model. However, demand changes play no explicit role in the model. This is particularly significant for this thesis and for understanding the role of skilled labour in the accumulation process which is discussed theoretically in chapter three and illustrated through the case study of biotechnology labour markets. The FS model therefore is even more ambiguous given that growth in flexible specialisation is a function of the growth of a (primarily highly skilled) workforce. The possibility that some industries have greater potential for rapid growth of demand is, however, never explicitly considered. Eaton (1986) discusses accessing skilled labour in regional agglomerations and suggests that 'external economies' may emerge when firms engage in 'on-the job' training, thereby, reversing the logic of competing resources which conventional economic theory assumes. Eaton shows that the labour costs to firms undertaking in-house training reduces the cost to competing firms in the locality when the trained workers seek employment there. It is shown in his argument that the presence of a pool of skilled labour created by the previous job experience of the local labour force and previous investments within the locality may explain the emergence of regions with concentrations in certain high-technology products. Silicon Valley, Route 128 and Cambridge-Reading-Bristol are obvious examples (also see Castells and Hall, 1994) (See Granovetter, 1985 for a discussion on 'free markets' and 'embeddeness'; Hutton, 1995, p.252 on 'trust' relations). The conceptualisation of FS and industrial districts also fails to account for certain behaviour implicit in the paradigm. For example, Sabel admits that it is unclear why the 'second industrial divide' actually emerged. However, he does suggest that it was spurred by inter-firm competition which represented some kind of institutional shift in terms of norms and behaviour in the business community in the way production is organised. In so doing, Sabel does not attempt to explain this *shift*; moreover, he leaves this unexplained despite its centrality to the whole FS thesis. By invoking a firm driven account of structural change, as the FS and industrial district paradigm do, the firm is regarded as atomistic, a rational choice making unit, unfettered by wider structural changes taking place within the broader social and economic environment. Krugman has written extensively on the power mainstream (neo-classical) orthodoxy, arguing '.. that to be taken seriously an idea has to be *something that you can model'*. This, in his view, has led to the privileging of some assumptions at the exclusion of other academic (non-model, anecdotal) ideas (Krugman, 1994). This has prevented economic thinking from addressing the realities of the market which are more akin to 'imperfect competition'. Trade is based more on the advantages of large-scale production, cumulative experience and transitory advantages arising from innovation and less on 'perfect competition'. Far from being atomistic and rational agents, as perfect competition contends, firms are facing a different kind of competition. They face a few identifiable rivals, they have some ability to affect prices, and they make strategic moves designed to affect their rivals' actions (Krugman, 1986). Krugman comments:

> 'Firms in this situation are described by economists as being in 'imperfectly competitive' markets. This does not mean that competition is fierce or that the firms are somehow misbehaving. What it means is simply that what can happen in these markets is different from, and more complicated than, what is captured by the simple concepts of supply and demand. The imperfection, in other words, is in the economist's understanding, not in the world' (Krugman, 1986, p.9).

In additional problem is that flexibly specialised firms are said to have a competitive advantage in industries for which demand is fragmented and volatile. In a world of fragmented markets and volatile demand for some products, countries that create industrial districts will have a competitive advantage over those which cannot. Furthermore, since industrial districts are believed to be better structured than Fordist organisations to achieve economies of learning, it is possible that a flexible firm or industrial district that is first to enter a new, or newly fragmented market, will have a widening advantage over late arrivals as it moves steadily down a learning curve. Therefore in a world of industrial districts, it would be expected that trade will be structured by relative advantages in specific products due to the existence of industrial districts and to the good luck of being first to enter the market (Markusen et al ,1993). In practice, adherents of flexible specialisation advocate training to enhance the skill level of the labour force and infrastructure investment to smooth communication and transportation. However, as it is argued in the following chapter, investments in 'human capital' to improve firms' productivity are unlikely to accrue benefits if other institutional factors relating to the labour market are left unaddressed.

2.1.2 Local and Global Knowledge-assets

Another related problem with the FS thesis is a spatial one. The idea of territorially bounded production systems assumes that the 'local' is in isolation and dislocated from the wider interdependent global system thus obscuring the growing significance of the local-global nexus (Alger, 1988). In particular there is no recognition of powerful tendencies towards accelerating economic concentration and integration at a global, not local level. For example, although there are tendencies towards local agglomerations in spatial terms, there are also powerful countervailing and competing tendencies towards transnational networks and 'global space flows' (Castells, 1987). In this respect, the flexible specialisation and industrial districts invocation of the economic and social organisation of markets fails to acknowledge the complex and contradictory nature of the restructuring process (Amin and Robins, 1990). Amin and Robins argue that concentration on the local territorial production system ignores the tendency towards internationalisation and the global integration of local and national economies. Regional and local economies, they argue, have to be understood in the context of the global field. They point to the internationalisation of financial markets, the deepening of unequal economic development, and the dominance of transnational finance, based on ever closer links with transnational corporations and banks. In addition, they point to the impact of the 1980s, marked by the rise of foreign direct investment through mergers, take-overs and strategic alliances. (The widening of multinational activity in the biotechnology sector is discussed in chapter five, however more generally see Ohmae, 1990; Bartlett and Ghosal, 1989; Livingstone, 1989 and Dunning, 1992a). In terms of labour market activity, the FS thesis implies that skills and knowledge are conditioned by local forces. As a result (cf. Reich (1991) discussed in chapter one) there is no recognition in the flexible specialisation thesis or industrial district paradigm of the 'global webs of enterprise' or the existence of international labour markets for certain globalised sectors, or the locus of power within international production such as the relationship between multi-national corporations and local economies and thus global 'knowledge structures' in the contemporary world economy.

Amin and Robins (1989) urge caution concerning the need to raise important conceptual and theoretical issues about the extravagant scenarios being projected around industrial districts and flexibly specialised regional economies. They argue that any consideration of this phenomenon must be located within a broader political economy perspective of the nature of contemporary capitalist development and transformation. The flexible specialisation thesis is a simplistic and contentious understanding of historical change whereas, in reality the contemporary processes of macroeconomic structural change are far more complex and contradictory than the flexible specialisation thesis assumes. Following their argument, there must be strong doubt that the industrial district can be the paradigm for future development and that in the late 20th century the local economy can 'only be seen as a node within a global economic network' (Amin and Robins, 1990, p.28). Thus an understanding of the global economy becomes necessary. One literature that has directly attempted to deal with contemporary structural transformations in the 'international' are debates within 'new' IPE. Here there has been an attempt to challenge current orthodoxy in relation to understanding 'international' economic relations by taking a broader ontological approach drawing from political economy.

3. 'NEW' INTERNATIONAL POLITICAL ECONOMY (IPE)

Debates within the 'new' IPE fit into this overall discussion of skills and training in the accumulation process by offering an important contribution for conceptualising the contemporary global economy, which the flexible specialisation thesis and new trade theory (described in next section), generally ignore. This discussion is necessary for the overall focus of this thesis, precisely because it addresses directly the relationship between 'structure and agency' in the global economy and thus deals with the relationship between the domestic and international sphere (also see Giddens, 1984). This is particularly useful contribution for understanding global knowledge-based activities because inherent in its analysis, is the acceptance of an intimate relationship between the 'local' and the 'global'. In knowledge based industries, methodologically this complex relationship between the national context and the global industrial system needs to be addressed given the significance it has for the development of these industries, as I show in chapters four and five in the case of biotechnology. In contrast to the other literatures discussed here, IPE focuses on transformations taking place in the world economy and the implications that they have for social change. Thus these theories, I argue, are particularly useful for understanding the biotechnology sector which, as a global, knowledge-based industry has a number of transnational networks or communities and 'non-state' actors surrounding its economic development such as transnational financial investors, social groups opposed to certain biotechnical techniques (for example, the Church and the Green Party), supra-regional programmes (such as the European Community initiatives) and transnational scientific labour communities. As I show in this study of the biotechnology industry, such 'non-state' actors have has an important bearing on the shape and economic development of the biotechnology industry.

Additionally, the non-state actor theme offers a vehicle for a discussion of highly skilled labour as a knowledge activity in the accumulation process. Indeed, the interest for this discussion lies with what 'new' IPE can offer for understanding the impact of highly skilled labour in the world system. As an IPE concern, training, education and labour market activity has generally been neglected in the scholarship (Hayward, 1997), despite its economic salience in contemporary debates concerning macro-economic change, as discussed in the earlier section and in chapter one. Where it has been discussed it has generally been subsumed under the broader categories of 'knowledge' (Strange, 1988; Murphy and Tooze, 1991), the labour process (Cox, 1987) or 'technology' (Talalay and Farrands, 1993).

3.1 Conceptual Approaches in 'new' IPE

The new IPE is principally concerned with how to conceptualise the relationship between production and power and considers the implications that this has for shaping outcomes, such as state policy effectiveness. The assumption driving 'new' IPE is that nation-states have undergone significant changes and that the power base has shifted with the rise of a global economy. There are a number of common themes to 'new' IPE, which we can also identify with global political economy (GPE). First, the social, political, economic and cultural relations that were previously organised under the umbrella of the nation-state are becoming less disparate and constitute a more heterogeneous process across national boundaries (Strange, 1988; 1991; Murphy and Tooze, 1991; Gill and Law, 1993; Stubbs and Underhill, 1994). One of the causal factors for this change in the organisation of states is the transnationalisation of technology (Amin et al, 1994; Talalay et al, 1997). It is argued that the transnationalisation of social activities as a consequence of 'knowledge' is one factor why the 'international' realm has become significantly 'globalised'. For example, Talalay et al (1997) point to the significance of the transnationalisation of technology for understanding global political economy, others point to how technology has led to the intensification of global communications and international migration with 'the rise of global cultural flows and territorial signs, meanings and identities' as factors of global change (Amin et al. 1994). Whilst technology is not the only causal force behind the emergence of an increasingly interdependent world system, other forces of globalisation are not specifically treated in this thesis. However, it is noteworthy to mention that Amin et al, (1994) do suggest three other related driving forces behind the emergence of the global economy. These are first, the emergence of transnational corporate strategies with an increased necessity for corporations to pursue global strategies earlier than previously (also see Dunning, 1992; Ohmae, 1990). Second, the rise of transnational economic diplomacy and the globalisation of state power (also see Stopford and Strange, 1992) and third, the rise in what has been termed 'global geographies' (also see Castells and Hall, 1994). This resonates with the widely cited 'globalisation' thesis which has engendered a vigorous debate across the social sciences, but is not specifically treated in this thesis. (For example, the cultural studies literature is concerned with how 'deeply' the process of globalisation has permeated contemporary societies and led to social exclusion in the world system see McGrew, 1992; Harvey, 1989; Robertson, 1990. Others have commented on how globalisation has enabled a centralisation of power and the rise of a small number of global cities exercising structural power through the command of finance, production and knowledge see McGrew, 1992; Ferguson, 1992. The business and management studies literature see globalisation as offering a new opportunity for local or national renewal with the promise of new ideas, new people, new investment, new opportunities for embarking on a new development path, see Ohmae, 1990).

This has led to the domestic realm becoming indistinguishable from the international in such a way that the global political economy can no longer be meaningfully understood by the orthodox realist approach whereby the international system is packaged in to a separate 'international' realm of politics, structured by the principle of anarchy, which generates the behaviour of an arrangement of 'units' (states) in relation to the distribution of power (on structural power see Waltz, 1986; on realism see Bull, 1977; Northedge, 1956). Thus according to new IPE, the contemporary global economy is characterised by the 'fluidity and indeterminacy of transnational relations' (Amin et al. 1995).

The second theme in new IPE follows in the tradition of classical political economy in acknowledging that politics are inseparable from economics and that economic structures are not the result of spontaneous interaction by individual economic agents (Strange, 1988; Underhill, 1994). Implicit in this research agenda is the intractable relationship between politics and economics (Strange, 1988; Higgott, 1994; Underhill, 1994) and a challenge to the political economy of orthodox writers such as Caparaso and Levine (1992, p.31) when they say '[e]conomics is a way of acting, politics is a place to act.' Conversely, the 'new' IPE theories draw on the tradition of political economy where politics is the means by which economic structures, in particular the structures of the market, are established and in turn transformed. Economic structures and processes are the results of political interactions, or of the spontaneous interaction of individual economic agents (the rational choice theory preferred by the traditional IPE approaches), even in the market setting where political authorities may refrain from direct intervention in economic decision-making and are thus seen as being generated by competing socio-political interests in particular economic and institutional settings (Stubbs and Underhill, 1994). In this sense, the institutions of the market and the agencies of the state determine outcomes and asymmetries of power are inevitable.

The third theme relates to methodology and how this interdependent world economy is creating 'levels of analysis' problems for understanding social change in relation to the 'international' and 'domestic' sphere (Underhill, 1994). The 'new' IPE theorists attempt to develop theories that give weight to both 'structure' and 'agency' rather than subsuming one under the other. Thus, the new IPE attempts to transform the epistemology of international relations by shifting attention away from restrictive and exclusive methods of generating knowledge and seeks to develop a more inclusive and at the same time eclectic approach. Thus by arguing that the 'international' system has fundamentally transformed into a 'global' one based on a variety of social, cultural, economic and political transnational interrelations, the 'new' IPE theorists argue that such profound, ontological changes necessitate new theories for understanding the relationship between the political and economic domains of international society, the primary area of study in the discipline.

In theoretical terms then, the debate in 'new' IPE is about creating new, epistemologies, ontologies and approaches that can address the realities of changes taking place in the world system. In addition, it is about broadening a research agenda for the study of IPE thus its core questions of which it is concerned. To do this the orthodoxy of IPE has been challenged, particularly in relation to how IPE questions have been approached by extending realist assumptions about the international system. For example, new IPE was developed primarily by non American scholars keen to move away from the centrality of United States academic hegemony in international affairs governed by realist assumptions which in turn have shaped the overall research agenda. For example, the traditional divorce between economics and politics fuelled a research agenda for understanding 'the politics of international economic relations' (the phrase used by Spero in her book of the same title published in 1977). This IPE approach was based on market provision and rational choice theory to allocate preferences for welfare maximisation in the international economy. The principal issue area of IPE concern therefore was trade and the maintenance of US supremacy (see Gilpin, 1987 and for greater discussion on the privileging of 'issue-areas' see Tooze, 1988; Higgot, 1994). Higgott states that the main problem with the initial IPE has been with the application of economic analysis to the various arenas (domestic and international) of politics (Higgott, 1994). Murphy and Tooze (1991) argue that mainstream IPE formed a specific 'culture of orthodoxy', meaning that the material base encompassing not only the production but the dissemination of knowledge created a consensus on which the knowledge was based and re-produced (Murphy and Tooze, 1991).

In attempting to bring together its themes into one conceptual approach, the new IPE perspective suggests that the 'international system' is much more sophisticated and diverse than it has been previously conceptualised (see Keohane and Nye, 1971; 1984). However, IPE theorists have begun to move away from a state-centred model of international political economy. The two primary contributions towards a non-agency based IPE that has broadened the research agenda have been the work of Robert Cox (1982; 1987) and Susan Strange (1988).

3.2 Towards a non-agency based account

Both Strange and Cox have contributed to a research agenda that has gone beyond realism. Thus a structural rather than an agency-based account has emerged. Cox (1982) addresses the levels of analysis problematic in the world system and the need to move away from agency based accounts by describing this order as the 'state-society' complex, spanning domestic and international levels of analysis, with the institutions and agencies of the state at its core. In so doing, Cox depicts world order as a multi-level world that challenges the Westphalian assumption 'that a state is a state is a state' (Cox, 1993, p.263). Cox recognises the relationship between work and politics and methodologically therefore rejects positivist epistemologies. However, while Cox attempts to create an organising framework for exploring the inter-relationships between world order, production and the state, his analysis of the 'modes of production' does not address the rise of flexible working practices, the role of highly skilled labour in contemporary production systems. Strange (1988, p.26) criticises Cox for failing to address the realities of transnational movements and activities and over-emphasising the autonomy of the state in the world system. Missing from his analysis therefore, is any discussion of the rise of knowledge-based production activities and the rise of mobile skilled labour in the state, production, world system complex.

It is the work of Susan Strange (1988; 1991) that is more useful for analysing knowledge activities such as labour functions in the global economy. In her work, she has outlined an eclectic analytical framework for studying the politics of the world economy which moves away from the centrality of the state. Strange's theories categorise power as distinct from a more common separation of economic and political power. This begins with a description of the way in which interactions with political realms (states) and economic realms (markets) are conceptualised. Four mutually supporting primary structures are identified within which various categories of actors interact, with relational power being a key variable. Strange defines relational power as '..the power of A to get B to do something they would not otherwise do' (1988, p.24). She explains this in terms of the power described by traditional realists in international relations. Important as relational power is, Strange argues that even more significant is the application of structural power. Structural power confers:

> 'the power to decide how things shall be done, the power to shape frameworks within which states relate to each other, relate to people, or relate to corporate enterprises' (1988, p.25).

The four primary sources of structural power are: 'control over security; control over production; control over credit; and control over knowledge, beliefs and ideas' (1988, p.26). None are mutually exclusive and all are inter-related. However, it is the knowledge structure that is of interest for this discussion. For the most part, the knowledge structure has eluded specific analysis in IPE, with debates focused on the importance of the production, financial and security structures. For example, changes in political bargaining power in the nuclear age as a consequence of military technologies, the augmented powers of the state on the individual through surveillance technologies (Giddens, 1985) or through industrial structural change and financial globalisation (Cerny, 1995). Despite this general neglect, Strange herself recognises the ramifications of changes in the knowledge structure (1988) when she states:

> 'power from the knowledge structure is the one that is the most overlooked and underrated. It is no less important than the three other sources of structural power in the international political economy... but it is much less well understood... Analysis of the knowledge structure is therefore far less advanced, and has far more yawning gaps waiting to be filled than analysis of other structures, even though they may be subject to less rapid and bewildering change' (Strange, 1988, p.115).

In 1988, Strange concluded that three broad developments were occurring in the world system. First, competition between states was increasingly becoming 'a competition for leadership in the knowledge structure' or a place at the leading edge of advanced technology. Second, there is a growing increasing asymmetry between states of technical knowledge, as political authorities attempt to acquire and accumulate knowledge. Finally, Strange observed that more than any other structure (security, finance, production), change in the knowledge structure is 'bringing new distributions of power, social status and influence within societies and across state borders'. This led Strange to conclude that power was passing to 'the information-rich instead of the capital rich' (Strange, 1988, p.132-133).

Conceptually, for Strange, the knowledge structure is the most problematic of all the structures to define. Power in the three other structures lies in the positive capacity to provide security, credit and organise production. However, power in the knowledge structure lies in the negative capacity to deny knowledge and to exclude others. Since knowledge is known to be unquantifiable problems of measurement are so much that 'in a rapidly changing global knowledge structure..it is by no means clear to the social scientist who has that power' (1988, p.115). Furthermore, in contrast to the control of production or credit, knowledge can have strong characteristics of a public good, but is not 'truly a public good in the sense that the term is used by economists, for the value of the supply to those already holding the knowledge may well be diminished when it is communicated to others' (Strange,1988, p.118).

The definition that Strange offers of the knowledge structure is how it 'determines what knowledge is discovered, how it is stored and who communicates it by what means to whom and on what terms' (Strange, 1988, p.117). Consequently, power and authority are conferred on 'those occupying key decision-making positions in the knowledge structure' (Strange, 1988, p.117). This embraces those who are entrusted by society with the storage of knowledge, the generation of more knowledge, and those who control 'in any way the channels by which knowledge, or information is communicated' (Strange, 1988, p.117). Of importance therefore, is how Strange conceptualises the knowledge structure not only at an operational level such as 'know-how' and access to knowledge activities. But, equally, the knowledge structure represents less tangible facets in the value system of a society such as culture and beliefs thus implying a transcendental meaning. To explain this, Strange argues that society is shaped by the hegemonic beliefs of the ruling elite. For example, during medieval Christendom, the beliefs taught and preserved by the Church had far reaching influence, including authority of the Church over 'rulers of states, merchants and craftsmen in the market'. In other words, the Church claimed 'a monopoly of moral and spiritual knowledge' (Strange, 1988, p.119-120). This resonates with Cox's (1982) state-society complex, and the knowledge on behalf of the states agents on what the class structure makes possible and what it precludes - thus the tasks and limits of the state by its social forces. Although the hegemony of the Church has declined in western industrial societies, the power of contemporary social forces and groups albeit highly fragmented, exert powerful forces on contemporary value systems. In later work, Strange reinforces this by stating that it is the 'belief systems and their associated value preferences that inhibit or validate some kinds of actions rather than others' (Strange, 1991, p.37). She illustrates the point with reference to the impact on government control over a variety of communications activities in the face of the information revolution:

> 'when systems of accumulating, storing, or communicating information change, the change is apt to have a direct and sometimes quite substantial effect on the bargaining power of actors as well as on the prioritised values of the system' (Strange, 1991, p.37).

As the study of biotechnology shows, the 'knowledge structure' for biotech development has had a major impact on the pace of the industrial development of this sector. This is the case not only in terms of accessing 'know-how' through acquisition and mergers of small firms by large transnational corporations and employing highly skilled scientific workers, but equally, as the case-study shows, the role of non-state actors and their powerful influence on the value-systems on nation-states has greatly informed the knowledge of European states of what it can and cannot do in relation to economic development of the biotechnology industry. This is particularly pertinent in relation to the development of a European safety and regulatory regime, where transnational and social forces have played a major role in determining policy agendas. In this sense, the knowledge structure has a number of ramifications for the overall pace of the development of biotechnology.

3.3 Critique of new IPE and 'the knowledge structure'

The limitations of the new IPE lie in that it is often open to overgeneralisation and this can lead to imprecision. The levels of analysis approach in IPE tends to underplay the significant differences, imbalances and national institutions which characterise the world system, nation-states and social forces of production (see for example Hutton, 1995; and next sections on new trade theories and national systems of innovation; Albert, 1993; O'Donnell, 1993). As a consequence the range of actors discussed in IPE debate such as 'firms'; 'governments' 'states' and 'industrial sectors' are frequently treated as monolithic and homogenous. Thus importantly from the point of view and concerns of this thesis, IPE could be accused of ignoring the disaggregation of the state and the importance of variegated sectors, institutions, firms and government responses to contemporary macroeconomic transformation. This becomes very clear in the discussion of the case-study of biotechnology in chapter four and five and the different responses of American, European institutions to promoting and regulating the technology. Equally, as it is shown in chapter six and seven, in the analysis of different national systems within the European member states themselves according to their own social forces. Russell (1997) recognises these limitations in Strange's identification of three major sources for structural change, namely states in the international political system, markets and technology which affect 'the range of options open to states, firms, labour unions or others' (Strange, 1991, p.38). This follows a broader trend in IPE debates concerning the role of 'agents' in contemporary globalisation, in particular the idea that nation-states are no longer effective policy-makers in the face of powerful macro-economic forces such as global capital, as Cerny (1995) argues. Finally, despite the salience of the political economy of training and education in advanced industrialised societies, IPE debates have generally subsumed the role of labour within wider concerns. Indeed, this thesis is the first serious analysis of labour market issues taking IPE/GPE concerns.

Despite these limitations, the contribution of the new IPE to this thesis is still important because it attempts to incorporate and address the locus of power within the global economy. Strange recognises the role of knowledge in that process, even if it is not adequately defined. IPE scholars have argued that levels of analysis are only useful as organising tools for approaching the global system, by way of denoting different patterns of institutional arrangements (local, domestic and inter-state), however taken on its own, the international level of analysis cannot be properly be regarded as any source of explanation (Underhill, 1994). IPE theorists have attempted to reconcile this problem (see Underhill, 1994; Ruggie, 1983). It can be reasonably argued that the power of the realist paradigm is that it presents a structured research agenda, and one of the problems for new IPE has been how to create an eclectic research agenda which takes a structural agency approach (Strange, 1991). Whilst the new IPE has primarily been focused on raising large questions for analysis, it has begun to identify a framework within which these questions can be addressed (see Higgot, 1994; Gamble, 1995; Amin et al 1994; Murphy and Tooze, 1991; Gill, 1994). Underhill comments on the new research framework:

> 'We must begin developing an understanding of the "state-society" complex that is the IPE by analysing the structure of economic relations (production and the market, as opposed to the neo-realist notion of the political structure of anarchy/distribution capabilities) as it becomes increasingly transnationalised. In doing so, we begin to come to grips with the material self-interest of political economic agents, and of key social groups, at domestic and international levels of analysis' (Underhill, 1994, p.35).

In this sense, structure is part of a successful theory of international political economy However, Underhill argues that more important is what is meant by 'structure' and how one employs structure in a theory that is important. Structure is not a causal variable - in and of itself does not explain outcomes. Structure, however, does inform one of the terms under which the political interactions of particular agents or groups occur at a particular time in history. Gamble and Payne (1996) make a similar point in relation to international political economy theory and the role of structure.

3.4 Conclusions: Missing Dimensions - meso-level theories.

From the two sections so far, the main point is the need to develop a research framework that recognises the intimate relationship between the domestic sphere (regional and national systems of production and economic development) within a wider context of structural transformation (global political economy). This broad methodological starting point recognises the limitations of traditional analytical categories for understanding economic outcomes. However, the essentially wide questions that are raised by such a framework, itself, is not particularly helpful for understanding labour market issues in contemporary economic affairs and the relationship of skills and training with GNP. In this sense then, these debates require more detailed theories concerned with economic change at a meso level. The discussion now moves on to look at a number of debates taking place in economics, industrial economics and management studies in relation to understanding the current role for public policy in advanced capitalist systems.

4. NEW TRADE THEORY AND SYSTEMS OF INNOVATION

The aim of this section is to review a number of debates in social science that have sought to challenge the totalising view of *globalisation* and open the possibility that government action may be in the national interest. The first section discusses the main conjectures underpinning 'new trade theory'. At the base of new trade theory is the policy question of state intervention in industry. Based on this theory, there has been a growing shift among some mainstream economists that industry could be targeted as *strategic* and that some form of managed trade and industrial policy is necessary (Borrus et al 1986) and this is discussed next. Alongside these issues, other debates in economics are emerging focusing on the role of 'learning' within economic growth and the importance of the scientific and educational infrastructure within nation-states for supporting national competitiveness (systems of innovation) and these are discussed in the third section. Michael Porter's work is included here because of the significant questions that it his analysis raises concerning whether national solutions can be found to securing international competitiveness in some sectors in a global economy. The fourth part considers some limitations with these approaches and discusses a number of arguments which point to the enduring significance of the nation-state while simultaneously recognising that some form of internationalisation of economic systems is taking place. The concluding section then, moves on to argue for a more inclusive approach to understanding contemporary economic outcomes whereby the nation-state is situated within the global industrial system.

4.1 New Trade Theory

The 'new trade theory' has been developed to challenge conventional economics in relation to international trade premised on comparative advantage theory. Significantly, these theorisations connect knowledge and technology to changes in international trade (Romer, 1986). This continues the theme of this chapter related to knowledge and the accumulation process. New trade theory examines the determinants and patterns of international trade under conditions that diverge from the stringent and unrealistic assumptions on which traditional comparative advantage theory is based. Krugman states:

> 'The industries that account for much of world trade are not at all well described by the supply and demand analysis that lies behind the assertion that markets are best left to themselves. As we have seen much of trade appears to require an explanation in terms of economies of scale, learning curves and the dynamics of innovation, - all [of these] phenomenon [are] incompatible with the kind of idealisation under which free trade is always the best policy. Economists refer to such as 'market imperfections' a term in itself conveys the presumptions that these are marginal to a system that approaches ideal performance fairly closely. In reality, however, it may be imperfections are the rule rather than the exception' (1986, p.12).

Such an approach is also historically based with Krugman (1986) arguing since the second world war, large proportions of trade cannot be explained by factor endowments (land, labour, capital). Instead, trade reflects arbitrary or temporary advantages resulting from economies of scale or shifting leads in technological races. Mass production has led to an international division of labour and traditional trade theory does not account for these kinds of motivations for international specialisation. Similarly, there have been a variety of transformations taking place in the organisation of trade culminating in the changing position of the United States in the world economy as an 'internationalised' market. Krugman (1986) argues that the changing character of trade away from trade based on simple comparative advantage and toward trade based on a complex set of factors, has required a reconsideration of traditional arguments about trade policy. Increased sophistication within the economics profession has made practitioners willing to abandon some of their traditional but increasingly untenable simplifying assumptions. Borrus et al state that:

> '... these assumptions, which include perfect competition, constant returns to scale, and the absence of externalities are clearly at odds with conditions in the markets for manufactured goods' (1986, p.112).

New trade theory is premised on academic work on constant returns to scale (Kaldor, 1989; Krugman, 1991a/b; Romer, 1986, Arthur, 1990) which in turn stresses the likelihood of increasing returns to scale and imperfect markets, rewarding those industries first successfully penetrating foreign markets while resisting penetration at home. According to this theory, trade arises because of advantages of large-scale production, the advantages of cumulative experience (therefore access to knowledge and skills) and transitory advantages resulting from innovation. Importantly, it is argued that the changing pattern of trade has made classical 'tools' clearly unworkable assumptions for trade policy. Methodologically, taking place by place socio-economic costs and dynamic comparative advantage construction into account, a different way of thinking about and researching international trade issues is required than is offered by the static, neo-classical general equilibrium approach. It calls for an historical industry-by-industry approach. For example, some industries grow more rapidly than others due to larger potential markets and in a world of less than full employment, offer greater potential for rapid productivity growth, rising per capita income and overall contribution to economic growth. Not only are dislocation and unemployment the most inevitable consequences of free trade, but that acceptable levels of growth, employment and per capita income require sectoral policies to promote strategic industries (Howes and Markusen, 1993). In addition, it is argued that important trading sectors are also sectors in which rent may not be easily competed away. 'Rent' in conventional economics, means payment to an input higher than what that input could earn in an alternative use. It could mean a higher rate of profit in an industry than is earned in other industries of equivalent risk, or higher wages than equally skilled workers earn in other sectors. The conventional view is that rent distribution cannot be an important issue: in a genuinely competitive economy there will be very little rent. If profits or wages are unusually high in an industry, capital or labour will come in to the market and restore equilibrium (non-rent) returns.

However, Krugman argues that if there are important rents in certain sectors, trade policy can raise national income by securing for a country a larger share of the rent-yielding industries. Because of the importance given to economies of scale, advantages of experience and innovation as explanations of trading patterns, it seems more likely to the 'new trade theory' school that rent will not be fully competed away - that is labour and capital will sometimes earn significantly higher returns than others. Thus the possiblity of creating 'external economies' (meaning a benefit from some activity that accrues to other individuals or firms than those engaging in the activity), presents a justification for activist trade policies. Although external economies are different to rents they provide a reason, for Krugman, for favouring particular sectors. This time the point is not capital and labour in the sector will themselves earn exceptionally high returns, rather they will yield high returns to society because in addition to their own earnings they provide benefits to capital and labour employed elsewhere. Given the critical importance of technology, it is argued that certain sectors will yield important external economies, so producers are not paid the full social value of their production.

The reason why external economies have become more of a 'trade issue' is this approach is the critical role attached to technology, rather than a subsidary one as in orthodox economics. Traditionally, technology is generally regarded as codifiable knowledge, which is easily transferable and often without cost. Technology is seen as, 'information that is generally applicable, and easy to reproduce and use...one where firms can produce and use innovations by dipping freely into a general 'stock' or 'pool' of technological knowledge' (Dosi, 1988, p.1130). However, as previously argued in this chapter, knowledge and its related activities such as skilled labour are critical factors of production in advanced industrialised societies. Innovation, because it involves the generation of knowledge, is particularly likely to generate valuable spillovers into the economy thus important external economies. Combined with this is the importance of cumulative experience and 'learning by doing' alongside the problem of appropriation in the diffusion of knowledge and technology. These developments in economic thinking give technological innovation an enlarged role rather than a subsidiary one and good reason to suspect that trade policies can be used to encourage external-economy-producing activities.

In empirical terms, Borrus et al (1986) have used this approach to explore the United States market position in the semi-conductor industry. Their findings supported the new trade theory, reporting that successful innovation requires that firms be plugged into a whole range of past and contemporary technologies that are related to their R&D efforts. Borrus et al (1986) also argued that this interdependence has been critical to the ability of

American semi-conductor firms to stay at the frontier of technological change. In addition, Borrus et al research found that the role of integrated human communities has been an essential factor for Japan in the semi-conductor industry. They cite that in Japan the scientific and business communities are close in comparison to the United States and Western Europe. As a result, technological information is more likely to flow more rapidly in Japan that between Japan and the rest of the world. To some extent the flow of technological information across national and international markets through product sale and purchase can keep individual firms abreast of the latest technological developments. However, they suggest that a new product often does not embody the entirety of a new technology. The know-how and the understanding of the technology developed is extended beyond the product into:

> '..the network or community of people who developed the technology and who helped to apply it. Moreover it is often the case that potential users of a new technology require knowledge of products in development months and even years before such products are available on the market is their own research and innovation activity is to be successful. Often the only way to acquire such information is to be involved actively in related research areas and to participate in the related scientific communities.' (Borrus et al, 1986, p.93).

Borrus et al (1986) point to countries that lose a substantial market share to a foreign competitor and so may lose the domestic scientific community on which the ability to innovate depends. In their research, the business and scientific communities, despite their international character, remain more tightly knit on a national than on an international level. They will also be highly segmented by technology or industry sector. Therefore it is unlikely that the international exchange of scientific information can be a complete substitute for the erosion of a domestic research/science base. As I show in the reported study in the subsequent chapters, these conclusions are very similar to the biotechnology industry.

4.2 Policy implications of new trade theory: strategic trade policy

The rationale for governments pursuing some form of strategic policies has been put forward with rigour, gaining respect in mainstream economics, by the 'new trade theory'. The aim of strategic trade policy is to move away from the unrealistic conjectures and body of assumptions that underpin mainstream economics and address the concerns of the business community and policy-makers (Krugman, 1991a/b; Grossman, 1986; Borrus et al 1986; Johnson et al 1989; Zysman, 1993). Strategic trade theorists call for activist government industrial policy because of the inherent limitations and weaknesses of neo classical tools for description and prescription. These theories suggest an alternative explanatory framework, offering a theoretical point for supporting government intervention not only in relation to the supply-side, but also for an industrial policy based on the recognition that growth is not constrained by factors such as the supply of labour, but by the overall structure of demand (a similar point is made in the earlier critique of flexible specialisation).

Essentially, the premise of the strategic trade theories is that success at international market penetration is a function both of competitive advantages in relative prices, technology and productivity, themselves a function of both cultural and institutional factors and of concerted government policies to pursue strategic advantages. Such policies are almost always implemented at a sectoral level - within and among a group of firms concentrating on certain industry lines. The assumption that sectoral mix does not matter to economic growth is contested indirectly by some and directly by others (Kaldor, 1989; Dosi et al, 1989). However, in general it is argued that government polices can have a dramatic effect on the evolving location of an industry internationally, by cultivating it in one region at the expense of another (Howes and Markusen, 1993). Through a collection of sectoral case studies, Markusen et al (1993) show that entire regions can suffer severe adversities and adjustment costs that must be weighed against purported gains from free trade. They challenge the notion that cheap imports are unambiguously better for the consumer, by pointing out that many of the consumers so served may simultaneously be workers whose incomes have been severely depressed by redundancy or plant closures. Government policies can, in short, construct comparative advantages in ways not taken into account in traditional free trade theories.

In policy terms, for many decades a real alternative to neo-classical theory has been embodied in the economic development strategies of Japan, and more recently the newly industrialised countries (NICs). Recently this work has been codified by 'revisionist' approach mostly notably through the work of Kaldor (1989); Johnson et al (1989), Scott (1991) and Shinohara (1982). The revisionists trade theory as practised in Japan and other South East Asian countries is producer oriented and growth oriented. Growth is achieved through strategic promotion of industries with high potential for productive growth. Short term concern for consumer prices is subverted to long term concern for overall growth rates. Per capital income grows not due to lower prices but due to high rates of productivity growth (Markusen et al 1993). Scott (1991) groups strategic trade theory under the 'revisionist trade theory' rubric. In sum, these new 'international economists' have theorised that nations must strategically exploit product market imperfections to their advantage. Attempting to remedy the failure of neo-classical theory to explain intersectoral trade, these theorists raise the theoretical possibility that economies of scale could be so large relative to the size of the market that an early entrant might successfully discourage any competitors from entering the market.

In summary, critical to the new trade theories are changes in international trade as a direct consequence of changes in technology, knowledge and skills. As with GPE theories, among the forces of change in international trade, technology is seen to be an increasingly important one. In many industries competitive advantage appears to be determined neither by underlying national characteristics, nor by the static advantages of large-scale production, but rather from the knowledge generated by firms through R&D and experience. Thus, there are two important issues raised by the new trade theory that have direct bearing for this overall chapter. First based on academic enquiry, the 'new trade' theorists offer an important challenge to conventional economics based on its conceptualisation of the forces behind the behaviour of markets and economies. They recognise that imperfections in markets are more likely to be the rule rather than the exception (Krugman, 1986; Stopford and Strange, 1992) and therefore theories that address these imperfections are more appropriate conceptual tools for understanding market behaviour and for informing policy-making. Second, at the base of the complementary scholarship to new trade theory is the argument for state intervention in industry. From this basis, there has been a growing shift among some mainstream economists that industry could be targeted as strategic and that the driving force behind the emergence of certain sectors has moved from markets to institutions.

The overall importance of new trade theory and the related strategic trade policy to this chapter is to offer an alternative paradigm which opens a new dimension and a different set of questions. The general line of argument in this perspective is that causality can take both directions: governments can take the initiative to influence the composition or output of trade or can feel forced to respond to external changes they regard as undesirable. These developments challenge conventional wisdom concerning globalisation, the labour market and the role of the state in the global economy. In direct contrast to Reich's argument reviewed in chapter one, these theories question the extent to which actual trade can be explained by comparative advantage theory and open up the possibility that government intervention in trade may be in the national interest (Krugman, 1994).

This whole question of whether some sectors can be 'picked' for targeted government policy and the importance of technology, knowledge and skills (R&D infrastructure and labour markets) has more recently spurred new debate in economics and industrial sociology about creating polices to nurture economic development around institutions. The 'systems of innovation' approach is discussed below.

4.3 Systems of innovation

> 'The nation state should be recognised for what it is: the single most powerful mechanism of legal and organisational powers for economic intervention' (Costello et al. 1989, p.55)

If, as conventional wisdom implies that the nation-state no longer functions as a legal entity within its own borders or within its international affairs in the world system then the implications of this argument is that the world system is entering a period of convergence through the homogenisation of economic systems. Thus the concept of national differences in innovative capabilities determining national performance can be challenged on the grounds that transnational corporations (TNCs) change the face of economic activity in the direction of globalisation (Ohmae, 1990). However, there is a growing debate which seeks to identify the relations between technological change, the economy and wider society and why some nations perform better than others.

National systems of innovation is a broad term which includes the processes of innovation and diffusion in the context of the production system and of social and economic institutions. McKelvey's (1991) definition of innovation system is a useful one when she refers to three interrelated dimensions: (a) to denote a specific stage in the process of technological change - when an invention is introduced into the market; (b) to denote all kinds of non-technical novelties of an organisational, social and institutional nature, and (c) to denote the process of creating, diffusing or using these various changes. Different definitions of technology are part of crucial differences in the understanding of economic and technological dynamism in national systems. As with developments in new trade theory others in economics have attempted to address this question about technology in analytical detail (see Dosi et al 1988; Freeman and Perez, 1988). Rather than being understood as a generally accessible 'pool' of knowledge, technological development is seen to be dependent on historically determined skills and search routines detail (see Dosi et al 1988; Freeman and Perez, 1988). The 'national systems of innovation' approach accepts this critical role of knowledge generation in contemporary economies thus the education system is taken as pivotal to economic development (Mjoset, 1992). (For a historical perspective of the national system of innovation see Freeman, 1995). Thus, while traditionally the emphasis has been on radical technical breakthrough, Kenny (1995) reminds us that innovation is ubiquitous, gradual and cumulative and that necessary institutions need to be in place to enable learning. Fundamentally, innovation is about learning: learning by doing, by using and by interacting. Given the central importance of knowledge in modern economies, learning is the most important social process. According to Lundvall, to understand how it occurs, and therefore how it can be strengthened and developed, it is essential to recognise that 'learning is predominately an interactive, and therefore a socially embedded process, which cannot be understood without taking into consideration its institutional and cultural context' (Lundvall, 1992 p.1).

The notion of national systems of innovation is rooted not only in theoretical developments, but also in the growing awareness that all industrial countries have very different institutions fostering innovation which have been determined by a number of factors (and thus directly challenging the notion that the nation-state is disintegrating under the twin pressures of supra-regional blocs and globalisation). As discussed in chapter one, for some writers the globalisation of knowledge and technology presents a profound challenge to national economic policies. However, the evidence for the emergence of a disembodied knowledge network that transcends national boundaries is not convincing (Amin and Tomaney, 1996). For instance, Archibugi and Michie (1993) find evidence for increased global exploration of technology and increased international technological collaboration (as does Howells, 1990), but much less evidence for the global generation of technology. This has also been empirically argued by Pavitt and Patel (1991b) in relation to world R&D and patent data and by Ruigrok and van Tulder (1995). Archibugie and Michie (1995) conclude that in spite of globalisation, national innovation systems continue to play a crucial role in the organisation of research and know-how. They suggest that firms appear to be heavily influenced by national capabilities when taking strategic decisions concerning international joint ventures or the internationalisation of their R&D facilities, which, argue Amin and Tomaney (1996), make national innovation systems more not less important.

In line with this broadened conception of technology to include institutions, much of the new research on national systems of innovation has involved an attempt to widen the analytical scope to reach a deeper understanding of the relationship between technological change and economic growth. In so doing, there has a been a move away from universal general equilibrium analysis in favour of exploring the role of national institutions, norms and procedures and the entire system of national political arrangements (legal, social, defence, labour market relations) as a source of explanation. Johnson (1992) comments that the wide range of institutional factors which impact on innovation include: communication and interaction within firms; interaction between firms (through forward, backward and horizontal linkages); user-producer relations; the institutional infrastructure (including education and training and incentive systems); co-operation and consensus; demand-side factors (dealing with the appropriation of the benefits of innovation) and formal institutions concerned with searching and exploring, such as universities and R&D departments. It is the importance of these institutional factors and the cumulative impact of their interaction that has led to a growing interest in the concept of national systems of innovation.

The conceptualisation of the relationship between actor and structure (see earlier discussion on IPE theory) overshadows the question of how much room for choice or novelty is assumed to exist in the innovation process. Theories relating to the national systems of innovation vary in relation to the importance of government policies and about the possibilities of affecting the future. McKelvy (1991) discusses four researchers (Porter, Freeman, Lundvall and Nelson) all of whom have attempted to reconcile the structure/agency problematic in relation to the adequacy of theory in addressing real world national systems of innovation. The work of Lundvall, Nelson and Freeman is more closely connected to the debates with economics and the role of institutions and technology. Porter, however, is more closely related to the management studies literature, focusing less on economic theory, albeit receiving considerable attention within policy circles and attention across the broad range of social science. (For example, 'Porter studies' of indigenous strengths in national economies have been made of Denmark, Finland and more recently Ireland. The Porter model is also being applied to regional innovation systems such as in Massachusetts).

But, Porter's work is relevant to this overall discussion because of his interest in national solutions to national competitiveness (Porter, 1990). He argues that relying on foreign activities that supplant domestic capabilities is always a second-best solution. As Reich, Porter focuses on the role of knowledge and skills as essential ingredients for factor creation. However, he differs from Reich in his understanding of global competition and the role of the national environment (home-base) when he states (for a detailed comparison of Porter and Reich see Lazonick, 1993):

> 'competitive advantage in advanced countries is increasingly determined by differential knowledge, skills and rates of innovation which are embodies in skilled people and organisational routines. The process of creating skills and the important influences on the rate of improvement and innovation are intensely local. Paradoxically then, open global competition makes the home base more not less important' (Porter, 1990, p. 158).

Porter advances strong arguments to show that firms draw their vitality from the conditioning forces in their home markets. He asks why some nations are more prosperous than others and why some national sectors flourish while others stagnate. He focuses on four factors. First, the basic structure of national factor costs, including the supply of skilled workers and an efficient infrastructure, for which he draws on earlier work in trade economics (Ohlin, 1933) to question many of the basic assumptions of comparative advantage (also see earlier discussion on trade theory). Second, the structure of demand conditions, affected by national macroeconomic policy and in turn affecting the composition of trade. Third, the nature and type of competition (see Schumpeter, 1942) and the impact of related and supporting industries (external economies). Finally, groups of domestic rivals are integral to the operation of industry clusters. These industry clusters are in turn at the core of his analysis of the institutional mechanism for specialist factor creation and the sources of global competitive advantage. His central thesis is that competitiveness is borne out of fierce local rivalry, an active anti-trust policy and an avoidance of protectionism (see McKelvey 1991; Kenny, 1995; Lazonick, 1993). For Porter, the success of individual firms can be understood not by examining firm's actions, but only as part of the overall national system (a similar theme to the national system of innovation debate).

The importance of these contributions for this overall discussion relates to the overall theme of this section which seeks to question the totalising view of globalisation and 'unpack' conventional wisdom concerning government intervention in knowledge-based societies. First, these contributions legitimate a level of analysis above that of the individual or the firm thus challenging conventional economics in doing so. Rather than the reductionist imperative to explain all phenomena in terms of the (rational) individual (or firm), Porter, along with the national systems of innovation researchers, implies that national systems have their own autonomy. To varying degrees, they suggest that the national system of innovation may represent a level of analysis that is not entirely reducible to its individual components. Second, relates to what these contributions imply for the role of the nation-state. Despite the internationalisation of business, the nation-state still has a fundamental role in shaping its own national system of innovation which, as the study of biotechnology supports, is critical to its overall economic development. This re-conceptualisation of trade and the 'real world' has ramifications for the idea of the 'residual state' (Cerny, 1995) which challenges the nation-state's policy effectiveness and for the 'hollowing out' of the state, which in part refers to the blunting of traditional macroeconomic polices by global forces beyond the control of individual states (see Amin and Thrift, 1994; Jessop, 1992) but also, refers to the pressure on states both weak and strong to accommodate other powerful global economic institutions (see Dicken, 1994; Sally, 1994). Krugman (1994) has criticised Reich and Thurrow (calling them 'strategic traders') for mis-interpreting new thinking in economics and for promising polices that by following the recipe for promoting high-value or 'sun-rise' industries, they could not only improve the economy but solve its problems. For Krugman, strategic traders make a misleading diagnosis about the American economy's problems '...the idea of strategic traders seemed to the economists to be a crude set of misconceptions, presented as if they were sophisticated insights' (1994, p.7).

Following this discussion of new thinking in relation to developing new conceptual approaches in economics, there are a number of caveats to these approaches, notably that these approaches do not include any discussion of power in their analysis. These are discussed below in relation to a number of other scholars that have sought to re-conceptualise the nation-state in its changing environment and consider the political economy of the state in the modern world. For example, Hirst and Thompson (1996) join a growing number of others (Amin and Tomaney, 1995; Cox, 1987; Teague, 1994; Archibugi and Michie, 1995; Hutton, 1995; Lazonick, 1993; O'Donnell, 1993; Hayward and Tomaney, 1996) in arguing that despite powerful external macroeconomic tendencies, the nation-state still remains the most important social organisation in the international system and still retains room for manoeuvre in important areas of economic policies. Rather than diminish in importance, these scholars point to how the role of the nation-state has become more important given contemporary economic systems have become more 'knowledge-intensive' than in the past. These debates suggest that the popular conception of a globalisation of the world system is misunderstood. To think of globalisation only as a threat or opportunity for local and national communities is to miss the point and provide an excuse for non-action. Thus these scholars critically assess the idea of globalisation as an exogenous force which is threatening local and national communities and policy-making effectiveness (see Ruikgrok, 1995; Ruikgrok and van Tulder, 1995; Teague, 1995; Hutton, 1995; Pliger, 1995). Both some general limitations of new approaches in economics and these new developments concerning the role of the state are turned to below.

4.4 Limitations

Broadly speaking, one of the main criticisms against the national systems of innovation approach is that it fails to connect the system of innovation to a broader structure of power within the political sphere. In particular, it fails to recognise what Hirst and Thompson (1996) have observed to be the emergence of new forms of governance of international markets and other economic processes involving the major national governments, but in a new role: states will come to function less as sovereign entities and more as components of an international polity. New forms of governance are emerging with the state providing legitimacy for and ensuring the accountability of supra-national and sub-national governance mechanisms. Thus without adhering to the tenets of the extreme globalisation thesis, the international system of production, knowledge and finance that characterise areas such as competitive strategy cannot be ignored and are generally neglected in the new trade theory and national system of innovation literature.

Another general criticism against the national systems of innovation concept is the use of the terms 'system' and 'national'. The term 'system' narrowly defined, suggests something that is designed or built, a set of things or parts, or a mechanical process. However, when defined in terms of 'national system of innovation', the orientation of 'system' is very different and presents an image more of a 'society' whereby behaviour is shaped through relationships, set of procedures and norms and linkages. For example, 'systems of innovation' we are told, are characterised not by the narrowly defined R&D

base, but by the relationships which interact in the production, diffusion, creation and use of economically beneficial new knowledge, these of which, are located both in, outside and beyond 'national' borders (for example Nelson, (1992) in relation to technology creation and the firm; Freeman's (1988) underlying theory of radical technological change which spreads internationally).

This leads to the second ambiguous concept - 'national'. This term is used despite the acknowledgement of some scholars that technology is not limited to the national context, (as argued in the earlier section on IPE), it cannot be ignored that the global industrial system has been driven by the transnationalisation of technology. Despite recent changes taking place in the international system even in early international relations underpinned by realist assumptions, Aron (1966) explored the nature of a space 'transnational society' to indicate that state options are affected by developments in the flow of ideas and beliefs across borders and by non-national organisations.

Although the national systems of innovation approach attempts to address some of the relationships between agency and structure, there is a general neglect to discuss the relationship between technological outcomes and power. For example, the trade off between the political imperatives of non-state interest groups (for example, transnational business classes; the role of supranational organisations such as EU policy) and structural constraints facing the state (for example, state security concerns and interests). Overall, there is a failure in the national systems of innovation approach to address the relationship between nation-states and the world order and the influence that this can have on determining policy. There is a similar problem with the Porter model which is primarily concerned with territorial systems of production. Despite the title of Porter's work *The Competitive Advantage of Nations*, the main levels of argument apply at the level of the firm (Stopford and Strange, 1992). Aggarwal and Agmon (1990) criticise Porter for failing to examine the interaction between the international competitiveness of local firms and government policy, a crucial issue particularly for developing countries. Thus, Porter omits detailed consideration of investment and entrepreneurship, almost wholly ignores the changes in the world system outside countries and fails to recognise the composition of government as groups of parties with different interests (Stopford and Strange, 1992). Dunning (1992b) argues that whilst Porter offers a useful:

> '..paradigm for identifying the main determinants of national competitiveness, his lack of attention to the ways such competitiveness may be affected by the ownership structure of firms and the way cross border markets are organised weakens both the content and the force of his thesis' (Dunning 1992b, p.165).

Stopford and Strange (1992) have adapted Porter's analysis to add more explicit treatment of government policies that balance economic with social conditions. However, Lazonick (1993) argues that the basis of Porter's analysis is incorrect and that the language of Porter is not of rivalry but of co-operation over technological communities. Lazonick argues in relation to the industrial district debate that rivalry in itself cannot explain the ability of an enterprise to respond innovatively to competitive challenges and pressure may eventually lead to paralysis rather than action (also see Hutton 1995). The main point made by Lazonick is that unless social organisations are put in place that can engage in innovation, heightened domestic rivalry will lead to decline. Furthermore Lazonick, (in a similar theme to strategic trade policy), argues that more domestic rivalry will not result in global competitive advantage when foreign rivals are innovating on the basis of their own industry clusters which have already acquired sustainable competitive advantage. Ferguson (1993) also argues that in the case of Silicon Valley, to fight foreign rivals requires a suspension of rivalry in order to build value-creating industrial and technological communities.

In terms of public policy, managing the relationship between knowledge, technological innovation and competitiveness has become far more complex. While the questions of when and how policies to promote innovation will be effective remain controversial, such policies have nevertheless been adopted in some form or other in the majority of advanced economies (Archibugi and Michie, 1995). Thus while national governments may no longer be entirely 'sovereign' economic regulators in the traditional sense, they remain political communities with extensive powers to influence and sustain economic actors within their territories. On this view, the political role of national government is central in new forms of economic management:

> 'States are not like markets, they are communities of fate which tie together actors who share certain common interests in the success or failure of their national economies. Markets may be international but wealth and economic prosperity are national phenomena. They depend upon how well national economic actors can work together to secure certain key supply-side outcomes. National policy provides certain key inputs that cannot be bought or traded on the market. The market is embedded in society and governments remain a crucial elements in the success of their societies - providing cohesion, solidarity and certain crucial services that markets of themselves cannot' (Hirst and Thompson, 1992, p7).

Some scholars have argued that the nation-state's role as a political entity shaping economic affairs and controlling economic decisions cannot be undermined. For instance, Hirst and Thompson (1992 p.3) argue that there are three key functions which stem from the nation-state's role as orchestrator of an economic consensus within a given community which is intrisincally linked to the political realm. First, the state must construct a *distributional coalition* that is acceptable to key economic actors that can sustain prosperity. Second, a distributional coalition is only possible if the state performs another function, the *orchestration of social consensus* - for instance, a collaborative political culture in which the major organised interests are accustomed to bargain over national economic goals. Such an overall consensus only works if it is also keyed in with the effective operation of more specific resource allocation mechanisms, such as the system of wage determination and the operation of capital markets. Finally, and importantly for this discussion it is still the nation state which determines the constitutional position, powers and fiscal resources of lower tiers of government for instance, at the sub-regional level. Sigurdson (1996) has also observed two areas that demonstrates the enduring influence of the nation state on shaping the national system of innovation. First, that the nation-state is still able to raise taxes, increase the national budget and make decisions on budget allocation. Furthermore, the strength of the nation-state also arises from its overall responsibility for social security which has its basis on its ability to raise taxes.

If production systems have become more knowledge intensive and the skills and qualifications of labour have become one of the most important factor inputs into an economy, the control over the creation and delivery of the labour market and the development of a science and educational infrastructure is highly influential. As shown in chapter seven, many firms in the biotechnology industry still believe that government acts as the main supplier of education and training, and is responsible for creating an adequate infrastructure for firms. Sigurdson (1996) comments on how this has traditionally been the preserve of the nation-state, with the state almost everywhere shouldering a very wide, if not total responsibility for education and training from kindergarten to engineering and scientific training. Linked to that can be added that the nation-state still has control over the majority of its peoples and labour markets. Hirst and Thompson (1996) state that while the state's exclusive control of territory has been reduced by international markets and new communication media, it still retains one central role that ensures a large measure of territorial control - the regulation of populations. They comment that:

> 'People are less mobile than money, goods or ideas: in a sense they remain 'nationalised', dependent on passports, visas, and residence and labour qualifications. The democratic state's role as the possessor of territory in which it regulates its population gives its definite legitimacy internationally in a way no other agency could have in that it can speak for that population' (Hirst and Thompson, 1996, p.171).

Teague (1994) has also commented on how despite the rhetoric of globalisation and global labour mobility, the nation-state still retains control over labour markets and the industrial relations system. Labour market policies, such as the social security system, currently remain a national responsibility and cannot be easily transferred downwards to local institutions or upwards to supra-national ones such as the EU (Teague, 1994). From the empirical research reported here in chapter seven and added to Teague's overall caveats to the globalisation thesis in relation of national public policy making in labour markets systems which within the European context has served as a barrier to labour movement around the member states on the basis of differing perceptions of the standards of certain qualifications. Similarly, it is almost impossible to conceive of a Europe-wide pay co-ordination as currently practised by national systems such as Germany and Ireland. Generally, problems of scale and heterogeneity - radically different union densities and scales and systems of wage determination themselves make European Union level corporatism highly unlikely. A supra-regional level labour market would be difficult to achieve because of linguistic, cultural and other barriers meaning that levels of migration between member states is low. This is made evident in the case study.

5. CONCLUSIONS AND RESEARCH FRAMEWORK

Returning to the argument in chapter one, this chapter follows Reich in so far that he recognises that the 'world' has transformed and that the relationships between public and private spheres have become far more intimately connected when he states '..[w]e are living through a transformation that will re-arrange the politics and economics of the coming century..' However, this convergence ends at this point and indeed leads to the conclusion that in his recommendations for future action, Reich merely re-packages the neo-liberal vision of globalisation. For example, the *dissolution* of the nation state along with the stateless corporation that Reich alludes to in the quotation at the beginning of this chapter and goes on to legitimise in his book *The Work of Nations*, resonates with the neo-liberal agenda on what governments can do in the face of uncontrollable and 'footloose' capital. Reich assigns the responsibilities of governments in industrial policy to that of improving the education and training levels of its skills base summed up as '..[e]ach nation's primary assets will be its citizens' skills and insights..'

The aim of this chapter then has been to provide the basis of the analytical framework to the overall thesis through a literature review and an analysis of relevant theoretical contributions that address knowledge-based structural transformation in contemporary capitalism and the ramifications that this has for firms, governments and markets. Significantly, these theories offer some explanation for the contemporary organisation of firms, states and markets. The discussion of flexible specialisation, IPE and new trade theories, all of which have treated 'knowledge and skills' in the accumulation process, have provided descriptive (and in the case of flexible specialisation and strategic trade theory prescriptive) analysis of the organisation of economic activity in contemporary capitalism. Each of these approaches offers a practical but necessary insight into the exploration of labour market changes. The approach used here is thus eclectic in its subject and in its ontology, although less radical in its epistemology than some propose for new IPE (cf. Murphy and Tooze, 1991).

The literature review and the critique it embodies leads to a number of propositions which form the platform for the later analysis. The first proposition is that the role of the state has not diminished, instead it has been 'modified' as a result of transformations in world structures. To suggest that the nation-state is no longer a relevant entity in the organisation of resources, themselves located in the societal systems of nation-states (complexes of firms, markets and institutions) is to undermine the importance of the national environment as a determinant of the competitive advantages of enterprises in global markets, and the overall importance of the state in creating knowledge resources. A more useful way of understanding the nation-state is to suggest that it has been re-defined as a result of becoming more intimately locked into the global industrial system (cf. Cerny, 1995).

The second proposition is linked to the implications of this argument for conventional thinking about economic activities and the international system. Traditional analytical 'tools' of political realism and conventional economics in relation to 'nation-states' and the national 'economy' (for example, territorial production systems and national systems of innovation) are no longer adequate. Even if they were, the 'international system' can no longer be meaningfully packaged into a separate 'international' realm of politics, structured by the principle of anarchy, which generates the behaviour of an arrangement of 'units' (states) in relation to the distribution of power. Its weakening requires giving priority once again to the interactive processes of a unified world economy rather than the internal workings of the state. Furthermore, other scholars referred to above in the area of institutional economics have argued that the market is a more complex than a market for exchange. These scholars argue that the market is identified itself as an institution, comprised of a host of subsidiary institutions which interact with other institutional complexes in society. These institutional complexes are at once national and transnational: the economy is more than the market mechanism.

Third, firms and government choices are articulated through a complex negotiation process that represents both economic and political imperatives. Economic imperatives drive the change in the structure of production and financial markets and affect the international division of labour. Equally so, political imperatives are those choices faced by states, either solely or in alliance with others. The combination of a greater mobility of critical factors of production, (technology, skilled workers and capital notably), creates tensions and uncertainties for firms as they develop their global strategies. Additionally, world structures have a direct bearing on the decisions that these (and other non-state actors) 'agents' take. Rather than diminish the role of governments (as neoliberal theories tend to suggest), structural changes have created both new possibilities for creating wealth and new dilemmas for governments on how to balance the conflicting demands of their domestic and international agendas. This point is made by Nelson on the need for a 'meso' level theory in between the macro and micro economic levels:

> 'it is now possible to begin to see industries in a more complex way, as systems involving a mix of institutions some private, some public... The orientation here should be understood not as an alternative to a focus on firms, or on the macroeconomic climate, but as a level of analysis in between and complementary to both (Nelson, 1991 p.9).

The fourth proposition addresses methodology. Following the arguments of a number of scholars, there is a need to develop theorisations that are capable of taking into account the rapidity of global transformations and major structural shifts (Amin et al, 1994; Gamble, 1995). The approach adopted in this thesis follows that of Gamble (1995), who has called for a multi-disciplinary approach across the social sciences, drawing from the diverse tradition of political economy to address the complexities of contemporary global order and transformation. He states:

> '..the fading of old ideological and methodological battles and the development of new intellectual agendas in response to far-reaching changes in the ideological, political, and economic parameters of the world system have created the possibility of a new political economy, bringing together methodological and theoretical approaches which for too long have been kept apart.' (Gamble, 1995, p.516).

This diverse 'methodological and theoretical approach' lead towards a final analytical framework which resonate with the conclusions reached by Humbert in his call for a systemic approach for formulating industrial policy (Humbert, 1994). This, he states, could serve as a sound basis for designing and implementing strategic industrial polices in a global industrial system. He concludes that activities of production located in each national territory cannot reproduce and expand themselves without strong links with others within the global industrial system. This leads Humbert to conclude that a:

> 'nation's territorial structure of production is the outcome of the articulation between the logic of the nation's societal system and the logic of the global industrial system. But both logics are usually different - in some cases they are clearly antagonistic - leading to somewhat orthogonal evolutions' (Humbert, 1994 p.458).

The fifth proposition is that the most effective way to test the idea that a particular institutionalist approach explains the intricacies and fragmentation of advanced technology labour markets such as biotechnology better than versions of the neo-liberal approach is to draw on these ideas and approaches. The conclusions to this chapter therefore, closely follow those of Humbert when he suggests that economic outcomes need to be understood as the articulation of the relationship between the contemporary logic of the '..nation's societal system and the .. global industrial system' and differs considerably from the argument of Reich as set out in the opening quotation at the beginning of this chapter. But, this thesis is concerned with one aspect of the 'globalisation' debate - the assumption that increasing the supply and levels of advanced skills leads to improvement in the overall competitiveness of firms. Having argued here that there is an intimate relationship between the global industrial system and national systems of production, the next chapter turns to a review of labour market theorisations. This is essential because it is here that the potent idea that investments in `human capital` can improve the competitiveness of firms can be grounded.

The relevance of this discussion is the opportunity it provides to review the traditional orthodox assumptions underpinning labour market thinking, and more importantly for this thesis, to examine the powerful conjectures of the 'human capital' theories that are generally regarded as the mainstream and have formed the basis for the current great interest in education and training and its relationship with economic performance. This has elevated education and training to a 'growth theory' in their own right. In the following chapter, two approaches in labour market theory are discussed: human capital (neo-classical) theories and radical labour market (institutional) theories. Despite its impeccable logic and mathematical rigour, the neo-classical box inadequately offers a basis for labour market behaviour in a highly globalised sector such as biotechnology. Institutional analysis, on the other hand, will be shown to provide a more useful methodological approach for understanding labour market behaviour in a high-technology sector such as biotechnology because it focuses on the role of institutions which shape and constrain firms, workers and government decisions.

CHAPTER THREE

ADVANCED SKILLED LABOUR: MARKETS OR INSTITUTIONS?

> 'What happens in the labour market .. is dependent upon factors outside workers' control. The notion that workers can 'price themselves' into work in a low-investment, low-activity economy is for Keynes inherently absurd. An individual employer cannot know if he hires a lower priced worker that other employers will or will not do the same: if they did the wages paid would help generate demand for extra production; if they did not the extra worker's production could not be sold - however low the wage. The price mechanism unaided cannot resolve this dilemma. Nor is there any way that workers in aggregate can lower wages sufficiently to price themselves in work, because the only uniform way is to raise the general price level thereby lowering their wages in real terms - but the factors determining the price level, such as monetary policy, are outside their control. They are *involuntarily* unemployed, and the origins of their problems lie in what has happened in the financial system, to investment and to the character and level of economic activity it has generated. In short, most of the economic cannonades of the past decade and half have been firing at the wrong target'
>
> (Will Hutton, The State We're In, 1995, p.242-243).

1. INTRODUCTION

The previous chapter discussed the role of skills and knowledge in the accumulation process. It also argued that markets are more complex than neo-classical theories would lead us to believe. This chapter moves on to consider a set of theories that have dealt specifically with labour market functions. Thus, it takes one 'market' that is crucial to the whole political discussion in contemporary spheres in relation to industrial policies and to economic competitiveness. The aim of this chapter is to discuss two main, conceptual approaches to labour markets - human capital and institutional labour market economics. The former contains a powerful set of conjectures that have driven policy-making in the area of skills and training in the European biotechnology sector. These assumptions about the functioning and behaviour of the labour market are also the logic behind the main tenets of Reich's thesis in the *Work of Nations* regarding the labour market for highly qualified (and in-demand) workers - 'symbolic analysts'. The argument advanced by Reich is that this market is a global one, characterised by open, free market competition and regulated by the invisible hand of market forces. Thus, global enterprises are free to secure the services of the best 'symbolic analysts' in this market place. These assumptions in relation to how the labour market functions lead Reich to conclude that the primary role of government in the global economy is to pursue policies targeted towards upgrading the education and skills-base of its domestic workers, thereby increasing the supply of symbolic analysts.

In chapter one, it was suggested that this argument has gained political salience within the Clinton Administration and more recently has been echoed in British debates and at the level of the European Commission. Furthermore, it was argued that the general interest in knowledge-intensive production systems has led way to a 'new orthodoxy' in relation to the politics and economics of education and training, or, as Hutton observes, is '..elevating education and training's economic importance that they are given the status of a growth theory in their own right' (Hutton, 1996). My own argument is that, given the importance attached to this perspective, closer analysis of these labour markets is required. The previous chapter specifically discussed the role of knowledge and skills within the broader global context of capitalist activity and examined academic contributions which attempt to understand these structural changes. I concluded that as a consequence of structural change, conventional economic thinking no longer accommodated the realities of economic activity in globally industrialised systems and that a broader conceptual base was required for explaining and predicting economic activities.

Taking these themes further, this chapter now turns to the specific sets of theories that have directly conceptualised labour market behaviour and the relationship of investments in human capital and worker productivity. This is a necessary task because, as I suggested in chapter one and show in this chapter, it is with orthodox labour market economics that many of the contemporary assumptions in relation to education and training policies and debates, and their relationship with the economy, can be found. For example, as I discussed in chapter one the favoured solution of the liberal left to the problems caused by both an increasingly open world economy and the rise of the Asian economies is that of training. Only in this way, it is argued can the beleaguered masses of the developed world hope to compete in a thrusting, new, dynamic global environment. Investment in training and education is a concept that is worth pursing by nation-states in the face of knowledge-intensive production systems as argued in chapter two. However, those who have argued in support of an industrial policy principally based around investments in education and training, fail to acknowledge some critical weaknesses of human capital theory. For example, Reich (1991) does not comment on the human capital and labour market economics literature directly, despite taking the main thrust of his argument directly from this body of theory.

The purpose here is to expose the limitations of orthodox labour market economics as a useful model for understanding labour markets in knowledge intensive sectors. The 'new orthodoxy' is a compelling argument for understanding labour markets in relation to the human capital assumption of rational choice, but fails to account for other factors that shape labour market outcomes. Drawing on this argument, subsequent chapters will seek to show that the labour market for a global, knowledge-intensive such as biotechnology reflect the structure of the firm and historical economic development patterns embedded in the nation-state societal system, which in turn reflect broader macroeconomic change.

This chapter therefore, examines labour market economics at a broad conceptual level, and assesses what new principles, if any, underlie these approaches, and whether the analytical reasoning described amounts to a useful understanding of labour markets in terms of their functions. It begins, for the purposes of clarification, by drawing a contrast between the tenor of debates since the 1950s in 'orthodox' labour market theories and discusses 'alternatives' that have emerged since. It then examines the schools of thought underpinning these positions: human capital theory and institutional labour market economics. The strengths and weaknesses of each approach are explored. It is suggested that the orthodox position which claims a new economic role for education and training is flawed: while there are clearly advantages to be gained by investing in workers' skills and training in the contemporary knowledge society, these are less dramatic and less certain than implied by the 'new orthodoxy' and shift the focus of attention away from discussions related to the complexities of advanced industrialised production systems interlocked in a global industrial system. It is argued here that the assumptions underpinning the current politics and economics of education and training require re-conceptualisation and alternative levels of analysis than those offered by conventional labour market economics. Specifically, that the institutionalist labour market approach is a useful starting point for understanding the labour market behaviour of highly skilled workers because it offers a more realistic picture of how the 'labour market' functions. Drawing from radical political economy, and following the themes developed in chapter two, this theory recognises how individual choice is constrained through the power structure of the organisation of capital. Consequently, individual investments in education and training may lead to slower pay offs within the economy than assumed by the new orthodoxy. Equally, unless investments in education and training are embedded in a wider array of policies to improve the overall production system, the results of investing in 'human capital' tend to be variable. The specific conclusions, however, raise a number of doubts about the comprehensiveness of the explanations of the institutionalists as a basis for understanding advanced skilled workers in globalised sectors. The conclusions suggest that the institutional labour market approach also needs to incorporate other dimensions of contemporary capitalism such as globalised institutions.

2.1 NEO-CLASSICAL LABOUR MARKET ECONOMICS

There is vast literature on labour market economics. The task here is to review in a schematic way the main tenets of neo-classical approaches (for more discussion on this area see the work of the economists themselves, for example, Fallon and Verry, 1988; Sapsford, 1981, Sapsford and Tzannatos, 1995). The weight of the orthodoxy in contemporary debates on the role of education and training necessitates a review of the assumptions and conjectures that underpin this position. The key to the economists' approach lies in the term '*labour market*'. Any interaction of buying and selling activity can be called a market and the term labour 'market' simply implies what is being sold - labour rather than the products of labour (goods and services) or currencies. In any one market there is an exchange between at least two people, one who buys and one who sells. There need be no more than one seller and one buyer (so the market need not involve the competition between buyers or between sellers) or it need not involve the exchange of labour for money. Economists were initially concerned to develop a theory that would explain both wage setting and the levels of labour supply and demand in a particular type of labour market. This is explained by Stoney as follows:

> 'The market for labour is not much different from the market for bananas; if demand exceeds supply, the price of the product should increase; if supply exceeds demand, the reverse should happen and the price should fall; at some point demand should equal supply at the equilibrium point' (quoted in Canning, 1984, p.6).

The neo-classical approach to the economics of education and training is known as human capital theory. The traditional labour market theory establishes a direct causal relationship between education, productivity and wages. Workers are assumed to choose how much education they wish to invest in, given the costs which are the wages foregone.

2.2 Human Capital Theory

> .. the human capital perspective considers how the productivity of people in market and non-market situations is changed by investments in education, skills and knowledge (Becker, 1993, p.386).

Until the 1950s economists generally assumed that labour power was given and not augmentable. The analyses of investment in education and other training by Adam Smith, Alfred Marshall and Milton Friedman were not integrated into the discussions of productivity. Then, however, Theodore W. Schultz (1963) and others began to pioneer the exploration of the implications of human capital investments for economic growth and related economic questions. During the 1960s economists extended their methodology into areas such as 'labour', traditionally the domain of sociology. Gary Becker took an important step in this development when in 1964 he published *Human Capital*. Becker was to extend the traditional theory of individual rational choice to analyse social issues beyond those usually considered by economists, and in so doing to incorporate into the theory a much richer class of attitudes, preferences and calculations (see Becker, 1957;1962;1968;1975;1993). Taking rational choice theory as a starting point, human capital analysis begins with the assumption that individuals decide on their education, training, medical care and other additions to knowledge and health by weighing the benefits and costs. Benefits to the individual making a rational calculation to invest in education and skills include cultural and other non-monetary gains along with a potential improvement in earnings and job satisfaction, whereas costs usually depend mainly on the foregone value of the time spent on these investments. The concept of human capital also covers accumulated work (ie know-how) and other habits (for Becker this can include addictions such as drinking and smoking (see Becker, 1993). Human capital in the form of good work habits or addictions to heavy drinking has major positive or negative effects on productivity in both market and nonmarket sectors. Following in this tradition, Freeman argues:

> 'We have made considerable progress along the paths developed in the late 1950s and early 1960s by T.W.Schultz, G. Becker and others on the economic analysis of the demand for education. While there are exceptions, the past two decades' work supports the general proposition that economic analysis of rational behaviour under specified market and international conditions goes a long way to understand the interplay between education and the economy' Freeman (1986, p.357-358)

For Becker, the coverage of the human capital theory was to include various kinds of behaviour in an effort to calculate both private and social rates of return to men, women and minority groups from investments in different levels of education. This led Becker to conclude that the thoery provides a useful tool for explaining many irregularities in labour markets (for example, on empirical analysis of investments in human capital see Mincer, 1974 and for a summary of the literature see Psachoaropoulos, 1985).

In its most extreme form, human capital theory proposes that all productivity differences between individuals reflect differences in the amount of investments made in human capital. Thus individuals who wish to maximise their present value of life time earnings will accumulate human capital up to the point where the marginal benefits - the discounted expected incremental income that arises from the investment - equal the marginal cost of acquiring it. On the demand side, profit maximising firms will employ labour up to the point where the wage equals the value of the marginal product, with technology and capital taken as exogenous parameters. Competition will then ensure that wage differentials reflect the value of the extra output made possible by the higher level of education and training (see Ben-Porath, 1967). Ben-Porath used this concept to explain the optimal life-cycle pattern of human capital accumulation and the differences between sets of workers in the job market. Based on the assumption of free choice and rational decision-making behaviour, it is argued that workers choose between jobs that offer different amounts of training opportunities. Those workers who choose jobs with training receive lower current earnings but higher future earnings than those who enter jobs with less training. The main point is that this choice primarily reflects differences in individual preferences.

During the 1970s and 1980s the emphasis of the literature shifted from the economics of education to the economics of training. This has produced new challenges for human capital theory, as the provision of training in market economies is only partly controlled by the state and therefore cannot be treated as analogous to education. Thus human capital theorists faced the problem of how to reconcile not only the issue of private versus social returns, but also the distribution of private returns between individuals and firms. The earliest explanation of the distribution of the rewards from training focused on the distinction between specific versus general training. Since then other alternative explanations of the returns have emerged which have resulted in generalisations of human capital theory (see the review by Bosworth et al 1991 for a fuller discussion of the development of human capital theory). Subsequent work by Becker (1993) has continued the themes of human capital theory by extending the model to accommodate differences in ability and family background, and the differential access individuals have to the resources necessary for funding education and training programmes.

2.3 Critique of Human Capital Model

Criticisms levelled against the human capital theory focus on its inadequate analytical categories and assumptions. It is argued that human capital theories do not satisfactorily explain the consistent and pervasive discrimination in wages, jobs advancement and segregation faced by some sections of the workforce such as women and ethnic groups. This is supported by evidence from an American study undertaken in 1986 which found that up to 20 per cent of the wage differential between men and women was unexplained by differences in human capital (Gregory and Ho, 1986). For example, Becker has described how employers have a 'taste' for discrimination which leads them to sacrifice profits. This 'sacrifice of profits' is difficult to explain alongside theories of long-run perfect competition which would predict any such firm being unable to compete with more efficient non-discriminating firms, forcing it out of the market. This argument is hard to sustain, as discrimination is generally more of an economic benefit than cost to employers allowing them to exploit sections of the workforce (Tzannatos, 1987). The notion of 'efficiency wages' has been developed to explain the persistence of discriminatory wages, as it suggests that increasing wages reduces absenteeism and staff turnover, improving the efficiency of the non-discriminated group (Bergman, 1986). Monopsony power has also been recognised as allowing employers to continue discriminating (Fanning Madden, cited in Cain, 1976). Indeed, the predominately male trade union demands for a 'family wage' that only men should earn had a significant role in maintaining women's secondary status in the labour market in both Britain and the United States (May, 1985). Such worker discrimination is theoretically tolerated when the transaction costs of 'firing' prejudiced staff and recruiting new employees outweigh the costs of discrimination.

The most restrictive assumption underlying this analysis is that it has very little to say both about the nature of skills which individuals acquire and about the nature of the training activity itself (McNabb and Whitefield, 1993). The human capital model offers no attempt to explain why some individuals have access to training and others do not. Similarly, human capital theory has very little to say about the demand side of the labour market. For example, why do some firms offer more training than others, and what determines the types of training that they offer? Within the human capital model, training is assumed to take place primarily 'on the job' and is simply an extension of the schooling decision, in which there is complete specialisation in education. This is only valid if the training involved is general, in the sense that the individual's productivity gain can be applied in any job and not just the one in which the training was received. In this case, the concept of the firm as an institutional entity is irrelevant and it is assumed that individuals spend most of their working life learning technical skills, with the result that they become more productive workers. Such 'learning by doing' may be an unavoidable feature of a particular job or may depend on the custom and social relationships of the workplace. In either case the relevance of the human capital individual decision-making model is called into question.

Another criticism of the human capital model is the idea that some skills can increase productivity only in the firm or on the job, where training is received. In the first place, the relevant period over which the benefits accrue are no longer in the individual's lifetime, but the expected duration of the employment contract with the firm, or the expected duration of the job itself (Dosi et al 1988). Second, it is no longer the case that the optimum pattern of lifetime investment is one that is heavily loaded during the earlier parts of an individuals working life. Moreover, contemporary thinking particularly at the European Union level is now focused on 'life-long learning' strategies and continual investment in skills and training through an individuals working life (CEC, 1993; IRDAC, 1991;1994; Bangemann, 1995). The new economic realities of flexible working practices have given rise to life-long learning strategies and the importance of learning while doing (IRDAC; 1991;1994; CEC, 1993; Blaug, 1990). Others have attempted to formulate human capital models in which the characteristics of the training activity itself are accomodated (see Rosen, 1972 and Parsons, 1990). In addition, the erosion of permanent employment opportunities has meant that life-time learning in one firm or in one organisation is increasingly unlikely.

The explanatory limitations of the human capital model demonstrate the inadequacy of its assumptions. Human capital theory is especially inadequate for a study of labour market activity in a knowledge-intensive sector such as biotechnology. The model offers a conceptualisation of training under a restrictive set of assumptions and fails to explain adequately why some individuals gain access to skills and training and others do not. Specifically, the model fails to conceptualise labour market behaviour in industries such as biotechnology where, as I show in chapters six and seven, the demand side of the labour market plays an important factor in determining why some firms offer more training than others and in explaining the type of training that they offer. Furthermore, in knowledge-intensive sectors (such as biotechnology), the training received through learning in-house tends to be highly specific to the firm (see Senker and Faulkner, 1992) and therefore not easily transferable to other firms or sectors. The notion that investments in training result in more productive workers is also highly speculative and depends on the tasks involved and the range of other influences that can affect the productivity of workers including working conditions, psychological factors, a worker's motivation and overall levels of investment.

The root of these problems is the assumption of a competitive labour market comprised of maximising individuals and firms which will be efficient as long as the following conditions apply: all workers have access to capital at the social rate of interest; job changing is costless; there are a large number of firms demanding the particular skills concerned; and there are no other externalities. As a result it is doubtful that a model based on such a restrictive set of assumptions can have any real value in explaining what happens in the real world, especially in a high technology sector.

Despite these inherent weaknesses, the human capital model endures as a powerful orthodoxy on which to base the political arguments of the economics of training and education. The implication for the policy-making process is that because of the limitations of such an approach for understanding the causal relationship between education, productivity and wages, policies based on these assumptions are generally misguided and at best will have a variable impact on the overall 'growth' prospects of an economy precisely because they fail to conceptualise the causal failures of labour market functioning. In so arguing, it is clearly necessary to turn to radical alternatives that offer a more realistic interpretation of labour market behaviour and outcomes in the economy. A radical political economy alternative can be found in institutional labour market economics.

3.1 INSTITUTIONAL THEORIES

> 'The ideas of economists and political philosphers...are more powerful than is commonly understood. Indeed the world is ruled by little else. Practical men, who believe themselves to be quite excempt from any intellectual influences, are usually the slaves of some defunct economist' (Keynes, 1936, p10).

There are a considerable number of economists who believe that despite its impeccable logic and mathematical rigour, the neo-classical approach does not provide a useful basis for labour market analysis. In particular, these critics point to the absence of any institutional content to neo-classical models. Concerning labour markets, there have been suggestions that basic economic theory is mistaken in its talk of one labour market, even at its most abstract level. There are a variety of terms to convey this 'radical' approach to labour market analysis including 'dual', 'segmented' and 'structured' labour markets. All are meant to imply that basic economic theory fails to take into account a number of other, influencing factors or 'institutions' that have a bearing on labour market behaviour.

This school of thought argues that, by ignoring the way institutions in an economy constrain the decisions of workers and firms in the labour market, the neo-classical model cannot possibly provide a basis for explaining labour market outcomes (see Marsden, 1986). These labour market theories have developed out of institutional economics, and are highly critical of the simple application of one relationship or theory to all workers, irrespective of the institutional frameworks and divisions within which groups of workers operate. The institutional literature on labour markets is diverse, although it owes much of Doeringer and Piore (1971). However, the modern development of an institutional alternative to the neo-classical analysis of training has its origins in the work of John Stuart Mill in work first published in 1848. Mill was critical of Adam Smith and proposed that institutional factors were too significant and prevalent to be seen as a simple short term deviation from the competitive equilibrium. Rather, he suggested that the labour market comprised of non-competing groups of workers. Within each group, wage and employment determination (including opportunities for training) differ, and are determined by custom and institutional rules. Access to groups of jobs is similarly constrained by custom and social norms. The institutional alternative was further developed by the American institutional economists of the 1940s and 1950s, who proposed the concepts of balkanised and structured labour markets to describe the role played by institutional factors in determining the way labour markets operate.

The debate in institutional economics is formed on the basis that the market is identified as an institution. Samuels describes the market as:

> '..comprised of a host of subsidiary institutions and interactive with other institutional complexes in society.........the economy is more than a market mechanism: it includes the institutions which form, structure and operate through, or channel the operation of the market.. the fundamental institutionalist position is that it is not the market but the organisational structure of the larger economy which effectively allocates resources' (Samuels, 1987, p.7).

In addition, according to Mjoset, an 'institution' can be understood as having two dimensions (Mjoset, 1992). First, institutions are the outcome of recurrent conflicts, where the parties have invested their 'power resources' to reach compromises which secure favourable outcomes. Second, institutions are:

> 'sets of habits, routines, rules, norms and laws, which by reducing the amount of information necessary for individual and collective action, make reproduction and change of society possible' (Mjoset, 1992, p.32-33).

The intimate and indeterminate relationship between politics and economics and thus political power and market behaviour that has already been suggested in this thesis in chapter two, is also recognised in institutional economics. In this respect, Samuels goes on to summarise the difference between conventional economics and institutional economics:

> 'Institutional economics asserts the primacy of the problems of the organisation and control of the economic system, that is its structure of power. Thus, whereas orthodox economists tend strongly to identify the economy solely with the market, institutional economists argue that the market is itself an institution' (Samuels, 1987, p.8).

This approach therefore, as with the new IPE (discussed in chapter two) suggest that the primacy of the problem regarding the organisation and control of the economic system is directly related to the structure of power. In this sense then, an institutional labour market approach recognises that market forces fail to distribute skilled labour equitably because as a consequence of power relations within the economy (for example, access to new knowledge and training) not all workers have equal access to jobs and as a result will not benefit equally from training. This can also be explained by Strange's conceptualisation of international political economy which is based on structural power across the international system. In this system, knowledge has come to constitute an important force and the intimate relationship between politics and economics in determining outcomes and shaping social choice is stressed. Indeed, as I discussed in the previous chapter, for Strange, the knowledge structure is the most important source of structural power in contemporary economic relations because it 'determines what knowledge is discovered, how it is stored and who communicates it by what means to whom and on what terms' (Strange, 1988 p.117).

In the case of labour market performance therefore, unlike the human capital assumption, access and information concerning opportunities are constrained by broader factors. As far as knowledge is concerned, power is conferred on 'those occupying key decision-making positions in the knowledge structure' (Strange, 1988 p.117). This embraces those who are entrusted by society with the storage of knowledge, the generation of more knowledge, and those who control 'in any way the channels by which knowledge, or information is communicated' (Strange, 1988, p.117). To understand how labour markets function therefore, it is necessary to understand how institutions and market imperfections develop and change through time, and how they affect and are affected by workers and employers.

3.2 Dual Labour Markets

The dual labour market approach places the emphasis on demand-side factors, and separates the labour market into two distinct spheres based on ideas about employer strategies. Workers in the primary market have relatively secure, well-paid jobs with good promotion prospects whilst workers in the secondary market face low wages and little chance of achievement (Gordon, 1972). The primary sector of the labour market within developed capitalist economies can be characterised in many ways, but they include the following. First, production is undertaken by large firms who employ capital intensive methods; second, workers have relatively high skills and are often organised in trade unions; and third, workers are employed on a long-term basis in that most workers have the expectation and experience of being employed in the same company for a number of years. The secondary sector can be characterised including the following features. First, production is undertaken in small firms employing labour-intensive methods of production; second, workers have low levels of skills and are unorganised in trade unions; and third, workers, are employed on a short- term basis, and do not have expectations of long-term employment (Piore, 1979). Averitt (1968) has also discussed these features as part of his theory of centre and peripheral organisation of industries within the economy. Furthermore, Atkinson and Meager (1994) discuss the core-periphery nature of labour markets in the firm.

Such institutional approaches to understanding labour markets owe much of their genesis to Doeringer and Piore's (1971) development of the concept of internal labour markets (ILMs). Doeringer and Piore discussed how technological development and the divergence of industry has brought about labour segmentation, whereby the increase in firm-specific skills has greatly reduced labour mobility. Internal labour markets develop as companies in the primary market need to be able to tie skilled workers to the firm and so promotional hierarchies develop within the firms themselves. Such markets are concerned with wage determination and the allocation of labour within the firm, including the availability and nature of training. The internal labour market can be seen as an efficiency response of firms in the face of uncertainty, fixed employment costs and the specific nature of skills. Doeringer and Piore emphasise the institutional and social nature and the mechanisms through which firms are able to develop rules and procedures that are isolated from external economic forces.

In 1978, Rubery expanded on this idea by showing how advanced technology led to substantial human capital investment in a stable, skilled workforce. In contrast, workers in the secondary labour market needed to be easily disposable in accordance with recessionary periods or unstable product markets. Doeringer and Piore however, emphasise the institutional and social nature of firms and the mechanisms through which firms are able to develop rules and procedures that are isolated from external economic forces. Within this framework the labour market can be seen as comprising favourable jobs in structured internal labour markets and more disadvantaged jobs in unstructured external labour markets. Access to favourable employment opportunities is not based on the productivity related characteristics that individuals possess, but on social acceptability and custom. Productivity is related to the job an individual does and is not the result of human capital decision-making. This is reinforced by the fact that training is acquired through learning by doing, which is an integral part of the job but which requires the co-operation of co-workers and the acceptance of group norms. For some institutionalists, productivity is a technical relation determined by the types and quantity of machines available, whilst others offer a more radical analysis in which productivity is rooted in social relations and the power relations between social classes. In both cases, however, a worker's productivity arises out of the job s/he does.

3.3 Segmented Labour Markets

The starting point of the idea of segmented labour markets is not only that there are different types of labour (hence different labour markets) but that mobility of labour between the different labour markets is very limited. These theories recognise that there are many separate groups of workers and that the segmentation of jobs (according to age, race and gender) has political and economic utility for capital, in thereby, enabling it better to control workers (Gordon, 1972). Thus the accumulation of capital is increased by employing workers at different wage rates and, in turn, worker stability is ensured by limiting the potential spread of class consciousness. The development of Taylorism (in short, Taylorism is a management control strategy named after F.W.Taylor who devised a systematic theory and practise of management to separate mental and manual labour subjecting both the measurement and scientific management techniques where scientific management is a more general response to the mechanisation of the industrial revolution) are seen as resulting in the stratification of jobs to break worker solidarity and similarly education is used as a tool to divide the workforce (Edwards et al 1973). Thus segmentation is the differentiation of the workforce into distinctive types of employment and is largely achieved on the basis of established status and control, rather than on actual job skill. There is a wide debate on the power of the workforce and in particular on the role of trade unions in structuring the labour market (for example see Edwards et al. 1973 who distinguished between the two sectors by looking at their techniques for controlling the workforce). Management in the primary sector has to rely on the co-operation of its employees mainly due to the costs incurred in replacing them. On the other hand, firms in the secondary market can use coercive tactics as their labour force is disposable.

Equally, the feminist literature argues that this serves to explain not only the lower status of women in the secondary market but the political benefit to individual men of having women's work primarily sited in the domestic sphere and the use of trade union bargaining power to exclude women from many primary sectors of economic activity has obviously (Seccombe, 1986). Furthermore, there are significant differences in the way in which labour markets operate and it is strongly implied that the conditions (for workers) in some markets are much worse than the conditions in others. In the neo-classical approach, where there is mobility of labour between different markets, it is assumed that there is an 'equalisation of net advantage' between the different markets. This equalisation would mean that (relatively) high wages would be associated with poor (non-wage) conditions, and low wages would be associated with good conditions. The segmented labour market perspective takes the view that high wages will be associated with good working conditions in the favoured labour markets, and low wages with poor conditions in the unfavoured markets. The discussion now turns to the treatment of training in institutional labour market approaches.

3.4 The Relationship between Training and Productivity in Institutional Labour Markets

The institutional economists discussed above argue that the supply of labour and skills does not as the human capital model implies depend on the rational choices taken by workers to invest in their skills base. Instead, institutional labour market economics is concerned with the skills the employers decide to give workers. ILMs, in theory, provide one way for employers to safe guard their investments in workers through prospects of job security and pay. In an institutional model of the labour market, therefore, underemployment is assumed to be the basic characteristic, whereby the opportunities available for training and promotion for the workers are dependent, not only on their efforts, but also on their options which are constrained by institutions. It is assumed that workers have very little control over their training development and are unable always to maximise their lifetime utility (in contrast to the human capital model). As a result, capital is more scarce than labour.

From this assumption, a worker's productivity does not result from individual human capital decisions which determine education and on-the-job training. Instead it is a result of command over resources, which includes on-the-job and off-the-job training. In this respect, a workers productivity is determined by access to capital, training and protected markets (ILMs) as well as by personal effort, already acquired skills and innate ability. For a given level of skill and effort, a worker's productivity depends on his job, since the job determines the workers access to resources (including capital and market rents) and training. Job placement thus determines the worker's long-run productivity, bargaining power and earnings. Additionally, the productivity of a firm's job structure reflect the firm's past investment decisions, which determine the technology used in the product design and capital stock and the demand for the firm's product, which in turn reflects the overall macroeconomic conditions (see McNabb and Whitefield, 1993; Brown 1988; 1993).

Brown (1993) has used this approach to argue that there is a lack of understanding about the role of training in the formation of a high-performance production system. Training in an institutional world reflects three important economic structures. First, there is the labour market structure which simultaneously forms and rations worker's skills. On the rationing of labour, given that capital is more scarce than labour, the labour market presents unequal opportunities. Institutions (i.e. social rules and customs) are used to ration people into and through the labour market. The need for job rationing reflects two phenomena - more than the needed number of available workers possess the required skills and the competence to make the required effort for any given job; and most workers talents are not utilised or developed in their jobs. Although it is true that most well-paying jobs require competent workers who work hard, the converse - that all people who are competent and hard working are well paid - is not true. The rationing process is responsible for this distinction which, according to the neo-classical theories, cannot exist in competitive labour markets. Although individuals do have innate differences in personalities and abilities, these are relatively small compared to the differences that are formed and rewarded, first by the education system and then, by the labour market. The socialisation and education of children, both within the family and the school system, teach children the appropriate rules and customs which govern their behaviour and thinking (Piore, 1979). The rationing process requires this socialisation process in order for the rationing to occur and be accepted automatically. These institutions thus form segmented or non-competing markets which each function as internal labour markets (Edwards et al, 1973; Doeringer and Piore, 1971).

The second institutional structure that has a bearing on training is the firm's organisational structure, including how the training process shapes the demand for, and use of labour. This is equally pivotal to labour market outcomes. The training process is one part of the production system created by the employer. Brown argues that the firm has four main instruments for setting up a production system - the process of training, the organisation of work, the design of the product, and the use of capital. Brown argues that since training is only one part of the production system, how it functions must be evaluated within the context of the overall production system, especially its employment or human resource system, which includes the organisation of work, the structure of compensation and the provision of security (for example see Brown et al (1991) for an analysis of the role of security, employee participation, training and compensation in a well-functioning employment system).

The third structure identified by Brown in an institutional environment for training and labour market outcomes, is the macroeconomic structure, particularly the institutions shaping unemployment and investment, which governs the economy. For example, the performance of a company is heavily influenced by macroeconomic policies and the macro economic environment (cf. chapter two). The latter affects the costs of, and returns to, its production system, including the training process, work organisation, product design and capital stock. According to this perspective, the firm's net cost of providing security or training is directly related to long run product demand and short-run variations in demand. The firm's hiring functions and employee leaving rates depend on the unemployment rate, that overall attractiveness of its jobs relative to alternative jobs. Macroeconomic policy can also affect the composition of jobs being formed. This determines the skills and attitudes in the workplace as well as the way that the rate of education in new entrants is put to use in the labour market. Significantly, supply does not create its own demand in institutional labour markets, thus highly skilled workers unable to find work that reflects their skills level are likely to experience skill deterioration rather than skill enhancement on-the-job.

3.5 Implications for labour market policies

The relevance of this argument for this thesis is that training is not necessarily the causal factor (as the 'new orthodoxy' suggests) of low productivity, quality problems or poor competitiveness in advanced manufacturing production systems. Institutional theory implies that there are broader concerns in the labour market as Hutton's quotation at the beginning of this chapter also implies. The primary ramification of institutional theory is that government plays a necessary part in creating the structure within which the economy functions and is largely responsible for labour market outcomes. The institutional structure, created and preserved by government, provides a social order sets out a set of social and work roles, ensures social reproduction and provides a system of value through the creation and enforcement of rule and custom.

The current assumption among policy makers that future employment will increase skill levels (for example, see the Labour Party, 1996) reaping economic dividends to the wider economy, is suspect not least on the grounds that there is no real certainty about the types of skills required in the future, given that demand conditions are variable (Bailey, 1991). In addition, the case-study of employer's skills and training requirements in the biotechnology sector presented later, shows that few companies reported concerns about skills shortages. Many companies, however, were concerned with investment and demand problems in Europe.

As Brown concludes, the lack of understanding about the role of training in forming high-performance production system may lead to an exaggerated focus on training as the cause of low productivity, when the actual problem may be insufficient investment within firms to develop superior products, insufficient use of engineers on the shopfloor to develop well-functioning equipment, or lack of co-ordination with suppliers to develop high-quality components. Large investments in training are unlikely to solve those problems, or compensate for an inferior product or a defective part or malfunctioning equipment. To this can be added, demand-side factors such as a general low demand expectation within the economy and low demand for certain products. Ormerod (1996) argues that courses which add little value to the human capital of those taking them should really be regarded as consumption not investment. But even if well designed and successful, the main impact of policies designed to increase training and education will be to increase the sustainable growth rate of an economy, rather than to reduce the level of unemployment. As regards the employment prospects of any individual, these are enhanced by education and training. But it is a fallacy of composition to suppose that the same result necessarily holds in aggregate. Evidence suggests that training requires evaluation as part of the overall organisation of the firm and its production system: the process of training, the organisation of work, the design of the product, the use of capital and the company's macroeconomic performance, which is heavily influenced by macroeconomic policies, effecting the level of unemployment and the variability of product demand. Over time, macroeconomic policy affects the composition of the jobs being formed. In turn, this determines the skills and attitudes that are created in the workplace as well as the rate at which education embodied in new entrants is put to use in the labour market.

4. TOWARDS AN INSTITUTIONAL ANALYSIS OF HIGHLY SKILLED WORKERS IN BIOTECHNOLOGY

This discussion has argued that the human capital model is an inadequate 'analytical tool' for understanding labour markets. In contrast, I have argued that the institutional labour market approach offers a more 'realistic' interpretation of labour market behaviour. This is based on understanding labour market activity as part of the whole production system. In this view, the labour market no longer conforms to one based on occupational labour markets with outcomes determined by the forces of competition. This is in direct contrast to the neo-classical view of the labour market which suggests a degree of harmony between the demanders and suppliers of labour whereby any conflict is resolved by movements in the real wage which reconciles demand and supply in equilibrium, which in itself is a situation of full employment. Although differences in the various approaches to institutional labour markets do exist, nonetheless each represents a significant departure from the harmonious view of the labour market. As I show in chapter four in the discussion of the characteristics and dynamics of the biotechnology sector, the institutional labour market approach is a more effective starting point from which to analyse biotechnology labour markets. Nevertheless, a number of deficiencies still need to be addressed.

First, institutional labour market theory does not directly explore the relationship between macro-economic conditions and the global economy, a relationship which (as argued in chapter two) has great significance on the investment decisions and choices of 'actors' in the contemporary global system. As I show in chapters five and six, a global, professional scientific community is emerging through transnational scientific networks, formed through co-operative research programmes such as European Community initiatives, personal contacts through education and training and strategic alliance formation. Despite these trends, the institutional labour market position bears no reference to the global institutions that are emerging in certain knowledge-driven sectors and the direct bearing this has on labour market outcomes.

Second, and following on from the first observation, a number of social norms and customs are being developed in the organisation of the workforce in some knowledge-based sectors that remain outside of the institutional labour market approach. Specifically, these factors are influencing the dynamics of the biotechnology labour market in such a way that theories such as dual labour markets have failed to address. Internal labour market theory, for example, assumes that the primary labour market can be found in large organisations with labour organisation large. In contrast, workers in small firms are generally less skilled, less organised and consigned to a secondary labour market with very little mobility between the two. Biotechnology small firms along with other knowledge-intensive sectors such as information technology however, are characterised by a highly skilled workforce (Bryce and Bennett, 1989; Bryce et al. 1990). The debate concerning the formation of new, more consensual relationships between labour and capital, as described by the protagonists of the flexible specialisation thesis (see my earlier discussion in chapter two), has salience in the biotechnology workplace. It was commented earlier on the existence of a wide literature disputing workplace restructuring in terms of the radical new logic of 'post-Fordism' with its inherent, positive implications for labour. Recent studies of high-technology workers in science parks have shown how consensual management exists in flat organisational structures. In some small high technology firms, new forms of relations between capital and labour are emerging whereby the traditional division of capital and labour has become less clear. Studies of small high technology firms show that where there is a greater concentration of the workforce undertaking research and development activities (R&D) (Massey et al, 1992; 1994) workers perform a wide range of both management-related and routine production functions within the firm. This has led to a decline in labour organisation within these types of firms and some have pointed to this period as indicating a crisis in class consciousness. For example, there is a debate which suggests that focus on class consciousness may be now considered to be dated given that class has been transcended ever since productive forces have been able to produce abundance and the real social issues turned upon, arousing consciousness directed towards physical emancipation. Gorz (1982) perceives the industrial workforce as now totally conditioned by and bound up with the capitalist organisation of society and completely incapable of leading a movement to transform that society. The eradication of capitalism he argues can only come from areas of society that stand outside social classes and prefigure their dissolution. Burowoy (1979) has also discussed the nature of industrial relations and the dichotomies of consensual versus conflict theory and attempts to move the discourse to a whole new terrain but is beyond the concerns of this thesis. In a recent study of work organisation in knowledge-based firms, it has been argued that 'consensual' style management places immense burdens on workers to perform with employees expected to work 'flexibly', 'globally' and 'on-demand' (Massey, 1994a). Additionally, this form of work organisation has significant ramifications for family life and family cohesion and at the same time socially excludes many women from such professions (Massey, 1994b). Massey observes:

> 'As we have said, this imagery in turn is held to mean that employees are relatively autonomous and creative. They are frequently characterised as having individual commitment to the company; as being highly motivated and competitive. Hierarchies are supposed to be low and status differences are weak; salaries are high and trade unions irrelevant' (Massey, 1992, p.90).

Indeed, research into the 'style' of work organisation of biotechnology workers shows how workers are frequently required to travel at short notice, work extremely long hours, and are usually highly motivated by their professional work. Moreover, these value-systems have become part of the routines, habits and norms of these categories of workers, thereby constituting important institutional constraints which shape biotechnology labour markets (Hayward, 1997).

The third weakness is that institutional theories fail to address the intimate relationship between the 'domestic' and the 'international' sphere. In the case of biotechnology, the relationship between the international structure of production, (including finance and knowledge structures), and the domestic structure of the national societal system, (the structure of firms, the scientific and educational infrastructure, culture) is very close. This levels of analysis has direct bearing on both the behaviour of firms and states and the choices that they make. At a deeper level, labour market economics fail to address macro economic forces and structural transformation and their bearing on the functioning of labour markets, despite the widely cited 'globalisation' of markets and the implications that this has for the international division of labour (Reich, 1991; Carnoy, 1994; Dale, 1995; Gewirtz, 1995; Reich, 1996; Ruigrok, (1995). For example, for advanced skilled labour the choice of location has become an integral factor in deciding where to work. Recent studies of science park tenants show that many choose such a location because of their amenities and, frequently, 'desirable' location (Charles et al, 1995). Massey et al (1992) has commented on developing the right 'physical environment' in relation to the science park phenomenon, as do Castells and Hall (1994) and Reich who describes 'symbolic analysts' as:

> 'substantially different to those of routine producers or in-person servers' Symbolic analysts usually work in spaces that are '...tastefully decorated [with] soft lights and wall-to-wall carpeting..calm surroundings..are encased with tall steel and glass buildings within long, low post-modernist structures carved into hillsides and encircled by expanses of well manicured lawns' (Reich, 1991, p.179).

In its most extreme form therefore, the existence of 'footloose' global capital and a global labour market for 'symbolic analysts' has compelled states to build into local economic planning inducements for attracting highly skilled workers into localities or regions.

5. CONCLUSIONS

The argument of this chapter leads to two propositions. The first relates to institutional labour market theory. The second marries the conclusions in chapter two with institutional labour market theory shown in Table 3.1. To summarise, as institutional theory implies labour markets are socially constructed and are characterised by under-employment, whereby allocation of workers is characterised by unequal job and training structures governed by institutions (i.e. rules and custom). Workers' productivity is as a result of the command over resources, which includes access to on-the-job training and off-the-job training. Workers can influence their training through their effort, however their options are constrained by institutions. Training produces job-related skills, as well as networks, and the correct behaviour and value-system. On-the-job training increases the value of the workers to the firm, and this training is embedded in the work process as well as taught by co-workers. Productivity of workers is primarily dependent on the technology used, which reflects the firm's investment decisions, and on demand conditions, which reflect macro-economic conditions.

Table 3.1

	The Institutional Labour Market for Highly Skilled Workers in Global Sectors.
1.	The labour market is characterised by underemployment
2.	Allocation of workers, within unequal job and training structures is by institutions (i.e. customs and rules).
3.	Worker's productivity is a result of command over resources, which includes on the job training, and off the job training.
4.	Although workers can influence their access to training, through their effort, their options are constrained through institutions.
5.	Training produces on the job related skills, as well as international scientific networks and a code of behaviour and value systems (a global knowledge structure)
6.	On the job training increases the value of the worker to the firm (firm-specific skills) and this training is embedded in the work process as well as taught by co-workers.
7.	Productivity of workers is dependent on a set of conditions including the technology used, the levels of motivation towards scientific discovery, perceived autonomy at work and 'flexible' working conditions, very little trade unionisation, flat, consensus management practices and the location of their workplace. Working on 'leading-edge' technology can be more important than salaried expectation.
8.	These reflect the overall investment decisions of the firm which reflect global demand conditions for products which reflect the nation-state societal system (local preferences and culture). In turn these reflect overall macro economic conditions that determine the investment decisions of high-technology firms (government investment, global venture capital markets, and global joint-venture agreements).

source: adapted from Brown, 1993

Second, drawing on the conlusions in chapter two, the research agenda reached at the end of the previous chapter which set out an framework for understanding economic outcomes in the global industrial system. Taking these themes and institutional labour markets, the institutional labour market for highly skilled workers recognises that national specific factors interpenetrate with global institutions. With respect to highly skilled labour markets, this relationship shapes the mobility of labour around international, national and regional labour markets. In this respect, there is a direct causal relationship with the domestic labour market and the production system through the articulation of the domestic production system and the global industrial system.

The argument advances in this chapter then has been that any analysis of the economics of highly skilled labour necessitates an examination *of the power structure through which labour market outcomes are shaped.* Moreover, the labour market for a knowledge-intensive and global sector such as biotechnology reflects the structure of the firm and historical economic development patterns embedded in the nation-state societal system, which in turn reflects broader macroeconomic change. In this sense and in relation to my earlier discussion in the previous chapter concerning globalisation, it was argued that the labour market for 'symbolic analysts' - or advanced scientific labour is one market which is not only conditioned by global macroeconomic forces, but is equally shaped through powerful national institutions. The state may have less control over ideas and knowledge (as demonstrated earlier in chapter two on 'the knowledge structure' and show in chapter five in relation to Amercian hegemony in the biotechnology industry). But, the state still remains a controller of its borders and the movement of people across them. Despite the rhetoric of globalisation, labour mobility is less prominent than the ideology of free market forces assumes.

Having argued that the labour market is more complex than human capital theories suggest, the discussion now moves on to a set of empirical questions which test the proposition that the labour market for highly skilled workers in globalised sectors is more complex than conventional thinking implies. The following chapter, focuses on an examination of the main features of the biotechnology sector, itself characterised by both advanced skilled labour and globalised production activities and knowledge accumulation. It is argued (discussed in more detail in chapter six), that skills shortages have been cited as a major impediment to the economic growth of this sector in Europe. In turn, this has fuelled the assumption that increasing the supply of highly skilled scientists and technologists will have a significant contribution towards improving Europe's competitive position vis a vis the United States in this sector. The wider implications of this approach for policy making, as Reich suggests, is that industrial policies should target investment in the education and training of labour. The problem with this conclusion is that it may privilege the economics of education and training at the expense of addressing other dimensions of the production system which impede economic development. With respect to this argument therefore, chapters six and seven show how skills and training issues in the biotechnology sector gained salience in European policy circles during the late 1980s and early 1990s. But, taking a specific case-study of European firms, it is argued that the labour market for this sector is much more complex than the labour market economics 'orthodoxy' implies. The empirical evidence suggests instead that a range of institutional factors underpin the functioning of this labour market and operate in conjunction with broader production and knowledge structures that underpin the global political economy as a whole, and that it is these institutional factors which offer an understanding of the way in which the European labour market functions in the global political economy of the 1990s.

CHAPTER FOUR

THE BIOTECHNOLOGY REVOLUTION

'Biotechnology - the very word was invented on Wall Street - is a set of techniques, or tools, not a pure science like much of academic biology. As a set of tools, it can be used to advance scientific experiments or to produce viable, useful products such as human pharmaceuticals and diagnostics. Technology, by definition, interlocks with the cogs and wheels of the workday world.'

(Robert Teitelman, Gene Dreams, 1989, p.4).

1 INTRODUCTION

The preceding chapters discussed theoretical debates concerned with the role of knowledge and skills in advanced industrialised societies. The argument advanced in these chapters has been that the world economy is more complex than the 'extreme' globalisers contend and that national policies still remain viable, indeed they are essential in order to preserve the distinct styles and strengths of the national economic base and the companies that trade from it. I argued that markets are more complex than the extreme globalisation theorists lead us to believe taking the example in the last chapter of one market - the labour market - which is a crucial focus in current political discussion. Reich's 'globalisation' thesis concludes that the global system is governed by the logic of market competition, and public policy will be at best secondary, since no governmental agencies (national or otherwise) can match the scale of world market forces. To repeat then, this view regards national governments as the municipalities of the global system: their economies are no longer national in any significant sense and they can only be effective as governments if they accept their reduced role of providing locally the public services that the global economy requires of them.

The aim of this chapter is to discuss the assertions made in the earlier chapters at an abstract level, and apply them at the level of a specific, global knowledge-intensive sector - biotechnology. Biotechnology represents a useful case-study of a sector that is dependent on the production of knowledge for its economic development. Furthermore, the potential of biotechnology-knowledge to 'revolutionise' traditional manufacturing has been widely recognised in both the United States and in Europe (OTA, 1991; CEC, 1991; IRDAC, 1991;1994; OECD, 1982). Biotechnology represents a useful case-study of the arguments advanced in the theoretical discussions in chapters two and three: first, in relation to the changing structure of production in as a result of knowledge and skills in the global economy - and consequently, how states and markets can be conceptualised. Second, that the market for labour is comprised of institutions and forms one part of an interlocking production system in the global economy. Although the specific interest of this thesis is with knowledge and skills in knowledge-based sectors, the argument advanced in the last chapter, is that knowledge and skills - or the labour market - is one dimension of the overall production system. In this sense then, an overall discussion of the production system of biotechnology is a necessary task given the argument advanced in the theoretical chapters that the specific character of the technology might be said to indicate something about the nature of the labour market. The argument advanced in this chapter is that biotechnology is one 'high-value' activity which transcends national boundaries with global markets for its products, ideas and know-how, and labour markets. At the same time, however, biotechnology is firmly rooted in its national environment and in the national societal system for its economic development.

The organisation of this chapter is as follows. First, the historical background of biotechnology from science to industry is explored. The main point from this discussion is that many of the scientific breakthroughs that have led to the biotechnology industry originated from Europe and in particular Britain. The discussion then moves on to examine in detail: What is biotechnology? What are biotechnology products and processes? What are the current market values for biotechnology related products? What are the characteristics and industrial structure of the biotechnology industry?

To conclude, it is argued that biotechnology has a number of distinguishable characteristics. These characteristics demonstrate that whilst biotechnology has global appearances and global market reach - the economic development of the industry is heavily reliant on the national environment.

2. HISTORICAL BACKGROUND TO THE SCIENCE OF BIOTECHNOLOGY

In many respects, the process of biotechnology is not new. The Spinks Report (1980) identified three distinct generations of biotechnology. The first generation of biotechnology dates from the Stone Age and concerns the use of biological organisms -

such as bacteria, yeast, enzymes and fungi - in the preparation of food, drink and textiles. For a long period, fermentation was a process of trial and error and it was often the impurities that crept into the process that gave the product (for instance wine or whisky) its unique qualities. Not until the end of the nineteenth century was there any attempt to standardise fermentation processes in order to produce a uniform (or nearly) product. Even so, research was still primitive and the master distiller worked on the basis of instinct rather than science (Sharp, 1985). Using fermentation, bakers yeast and lactic acid were made for the food industry, ethanol for the chemical industry. In addition anneals, an enzyme, was used in the textile and food industries.

A major boost for the fermentation industry came with the First World War when there was a huge demand for acetone for munitions. For the first time the research effort of scientists and process engineers was mobilised for large-scale manufacture through fermentation - a process which required pure cell culture and sterile manufacturing facilities. During the inter-war period acetone was used for the manufacture of rayon and fermentation was also used to produce riboflavin (vitamin B2), glycerol, sorbose (an intermediate vitamin C production) and citric acid- all fine chemicals used primarily in food processing and manufacturing. But the inter-war period also saw the emergence of the petrochemical industry and by the 1930s petrochemical feedstocks began to dominate the chemical industry, replacing for example the cellulose feedstock base for acetone. By the Second World War fermentation derived chemicals were of little importance.

The development of penicillin during the Second World War however led to a renewed interest in fermentation products in the pharmaceutical industry and research effort expanded rapidly leading to new antibiotics such as the cephaloporins, steroids like hydrocortisone and an increasing range of vitamin and enzyme preparations. Likewise growing interest in and knowledge of, biological processes led by the late 1950s to their use in the preparation of amino acids such as glutamic acid (used to produce monosodium glutamate, the food flavouring agent) and polysaccharides (used as a stabilising/filling agent in food manufacture). These developments constitute the second generation of biotechnology. Their significance is three fold. First they stimulated interest in micro-biology - that is the properties of micro-organisms such as fungi, bacteria and enzymes - and led to an explosion in our knowledge of the range and functioning of these organisms within the environment. This in turn led to the second development - the successful mutation and selection of strains to achieve very substantial improvements in yields and production efficiency. Third came the considerable refinements in fermentation technology, notably the development of biocatalysts and the use of immobolisation often at considerable cost, which meant that the biocatalyst could be used over and over again rather being discarded with each batch processed. This in turn led to the development of continuous conversion processes which opened the way for biological processes to begin to compete with conventional process technology of the petrochemical industry. The hopes of the 1960s that biocatalysts would become a major force in the 1970s have however, never been fulfilled.

Nevertheless the 1970s brought dramatic developments from another source. The study of genes[1] goes back to the work of G. Mendel,[2] an Austrian monk who by analysing generations of controlled cross-fertilisation between sweet pea plants, was able to identify the approximate characteristics of what were later termed genes. By the beginning of the twentieth century scientists had established that chromosomes in the cell nucleus were the vehicle by which the genes were transmitted from one cell to another. The historical evolution of biotechnology is shown in Figure 4.1 (Sharp, 1991b).

During World War II, new refinements of gene models continued to surface. In the 1940s studies of microbial metabolism led to the conclusion that genes act by producing crucial biochemical products. Each gene appeared to be responsible for the cellular production of a single enzyme- a member of a class of highly specific proteins that facilitate, or catalyse,

---

1 A gene "is life's way of remembering how to perpetuate itself.. The memory is chemical. It is woven into the intricate internal structure of a family of biological molecules, called nucleic acids found in chromosomes and other gene-bearing bodies in organisms ranging from viruses and bacteria to human beings. These nucleic acids are called deoxyribonucleic acid - or DNA and - ribonucleic acid or RNA Suzuki and Knudtson (1988). Genes are the vehicle for biological inheritance - the medium through which living things transmit genetic information from one generation to another. They are the organising principle by which lifeless raw materials are almost miraculously quickened into living organism; they are absolutely essential for life. Thus, genes- functional units of self-replicating genetic molecules- must have made their evolutionary debut, some scientists believe, simultaneously with the beginning of life on the planet.

2 The invention of the microscope in the early seventeenth century enabled the distinction between sex cells and thus illuminated the underlying mechanisms of sexual reproduction in animals and also firmly established in 1694 the biological basis for sexual reproduction in plants. This breakthrough led to the systematic studies in plant hybridisation and artificial selection paving the way for Gregor Mendel and British naturalist Charles Darwin. Mendel published the results of his meticulous breeding experiments using hybrid varieties of the common garden pea in 1866, but the impact of his work was not felt in the scientific world until the early 1900s. Mendel shattered the popular notion that traits were somehow transmitted through bloodlines. Essentially, Mendel's experiments followed inheritance of a number of selected physical traits over generations of plants. Mendel discovered that these inherited traits did not blend together as they were passed from one parent to offspring. Instead they seemed to be transmitted as if borne of discrete hereditary particles - indivisible genetic factors, borne of both female and male reproductive cells that somehow maintained their identity while being reshuffled into fresh combinations in descendant organisms. Through systematic statistical testing (see Suzuki and Knudtson 1988) Mendel's law would shatter the subjective, culture-bound belief systems that had shaped the ordered march of genes from one generation to the next. Now scientists could begin to quantify natural patterns of inheritance and explore the previously hidden behaviour of genes in living organisms by tracking their visible manifestations as particular heritable traits. Furthermore Mendel's laws offered insights underlying cellular mechanisms, such as the distribution of chromosomes during cell division.

life-sustaining metabolic processes inside cells.

It was considerable time however before scientists discovered what genes were made of and how they controlled cell functioning. In 1953 Francis Crick and James Watson published a brief but monumental scientific article that proposed a startling new image of the DNA molecule. They described it as a double helix - a spiralling, two -stranded structure endowed with a logical and biological symmetry. They had unravelled the double helix structure of DNA while subsequent research linked the nucleotide sequencing of DNA with the production of proteins within the cell.[3] The Watson-Crick version of the double helix launched an intensive exploration of the molecular nature of genes. By the 1960s scientists had deciphered the genetic codes of nucleotide bases inside DNA's serpentine central core in virtually all species are systematically translated into one or another of 20 possible amino acids. In 1967, a DNA molecule corresponding to a gene was artificially synthesised in the laboratory and by the early 1970s experiments were underway to snip genes from the genetic molecules of one species and insert them into those of another species. If the part of the DNA chain which is associated with the production of a particular protein could be isolated and made to work by itself, then the cell could be used, in effect, as a protein factory. For example if the genetic code for insulin manufacture within the gene sequence could be identified, isolated and implanted into the gene of a simple 'manufacturing' cell, then insulin could be 'manufactured' by cell culture rather than, as present, extracted from the origins of slaughtered animals.

---

3 Proteins are the base material of cells. Some proteins are enzymes which catalyse specific chemical reactions such as the various hormones, insulin etc., others are structural proteins.

It is precisely this process of isolation and implantation that has been achieved and which has earned the name genetic engineering, or more frequently now as genetic manipulations. The technique, which is properly called recombinant DNA (rDNA) is based on the use of restriction enzymes which cut the DNA in places where specific sequences of nucleotides occur. This sequence of DNA is then inserted into a bacterial host into a suitable vector. The host bacteria is usually a simple micro-organism such as the *E.coli* (*Eschenchic Coli)* bacterium, or yeast which is capable of multiplying itself very fast. As it multiplies, the vector carrying the gene also multiplies leading to the synthesis of quantities of the protein for which it is 'programmed' by the DNA transplant.

Besides rDNA there is another method of genetic engineering - cell fusion a preferable method when a large part of the genetic message has to be transferred. In effect the fused cells create hybrid genomes which combine the characteristics/functions of both the original cells. One application of this technique has been to produce monoclonal antibodies (MABs), by fusing mammalian cells producing a particular antibody with a type of cancer cell called a myeloma resulting in a hybridoma. The resulting fused cells combine the cancer's cell 'immortality' and growth characteristics (i.e. they will go on multiplying themselves) and with the other cell's antibody production characteristics. Through a series of steps these cells in turn are separated from one another and each spawns a separate colony or 'clone'. By using culture techniques, pure monoclonal antibodies can be produced in large scale by this method.

The great advantage of monoclonal antibodies lies in their specificity, monoclonals can be used to identify the presence of particular antigen, to help the separation processes or to deliver drugs to a particular location within the body. To date the main usage has been in diagnostic processes and purification; their use as a drug delivery system, which requires injection, means undergoing the same toxicology/testing procedures as other drugs which will delay their widespread use for this purpose.

These developments in genetic manipulation have ushered in the third generation of biotechnology. Their significance is that they enable biotechnology to break away from having to work solely with naturally occurring genetic combinations. In the immediate term this has brought with it some notable benefits. Previously rennet used in cheese manufacture was obtained from calves' stomachs, insulin from the pancreas of pigs, interferon by processing human blood and human growth hormones from corpses. The product was often difficult and expensive to obtain, purify and in the case of products obtained from human blood carried the high risk of contamination. Genetic manipulation enables the production of these substances in large quantity and with high purity. It also offers a technique for improving yields from existing fermentation processes, by 'doctoring' existing micro-organisms to increase their productivity efficacy.

Developments in genetic manipulation however are still young : the crucial breakthroughs in rDNA and cell fusion came in the 1970s and much still remains to be achieved in the laboratory. For example the widespread application of these techniques to the manipulation of plant genes (and therefore the extension of genetic engineering to plant breeding and plant cell culture) still has to be achieved. Moreover, although a breakthrough in scientific terms, the use of these techniques in mass production poses considerable 'scaling-up' problems. On the one hand the hybrid micro-organism has to prove itself to be stable (there has been a tendency for genes to be lost on scale-up). Finally, because most of the substances that are being produced are destined for the pharmaceutical and drug market, there are therefore subject to rigorous toxicology test procedures which can take anything up to ten years. Indeed, it is this testing as explained in the following chapter that has created financial problems for small biotech firms.

3. DEFINING BIOTECHNOLOGY

There is no biotechnology industry as such, but a set of enabling or generic technologies which has already pervaded a large number of traditional manufacturing industries (OECD, 1988; 1982; Sharp, 1985). For the purposes of broad definition, biotechnology is more commonly referred to by its scientific origins: organisms, cells and molecular analogues which are manipulated for the production of goods and services (EFB, 1993; ACARD, 1980; Spinks 1980; OECD, 1982). This is a broad definition and has the advantage of emphasising both the link (via biological organisms) with the long tradition of fermentation technology.

However, biotechnology is concerned with industrial and not just laboratory applications. The European Commission refer to biotechnology as more than a science, it allows the exploitation of micro-organisms, plant and animal cells to take place within an economic framework with the potential of applying science for the benefit of society (CUBE, 1991) or economically, to make or save money (Hacking, 1989). Hacking argues that biotechnology either produces specific products or is used as a process in a production chain its ultimate success depending on whether it is financially a viable option.

However, a number of observers comment that the organisation of global capital in the developed countries is such that the vast majority of biotechnological work is undertaken by and for the benefit for industry, rather than for the meeting of social needs (Yoxen, 1981; Ratledge,1992; Biotechnology Business News, 1992). Others have commented on how biotechnology is a 'knowledge' industry. For these observers, emphasis lies with the manipulation of knowledge and information. Biotechnology is a set of pervasive techniques and biological processes that relies on the manipulation of *biological information* (de Rosnay, 1984). Ravetz (1979) also refers to biotechnology as 'biological information' again, involving the manipulation of biological knowledge. He describes biotechnology as a 'high intensity' science:

> 'This new sort of science ...may be considered as a natural successor to the post World War II "Big Science" which was based on the gigantic structures (physical and administrative) necessary for the manipulation of very high energies. In this high intensity science; it is impossible to isolate the small research laboratory from entanglements on three general fronts: industry, the environment or politics' (Ravetz, 1979, p.97).

Equally, Russell observes that whilst the 'Big Sciences' were based on the manipulation of very high energies, whilst biotechnology is based on the manipulation of information along with the biological revolution which is, in effect "... a revolution in the understanding of biological information, storage and communication systems.." (Russell, 1990, p.10).

Biotechnology is also a technology that has elicited a wide public response through ethical groups and organisations. Importantly, to many commentators in Europe, elements of biotechnology bring issues of accountability, ethics, military and possible terrorist use, and these introduce difficult societal choices to make in the future (Yoxen, 1990; Suzuki and Knudtson 1988). For example, while biotechnology promises cures for some illnesses at the same time it brings potential risks for new illnesses, it can be an environmentally sensitive technology bringing alternatives to pesticides and fertilisers reducing the amount of chemicals released into the environment, yet it can also be an environmentally threatening technology with the release of genetically modified organisms threatening the delicate balance of the biosphere (Russell, 1990a; Munson, 1993; Dando, 1993; Walker, 1994; Erlick, 1989).

Others have argued that biotechnology represents little more than benefit to multinational companies rather than to the developing world (Biotechnology Business News, 1982). Russell (1990b) argues that it could draw European people together through technical co-operation or, it could divide them through new biological weapons of mass destruction or biological warfare, as suggested for the use of biotoxins in The Gulf War (Walker, 1994; Tisdall, 1994). In addition, some aspects of biotechnology concerned with reproductive technologies has attracted wide-spread criticism (Crowe,1990; McNeil, 1990). Indeed the 'ownership of life' question confronting European countries on the issue of whether companies should have the right to patent life has created a number of contentious areas concerning the patenting of biotechnology products (Mackenzie, 1992).

In this sense then, there is a dual problem facing European policy makers: how to promote biotechnology and at the same time, regulate the industry so that the fears and concerns of a growing number of voices are adhered to. This is directly discussed in the next chapter. However, in terms of definition which is the focus of this discussion, biotechnology can be best described as a high intensity science, drawing from a broad range of the natural sciences from genetics through to chemical engineering, This multidiscplinary base is discussed below.

3.1 An inter-disciplinary science

Biotechnology is not one scientific activity - but a collection of scientific activities. Third generation biotechnology for example is not only genetic manipulation but also requires the interaction of scientific and engineering principles and procedures related to both second and third generation biotechnology. Cantley (1983) identifies five important strands of development contributing to biotechnology :

i. fundamental progress in understanding chemistry and the functioning of the cell, and particularly in understanding the role of DNA as the molecular carrier of stored genetic information;
ii. techniques based on microbiology for the screening, selection and cultivation of useful

cells or micro-organisms;

iii. techniques for plant cell and tissue culture and their application in crop cultivation;

iv. development in chemical engineering including immobilisation techniques in fermentation and new downstream processing techniques for extraction, treatment and purification of useful materials.

It is noticeable that of these five strands of development, only one - point (iii) which essentially comprehends genetic engineering - could be labelled as third generation technique. The other four are firmly rooted in second generation techniques, although in all four areas there has been continuous, incremental innovation which has contributed substantially to their efficacy (and led for instance to a considerable raising of yield in areas such as antibiotic production). The fact that four out of five of these strands of development are rooted in second generation techniques underlies another aspect of the new biotechnology. Although genetic manipulation is at the highest technology spectrum of biotechnology, much of the technological endeavour needed to 'put biotechnology on the map' in areas where it is not already established will be of necessity based on the further development of second generation techniques. Genetic engineering is essentially a 'design input' (Sharp, 1985) into biotechnology to create novel generic combinations. But to utilise these combinations will require the application and development of second generation process technologies both in production and extraction. In this respect- and many others - biotechnology will remain essentially inter-disciplinary endeavour, marrying the disciplines of molecular biology, genetics, biochemistry, microbiology with those of chemical engineering.

Genetic engineering is however, important because it represents a discontinuity in the technological trajectory of biotechnology, a revolution rather than evolutionary development (Sharp, 1982). There has been continuous incremental development of second generation techniques that has led on the one hand to highly sophisticated techniques of selecting, breeding, and cultivating micro-organisms and on the other to the development of process technologies (via immobilisation and cell culture techniques) capable of handling conversions and extractions hitherto though impossible. The process of gradual but continuing innovation proceeds even today and underlines the view that irrespective of developments in genetic engineering, there is considerable knowledge embodied in the second generation biotechnology.

The importance of the discontinuity created by genetic engineering should not be underestimated. Sharp (1985) argues that in effect it sets biotechnology off in a new track, creating a new technological paradigm with its own trajectory of development (see Dosi et al, 1988). Until the advent of genetic engineering techniques, biotechnology was limited to the use of organisms which derived from nature and which could only be changed by the slow and uncertain process of mutation. Genetic engineering offers the possibility of producing novel (i.e. unnatural) genetic combinations. This widens the bounds of the potential application of 'biological organisms, systems and processes to manufacturing and service industries' (Spinks, 1980). This has rendered the technology to be practically limitless bounds: the combination of genetic engineering with the increasingly sophisticated second generation process technologies will effect a wholesale revolution in productive techniques in many areas, rendering existing techniques obsolete and opening up a whole new area of activity.

The interdisciplinary nature of biotechnology has significant ramifications for the labour market and these are discussed in more detail in chapters six, seven and eight. Importantly however, the range of skills required by personnel has meant that the levels of skills and experience required are very high.

4. BIOTECHNOLOGY - A GENERIC TECHNOLOGY

4.1 Biotechnology compared to other generic technologies

There are a number of features which biotechnology shares with electronics and information technologies which reinforce its potential and identify it as a 'generic' technology with pervasive qualities. Firstly, biotechnology is science based - the scientific input being the most crucial element of the technology trajectory. Secondly, the gap between the developments in basic science and their research and development applications and even further downstream is small and diminishing. Thirdly, a very major and growing stimulus is anticipated for process equipment, instrument and engineering sectors. Finally, the impacts of the processes, techniques and hardware represented by biotechnology are felt across a number of sectors. Thus biotechnology, like IT or electronics is generally referred to in policy terms as an enabling or a generic technology (Ratledge, 1992 OECD, 1989; OECD,1988). However, biotechnology has been estimated to be at a much earlier cycle of development than various applications of other generic technologies such as electronics and information technology (OECD, 1988). For example, in comparison to information technology , the number of people employed in the sector relative to all industrial sectors remains low; in many potential areas such as bulk chemicals and energy, applications are still not competitive and in many areas of application there exists widespread popular opposition to third generation biotechnology (commonly genetic engineering).

Since biotechnology is more usefully described as an *enabling or generic technology* which is driven by a set of rapidly, evolving and powerful techniques, biotechnology processes and products have a pervasive effect on industrial sectors. The OECD compared biotechnology with other generic technologies and it is clear that biotechnology has not reached maturation. The following criteria was used by an OECD group in 1988 (High Level Experts Group on the Social Aspects of New Technologies 1988) on which to assess the overall economic attributes of the technology:

a) to generate a wide range of new products/services;

b) have applications in many sectors of the economy;

c) reduce the costs and improve the performance of existing processes, products and systems;

d) gain widespread social acceptance with minimal opposition, leading to a favourable regulatory framework;

e) generate strong industrial interest based on perceived profitability and competition advantage.

Table 4.1 summarizes how biotechnology rates compared with information technology, materials technology, space technology and nuclear technology. In comparison with information technology, it is evident that biotechnology is not a dominant technology at present. Present applications are confined to a few sectors - healthcare, environment, agriculture, food and drink, forestery, chemicals and energy (very small percentage in mining and veterinary), although the potential for biotechnology to pervade other new sectors is widely cited, particularly in the launch in the UK of DTI initiative 'Biotechnology Means Business'. The number of people employed is still very small in the new biotechnologies and in the many potential areas such as bulk chemicals and energy the applications are still not competitive. This is discussed in greater detail in the following section. However where there is biotechnology activity this has mainly derived from the sequencing of genes and proteins, gene expression utilising fermentation and cell culture techniques to bring about important advances in seven major areas . A feature of this new or third generation biotechnology is its capacity to affect a wide variety of processes and organisms. As in second generation biotechnology, the new technology is very much based on bacteria, yeast and animal cells but there is much greater variation in the scope of applications. Potential and actual biotechnology-derived applications are discussed below.

5. BIOTECHNOLOGY PRODUCTS AND PROCESSES

As a result of intensive scientific research and major discoveries over the past four decades in molecular biology and recombinant DNA technology, biotechnology has emerged as one of the most promising and crucial technologies for sustainable development in the next century (CEC, 1993; Ratledge, 1992; Sharp, 1985). In terms of the quality of life the potential of biotechnology is estimated to be revolutionary (Sharp, 1985) for improving production processes, and for correcting pollution, and for improving healthcare (OECD, 1982). The confluence of classical and modern technologies (see Figure 4.1) enables the creation of new products and highly competitive processes in a large number of industrial and agricultural activities as well as the health sector. This would provide the impulse to radically transform the competitiveness and growth potential for a number of activities and open up new possibilities in other sectors such as diagnostics, bioremediation and production of process equipment (hardware).

This section provides a brief description of the main sectors affected or are likely to be affected by third generation biotechnology. Painting a statistical picture of the biotechnology sector is problematic since there is no Standard Industrial Classification for biotechnology. In general, there are large scale applications of biotechnology in the traditional fermentation processes of sewage treatment and purification, and food and drink preparation with small scale applications in high-value, low weight products, such as antibiotics, amino acids and enzymes (Yoxen and Green, 1990). Products based on biotechnological processes include pharmaceuticals and other speciality chemicals, diagnostic kits and other therapeutic agents; new strains of plant; food and drink products and additives; biological herbicides and pesticides; fuel alcohol; biodegradable plastics; micro-organisms for breaking down waste products; educational kits and intermediates and catalysts for chemical processes. In addition the processes for making these and other products using biological sources, intermediates, catalysts or processes, and extraction or waste treatment processes, may be sold to other firms as know-how (i.e. in the form of licenses to patents) and process equipment. Biotechnology firms may also sell services to other firms in the form of information, consultancy and subcontracted R&D. This is set out in table 4.2.

This level of detail of the main applications of biotechnology is necessary because it paints a picture of the persuasiveness of biotechnology techniques across most key manufacturing sectors. In this sense then, this discussion conveys the breadth and importance of biotechnology for future industrial manufacturing and thus national wealth. In addition, the breadth of applications is also an indication - which I turn to late in my conclusions, about the problems facing policy making in relation where to fit biotechnology in traditional policy-making categories. The real problem facing decision-makers in relation to creating mechanisms to support economic development in this sector is, as Sharp has observed (1982), that biotechnology does not fit into neat institutional boxes and that this renders policy problematic.

These areas are discussed in more detail under the broader sectoral classification : healthcare, fine chemicals, agriculture, food and beverages, and the environment.

5.1 Human Health Care

a) *Pharmaceuticals*

The new biotechnology or third generation biotechnology has clearly had its earliest and greatest impact on the pharmaceutical and health care industry. The industrial development of biotechnology-based pharmaceuticals is rapidly expanding (OTA, 1991). The pharmaceutical industry is using biotechnology in three ways: to produce drugs using r DNA technology to make "intelligent screens" for new compounds and to apply techniques for "rational drug design" by understanding molecular structures. Fifteen first generation have been approved by the US Food and Drug Administration and some have generated significant markets. For example, tissue plasminogen activator (TPA) has total sales of about US$ 285 million in 1990 and more than a hundred other drugs are awaiting approval (Table 4.3). It is envisaged that second and third generation drugs will be developed by rational drug design - a result of interdisciplinary advances in pharmacology and biotechnology. The main technique driving the production of second generation drugs now under development is protein engineering It is anticipated that that the development of genetic engineering at higher levels of biological organisation can be expected to have substantial benefits.

b) *Vaccines*

New biotechnology techniques offer safer replacements for existing vaccines as well as new vaccines for previously untreatable diseases. Sub-unit or vector vaccines use only a component of the pathogen to elicit the necessary antibody response. A number of different versions of genetically engineered hepatitis B vaccines are now on the market. Traditional vaccines can also be made efficient by using peptides or glycoproteins produced by genetic engineering. Table 4.4 presents projected development dates for 31 selected vaccines and some of these have proved to be optimistic.

A major area of investment for biotechnology is in the treatment of AIDS (Auto-immune Disease Syndrome). In the absence of a major breakthrough in prevention or treatment , AIDS will continue to increase not least in the Third World. Substantial funding, private and public is being directed at AIDS research and current R&D is focused on drug treatment and vaccines. At present significant breakthroughs are unlikely and even if they do, they will not be of immediate applicability to the developing countries (Anderson and May, 1992).

c) Monoclonal antibodies

The use of monoclonal antibodies (MABS) in diagnostic kits is now widespread with global sales currently valued at $2 billion per annum. In Northern Europe and the USA markets are growing by 6-7 % each year, in Southern Europe, by 15-20 per cent and in Japan, by 15 % per annum. Some 400 diagnostic kits are in clinical use today and a range of examples are shown in Table 4.5. In diagnostics a major area of importance is the expression of recombinant proteins which are used as part of the kit , for example, in the case of HIV coat proteins for AIDs diagnostic kits. MABS can also be expected to have important implications for the treatment of cancer and other diseases and similar products are also under development for the treatment of hepatitis, cytomegalovirus and herpes (NEDO, 1991).

5.2 Fine Chemicals

A recent report by the Senior Advisory Group Biotechnology (SAGB) forecasts a surprisingly high increase from US$ 40 million to US $ 70 million by the year 2000 in the world market for biotechnology -derived chemicals. Several of the chemicals from the fine chemical sector are used in the food sector and it is therefore difficult to draw the boundary between the two. Many chemicals traditionally manufactured by synthetic organic chemistry are likely to be produced by biotechnology-related methods in the medium term. Enzymes modified by protein engineering have already been developed for commercial uses, as in the case of subtilisin which is added to washing powder. Over half of the industrial enzyme market is expected to be supplied by biotechnology-driven enzymes within the next decade. However, it is becoming increasingly obvious that only those enzymes that can be produced more cheaply by biotechnology-related methods compared to conventional methods will obtain a significant share of the market. This will ultimately reduce the profit margins for recombinant products. The impact of the new biotechnology on the production of chemicals is shown in Table 4.6.

5.3 Agriculture

Over the next two decades biotechnology is likely to begin to significantly increase food production in several ways. These contributions will come through the improvements in yield, by reduction in the cost of agricultural inputs and by the development of high-value added products to meet the needs of consumers and food manufactures. Non-food uses of animals and plants for the production of antibodies and therapeutic proteins are also likely to become important.

a) Biopesticides

Biopesticides based on protein toxins produced by a bacterium, *Bacillus thuringiensis* (Bt), have been in commercial use for over 30 years. Their target specificity has become broader to include a wider range of pests including caterpillars, mosquitoes, blackflies, and beetles.

There is however considerable uncertainty about the long term viability of Bt as resistant pests have been already reported in laboratory and field trials (Moffat, 1992. In spite of these reports some company researchers expect the Biopesticides market to expand (Feitelson et al. 1992). The increasing demand for pest control and the environmental instability of traditional (i.e. non rDNA) Bt products are two factors stimulating the continuation of research interest in this area (Feitelson et al. 1992). The application of rDNA techniques to produce new products with extended ranges playing a major role in Bt

R&D programmes. The toxin genes have been cloned, sequenced and introduced into other Bt strains as well as different organisms. To date however only two rDNA Bt products have received approval as Biopesticides. In 1991, the US Environmental Protection Agency (EPA) approved Mycogen Corporation's MVP and M-Trak. Here , toxin genes from Bt are expressed in an inactive, transgenic bacterium, *Pseudomonas fluorescens*.

b) *The production of novel plant varieties*

Plants have been mutagenized and selected for altered genomes for many decades. However the first recombinant engineered plant was established in 1983. Transgenic plant technology is now well advanced and there is potential foe a very broad range of commercial opportunities. Over fifty species of crop plant can be genetically transformed (Gasser and Fraley 1989). These include many important dicotyledonous crops and a rapidly expanding number of monocotyledonous crops such as rice and maize. Current research is likely to lead to routine gene transfer systems for nearly all crops while technical improvements will increase transformation efficiency, extend transformation to elite germoplasm and lower transgenic plant production costs (Fraley, 1992).

During the last decade seed and agrochemical companies have invested very heavily in plant biotechnology R&D. Substantial progress has been made in areas of direct relevance to the industry namely the production of insect, herbicide and virus-resistant plants. None have as yet been commercialised.

The development of herbicide-tolerant crops can improve yield as weeds can be eliminated by spraying. The current crop targets for herbicide tolerance include soyabean, cotton, maize, oilseed rape and sugar beet. Two strategies have been employed to produce this effect. First, the level of sensitivity of target enzyme for the herbicide can be altered as in the case of glyphosate resistance in oilseed rape and soyabean. Second a gene which codes for an enzyme which inactivates the herbicide may be transferred into the plant. This approach was the basis for the engineering of resistance to sulfonylurea compounds in cotton and oilseed rape.

For biotechnology generally, herbicide tolerance in crop plants has probably attracted the most criticism from a wide range of environmental groups as it could encourage the increased use of herbicides (Hobbelink, 1989). The alternative view is that such plants could allow a shift in herbicide use towards more environmentally safe products (Moffat, 1992) as well as encouraging management practices that will reduce corrosion. R&D efforts have focused largely on those herbicides which have minimal environmental impact and on avoiding gene transfer into crops which could either outcross to wild relatives or become "volunteer" weeds.

With regard to disease resistance considerable progress has been made with the expression of a virus coat protein in transgenic plants. Expressing the coat protein of a single virus confers resistance to a variety of viral diseases (Powell, 1986). This approach has been applied to several crops including tomato, alfalfa, tobacco, potato, melons and rice. Resistance to fungal and bacterial pathogens is also being pursued using the same type of approach. for example, tobacco plant expressing a bean chitinase gene driven constitutively at a high level were more resistant to the fungus *Rhizovyonia solani* (Broglie, 1991).

Another area of active research in several plant biotechnology laboratories concerns the engineering of tolerance to specific environmental conditions. Genes which are induced by stresses such as heat , cold, salt, and heavy metals have been identified (Benfrey and Chua, 1986; Goldberg, 1988). However it remains to be seen whether the expression of these genes is dimple a pleiotropoc response to stress or whether the gene products actually confer protection and adaptation to the plant.

The improvement of crop plants by genetic engineering has considerable potential to contribute to the predicted need for the doubling of the food supply in many parts of the Third World (Persley, 1990). However, the enhancement of important agronomic characters such as yield and storage proteins involves the manipulation of complex gene systems which are not well understood. Another critical point concerns the fact that some of the crops on which the rural poor of the Third World depend could be by-passed by biotechnology. While public and private sector R&D is being targeted at major developing country crops such as rice and maize less attention is being given or is likely to be given to subsistence crops such as cassaca, millet and sorghum.

c) Plant health

Annual world-wide crop losses to plant disease are estimated to be in excess of US$ 60 billion. Although they may appear to be considerable commercial opportunities for the use of diagnostics in this area, there are several problems (Coombes, 1992). The essential difference between diagnostics for health and those targeted in other areas, is that individual plants have very low value. For most field crops, there will always be cheaper alternatives (i.e. a pesticide) to using a diagnostic test. One of the very applications however of this process are in the seed potato industry.

d) Biotechnology in animal production and health

Biotechnology is advancing over a wide front in animal production and health, including embryo technology and several aspects of the physiology , immunology and nutrition of farm animals (Cunningham, 1990). The genetic manipulation of animal will lead to the acceleration of the livestock improvement process by the introduction of specific genetic variation. The production of transgenic animals is very much an emerging technology with considerable promise (The Guardian, 15 December 1994). Successful production of transgenic farm animals has been reported from seven research centres. Proteins such as animal growth hormones can be produced in recombinant yeast or bacteria at low cost and them be administered to the animal with substantial affects on production .(Cunningham, 1990). In cows, bovine growth hormone (bovine somatotrophin or BST) produces 15-30 %

increase in mild yield while in pigs (porcin somatotrophin or PST) results in increased growth rates.

Near to medium term applications which are expected include the production of medically important proteins such as blood clotting proteins in the milk of sheep and cows. For example, the gene for human blood clotting factor 1X has been transferred to sheep (Wilmut et al 1988) . The aim of this technology is to isolate the factor (or other proteins) at low cost. How useful this technology will prove will depend on the identification of high-value added proteins which are difficult to produce by conventional means. The use of transgenic animals for human disease may be achieved in the long term. The application of restriction fragment length polymorphisms (RFLPs) to animal breeding is likely to be of considerable value. RFLPs can be used as markers for quantitative traits. This will assist in the selection of characters such as milk production and growth rates in the medium to long term.

Some of the developments of animal biotechnology are likely to be more useful to producers already using high technology. Thus the application of BST in diary production is predicted to accentuate the competitive advantage if larger-scale intensive diary farms to the disadvantage of small scale producers (Cunningham, 1990).

Disease is a critical constraint on livestock production (Doyle and Spradbrow 1990). Over US$ 100 billion may be lost annually through the incidence of disease of farm animals (Coombes, 1992). The veterinary market for diagnostics supports over 80 companies in the

USA and Europe. While sales of veterinary diagnostics are still relatively small, the considerable growth since 1985 has attracted a good deal of attention. Currently the emphasis is on direct benefits rather than disease prevention. Thus progesterone tests for fertility monitoring on the farm are now widely available. However some doubt has been cast on market estimates of US$ 50-100 million per annum for these bovine pregnancy and fertility diagnostics. It has been suggested that farmers remain, as yet, largely unconvinced of their value (ACOST, 1990).

5.4 Food and Beverages

Several of the developments in agricultural biotechnology are targeted at foods and beverages. For example genetic modification of plants to improve flavour, shelf life or to eliminate toxins are carried out in response to demands in the food sector. There are also several other areas of the food industry where biotechnology is beginning to have an impact and they are summarised in table 4.7.

The modification of existing new crops will provide new, raw materials. for example in the areas of oils and fats, Unilever is involved in the genetic manipulation of oil seed rape to produce improved, edible oils. The same company is also operating a pilot plant to produce a cocoa butter substitute using enzymatic transformation of lipids. The best known example of a completely new food is "Quorn" mycroprotein, produced by ICI.

The use of enzymes to enhance efficiency in the manufacture of food and beverages is growing. However the suggestion that half the industrial enzyme market will be supplied by engineered enzymes by the year 2000 has been argued as optimistic (Coombes,1992). Flavour and fragrances are high added vale areas for biotechnology. Three technical areas of potential importance are plant cell tissue culture, microbial fermentation and enzyme technology. As yet, the only commercial product derived from tissue culture is a dye, shikonin, manufactured by the Japanese company, Mitsui. Vanillin has also be successfully produced in culture but as with several other potential products, the yield is too low to be competitive. However improvements in the design and operation of bio reactors over the next decade may make this route more cost-effective. Microbial fermentation has been used by the food industry for many years and will continue to be applied to develop a wide range of products.

The global food industry is a US$ 3,000 billion market and quality and safety of food are growing in importance. Because the industry is likely to becoming subject to increasing regulation, diagnostic kits, based on MABS, could therefore play a significant role. Key areas include microbiological safety, microbial generated toxins, chemical contamination, nutrient value, chemical composition and origin of components. However the market for food diagnostics is relatively underdeveloped. In the UK and elsewhere, the food industry has remained relatively resistant to widespread testing and government surveillance of food has been described in some quarters as "ad hoc and unorganised".

Immunodiagnostic technology is widely viewed as being particularly well suited for screening foodstuffs for specific pathogens. The new methodologies are much quicker than standard techniques and can therefore offer huge savings in product holding times and product liability risk (Coombes,1992). A number of kits have been marketed to serve this area.

5.5 The Environment

During the past decade there has been a huge growth in the importance of environmental issues. Biotechnology, either directly or in association with non-biological methods has the potential to provide solutions to several environmental problems. In general industry is being encouraged to view the environmental management not as a threat but as a cost saving opportunity. As yet, there have been few applications in biotechnology to environmental problems and it is clear that the public sector, rather than industry , will need to take the lead.

Large environmental cost savings are expected from:

i. reduced industrial pollution through the use of biological processes in effluent treatment

ii. improved techniques for hazardous industrial and household waste management

iii. reductions in household and industrial waste volume

iv. biodegradable plastics and packaging

v. reduced agricultural waste

vi. reduced private and industrial consumption of public utilities (for example clean air and energy) (OTA, 1991).

A major advantage of using biodegradation to remove pollutants from effluent, is that when efficient, it is by far the most economic form of treatment. many organic chemicals used in industry are xenobiotic (not having chemical structures found in nature). Many xenobiotics are biodegradable, others are not. There is a pressing need to assess the effects of these chemicals on the environment and to devise methods of effective treatment where necessary.

There are few examples of new biotechnological waste treatment methods. However, the use of genetically modified organisms (GMOs) to enhance biodegradation of specific compounds is not likely until certain issues are resolved. For example there are uncertainties about organism stability in a waste treatment environment. Added to this are the legal problems concerning the uncontrolled relapse of GMOs. The use of specialised bacteria to degrade particular compounds is of major importance to biodegradation and an area that is likely to expand in the future for example, bacteria can be used to degrade cyanide waste and immobilised bacteria are being used on a pilot scale by Monsanto to detoxify effluent from one of its rubber plants. Biotechnology is likely to influence the treatment of waste waters. Some examples of the impact of new biotechnology are illustrated in table 4.8 with predictions for reductions in water pollution in table 4.9.

With regard to immunodiagnostics these are unlikely to displace conventional and well-proven chemical sensors and laboratory techniques (GLC), gas liquid chromatography (HPLC) and high pressure liquid chromatography for the foreseeable future. They may however prove to be of value where existing methods are slow or inefficient or where specific analyses (rather many compounds) are being tested.

6. MARKET DEVELOPMENT

Dunhill and Rudd (1984) have suggested that the industries which do or could use biotechnology together represent a major portion of the international economy. The Senior Advisory Group on Biotechnology (SAGB) which represents the large European chemical firms[4] and acts as a pressure group on influencing EC policy on biotechnology provides estimates of biotechnology world market share. They estimate that the present size of the world market for biotechnology products is 5.1 billion ecu and this will rise to over 83.3 billion ECU by the year 2000 (table 4.10). Industrialists are also optimistic about the share of various market sectors going to biotechnology, anticipating that biotechnology will have pervasive effect in key sectors as instrumentation, food, health-care, chemicals, agriculture and the environment (see Table 4.11).

According to SAGB forecasts, sectors where biotechnology is most likely to have commercial impact, are those which account for over 21 % of EC industrial production, employ 17 % of EC employees and contribute almost 30 % of EC exports to the rest of the world. These are sectors which are more important in the EU than in the American or the Japanese economy in terms of jobs, share of exports and share of production.[5] In

---

4 SAGB founder members were Ferruzzi Group, Hoechst, ICI, Monsanto Europe, Rhone Poulenc, Sandox and Unilever.

5 It is noteworthy that SAGB do not give any indication why there will be more jobs in the EC than in the US and Japan. However Ernst and Young (1995) have also indicated similar findings and a recent report in Scientist (1995) shows how biotechnology employment in the States is now falling .

comparison to the United States, in Europe the proportion of biotechnology activity by market is more biased to the chemicals, agriculture and supplies sectors .

The OTA (1991) has forecasted a lucrative growing world-wide market for biotechnology in environmental management which is conservatively forecast to increase from US$ 0.56 billion in 1990 to 0.78 billion in the USA alone by the mid 1990s. Furthermore, the number of drugs under development gives some indication of the potential impact biotechnology could have on drug discovery (for example see table 4.2), and the recent biotechnology therapeutics to go into trial (see table 4.4) shows the projected development dates for 31 selected vaccines. Current sales of approved rDNA drugs are approximately $US 1.2 billion with the greater part occurring in the United States. As yet, few of these drugs have been approved for use in Europe. By 1989 only seven rDNA therapeutic protein drugs had been approved by the American Food and Drug Administration (FDA). Although today this has only risen to 18, there are now over 100 awaiting approval with the world market expected to grow vigorously over the next few years, reaching an estimated $US 10 billion by the year 2000 (Marcel, 1990).

The potential of biotechnology to improve the quality of life in both the developed and developing countries is considerable (Ratledge, 1992; Thomas, 1993). Within the next 20 years, major impacts can be expected on health, pharmaceuticals, agriculture, food and the environment. Thomas (1993) has listed where the main developments will be made. These can be summarised as follows. Advances in drug design and delivery, targeted drug discovery and the application of these to genetic disorders, cancer and probably AIDs are expected to effect a major "revolution" in medicine.

In agriculture, transgenic plants with the potential to improve the yield and resist pests and diseases will be established for several crops. A shift from the extensive use of artificial fertilisers to engineered nitrogen-fixing crops is also anticipated in the long term. Improved drugs and vaccines for animals and for the use of transgenic selective breeding will produce significant changes in animal husbandry. There is also a strong possibility that the field will be substituted by the production of some foodstuffs. Finally, biotechnology has the potential to improve the quality of environment by the development of biomass energy, the application for enzymes to promote recycling and the production of biodegradable plastics. While third generation biotechnology undoubtedly has the potential to effect major impacts in several industrial sectors, commercial successes have been largely limited to rDNA drugs and diagnostic kits.

The use of MABs (monoclonal antibodies produced by hybridomas formed from cell fusion) in diagnostics is now widespread. In 1990, global sales of diagnostic kits totalled approximately $US 2 billion and currently show an annual growth rate of between 6-7%. Hormone-related test sales alone are expected to reach $US 1.6 billion by 1995 (Frost and Sullivan, 1992). The market is dominated by products aimed at the clinical health care markets. Because these are used *in vitro*, they are not subject to lengthy test procedures and regulations. In addition, the high rate of product innovation and rapid market entry means that many firms do not consider intellectual property protection worthwhile (Thomas, 1993).

7. INDUSTRIAL STRUCTURE

The commercialisation of biotechnology was based initially on the appearance of a large number of small innovative firms, particularly in the USA and to a lesser extent in Britain. This is clearly shown in table 4.12 which compares biotechnology markets in the United States with Europe. The reasons for American success in biotechnology is examined in more detail in the following chapter. However, the purpose here is to to provide a broad overview of the industrial structure of the biotechnology sector. This is divided into two sections - a discussion of the main 'actors', followed by the geographical location of firms in the biotechnology industry.

7.1 The main 'actors' in the biotechnology sector

The main 'actors' involved in the biotechnology are: small firms (for example, the European Commission definition is any company employing less than 500 employees, in the case study reported in chapter seven, biotech firms are often much smaller employing less than 50); publicly financed research centres, and the large firms. Walsh et al (1991) have described the main actors in the production and development of biotechnology as follows:

I. **Companies concerned primarily with biotechnology**: they are often small, and established entrepreneurs to exploit discoveries made by publicly funded research, although since the mid 1980s founders have come from industrial firms not only from academia. Jones (1994) has examined the partnerships between academics and industrialists in the creation of biotech firms. Biotechnology firms were established with the goal of making their own products, or as Sharp (1989) comments to become fully integrated pharmaceutical companies. The sale of processes and services has usually occurred because the firm lacked some element necessary for the production, marketing and sale of a product. Walsh et al compare the sales of the largest American dedicated biotechnology firms and their product sales. The product sales are a tiny fraction of the output of these firms, who depend on sales of know-how, contract R&D and other processes and services for their main business (also see earlier table on biotechnology services and products).

II. **Companies in the sectors which use biotechnology (chemicals, pharmaceuticals, waste treatment, food processing and so forth) as well as other processes**: they are typically larger, often multinational and may either have biotechnological expertise and generate biotechnological knowledge themselves, or acquire it from other firms in (I) either by interfirm alliances, joint R&D or other co-operative ventures, or by conventional arms length customer supplier transactions, or through merger with or acquisition of firms in (I);

III.**Publicly funded R&D labs which still have substantial inputs to firms doing biotechnological R&D** (in (I) and (II) above). Many of them retain links with those firms established as 'spin offs' from their discoveries, while co-operative research alliances with, and contract R&D for large firms have been established as a part of the latter's strategy for developing their own R&D capability. The EC publishes a list of publicly funded biotechnology projects in member countries (CEC, 1990).

There is some confusion surrounding the exact number of biotech firms currently in operation. For example, there are a number of lists of main firms in categories listed above, although the numbers do vary considerably. In 1990, Pisano quoted a figure of 700 firms involved in biotechnology world wide, which would include those under (I) and (II) . The OECD in 1989 lists 94 major firms which detailed the number of undertaking R & D activities in the biotechnology sector. The problem facing classification of biotechnology activities is that it due to the diversity of activities there, different definitions are adopted. For example, in some instances support services such as intellectual property lawyers, equipment suppliers are considered to be biotechnology companies.

7.2 The geography of the biotechnology industry

The geography of the industrial structure of the biotechnology sector clearly favours a concentration of biotechnology activities in the United States. To illustrate, the most comprehensive assessement of the global geographical distribution of biotech companies produced by the *Genetic Engineering News* (GEN) Guide in 1992, is listed in table 4.13.

This shows the concentration of biotech activities in the global economy and the concentration of biotech firms in the United States. This is discussed in detail in the following chapter, however, table 4.14 shows how these firms are clustered around a number of high-tech developments in California, Massachussets and New York. More recently, Ernst and Young (1995) show that there are 485 biotechnology companies currently operating in European Biotechnology. This is compared to 386 identified firms in 1994,[6] and over 1,311 in the United States (see table 4.12).

7.3 Science and Educational infrastructure

The most important feature of the 'new biotechnology' is the third generation or modern biotechnology which emerged in the latter half of the 1970s and is associated with the growing range of techniques procedures and processes such as cell fusion, rDNA technology and biocatalysis that can substitute and complement classical biotechnologies of selective breeding and fermentation (see earlier). These processes enable the synthesis of products by cultured cells or micro-organisms that are unnatural to them - and is the activity most commonly associated with the term 'biotechnology'. The major new interdisciplinary input which distinguished third generation biotechnology from its predecessors was molecular biology, which orientated and developed not so much in industrial R&D centres but in publicly funded government and university laboratories. Faulkner (1989) has pointed to the development of products and processes based on

---

[6] According to Ernst and Young (1995) there are three reasons for the increase. First, Finnish companies are now incorporated into their survey universe. Second, after the publication of the first Annual Report in 1994 on the Biotechnology Industry, a number of very small and previously unidentified companies announced their existence. Thirdly, new companies are being created in the industry.

genetic engineering as dependent on industrial capacity, which grew as a result of second generation biotechnology, based in turn on the less exclusively academic disciplines of microbiology, biochemistry and chemical engineering. This is discussed in more detail in the following chapter on the development of the biotechnology industry. Significantly then, *consumer demand played a minimal role in the origin and emergence of third generation biotechnology*, and technical change in biotechnology is still heavily dependent on quite fundamental advances in science and hence on the public research system (Walsh et al, 1991). The implication of this therefore is that biotechnology development is intimately linked to the *national environment* - the educational and scientific infrastructure and national institutions notably. Overall, however it is generally believed that biotechnology is highly dependent on national scientific and research capabilities for its development (OECD, 1982; Sharp, 1985; Sharp, 1989). This is discussed further in the next chapter on the economic development of biotechnology in Europe and the United States where national institutional differences and cultural value-systems have been an important factor in variable rates of industrial development of biotechnology applications.

8. CONCLUSIONS

The aim of this chapter has been to discuss the evolution of biotechnology as a science into a knowledge-based industry with important economic and social implications and to look at its market potential. Advanced industrialised countries have recognised the potential of biotechnology in the high value, low-volume products: in other words in those products destined for healthcare markets. However, some of the biggest revenues in the world from biotechnology processes continue to be from brewing and so forth.

The biotechnology industry also has a number of distinguishable characteristics that have began to be addressed in this chapter and will be explored in more detail in the following one. The main characteristics of the biotechnology sector are described below:

A. Knowledge-based factors

- it is multidisciplinary
- it is an enabling technology used in a wide range of industrial sectors and technological contexts
- it is highly dependent on the availability of advanced scientific skills and experience of labour
- it is dependent on higher education institutes, research centres and an advanced scientific infrastructure for advances level training and research
- there is limited transferability of skills between sectors

B. Demand-side factors

- there is growing concern amongst interest groups in relation to European biotechnology development
- biotechnology development began through publicly funded research centres and small firm 'spin-outs' - science-pull factors
- requires affluent society to buy biotechnology products
- ethical movements (Greens; Church and other transnational working parties) have all lobbied against the use of some biotechnologically-derived processes and products which have had a major impact on consumer demand in some countries

C. Finance factors

- historically biotechnology financed from medical research (as with semi-conductors industry financed by military defence budgets in the United States)
- commercialisation requires a high level of 'risk' capital - strict regulationary environment
- small firm acquisitions, mergers and strategic alliances with ethical pharmaceutical companies (primarily American companies).

As this chapter has shown, although biotechnology is an enabling technology with global markets, it is also embedded within the national environment. Most of the innovative and dynamic activity in biotechnology has germinated from the small firm sector and like all small firms (see Storey et al 1994) is highly dependent on national institutions and infrastructure - such as access to knowledge and skilled labour. However, the case of biotechnology shows how changes taking place in the organisation of production and the role of knowledge and skills has created new challenges for nation-states in terms of how to promote but at the same time regulate this industry. As it was shown in chapter two, changes in international trade are a direct consequence of changes in technology, knowledge and skills. In industries such as biotechnology, competitive advantage appears to be determined by the knowledge generated by firms through R&D and labour market experience. Furthermore, biotechnology is highly interdisciplinary requiring great levels of expertise and dexterity from its skilled personnel or - 'symbolic analysts'. Unlike Reich's analysis, the labour market in biotechnology is far from operating as a free market where labour is mobile and moves around global webs of enterprise. This is shown in the empirical discussion of biotech firms in Europe. However, the important point from this chapter and leading in to the next discussion, is that the specific characteristics of this knowledge-intensive activity, along with the industrial structure of the sector, means that competitiveness is firmly locked into the territorial structure of production. In this sense then, the role of government for actively supporting industrial policies to support firms in this sector is *more* not less important than the extreme globalisers contend.

The opportunities to be gained from the third generation biotechnology, for example in the production of biopharmaceuticals, requires an affluent society prepared to pay relatively high sums of money for health care treatment, antibiotics and for improved standards in medical diagnosis and treatment. Biotechnology therefore is fundamentally no different from other high technology sectors such as electronics and chemical industries, relying on an affluent society for its economic development. While biotechnology, as with any other knowledge based industry not only requires very high amounts of capital for research and development stage, in addition the extraordinarily high costs of evaluating the efficacy of a new product and its accompanying long-term safety has become a major deterrent factor for investors and for new developers (Green, 1994; Clarke, 1995). This has led to a spate of mergers and acquisitions in the biotechnology sector, lead by US companies. This is discussed in detail in the next chapter.

In addition to these factors, and linked to the theoretical conclusions in chapter two, understanding competitiveness in biotechnology needs to be linked to the range of national-societal factors, business systems and institutions, thus the social organisation of the nation-state. For example, the economic development of biotechnology faces a number of challenges that are related to social forces within the nation-state that precludes to some extent, what it can or cannot do (cf: Cox, 1987). For example, in Europe there are a number of problems related to the economic development of this sector related to the demand-side for biotechnology-derived products and to the levels of investor confidence. Consequently, despite European scientific strength in the technology, not as a result of the market, but as a result of institutions, European biotechnology has failed to deliver. These issues are discussed in more detail in the following chapter by comparing the development of biotechnology in the United States and in Europe. As shown here, Europe and in particular Britain, have made important scientific breakthroughs in earlier biotechnology. The next chapter moves on to consider the dominance of the United States in the biotechnology sector. It is argued that Europe has failed to take biotechnology-related discoveries from the laboratory and into the market place leaving the United States to gain considerable market advantages as a 'first entrant' (see new trade theories chapter two) in this relatively infant industry. This can be more usefully conceptualised in relation to Strange's theories of IPE on hegemony and structural power: the advantage of being a first mover in the sector has enabled US companies to gain hegemony in the production, financial and knowledge structures for biotechnology. This is marked by the spate of small firm mergers, acquisitions and strategic alliances with primarily, large American companies.

Figure 4.1 The three generations of biotechnology and the main areas of development of the new biotechnology

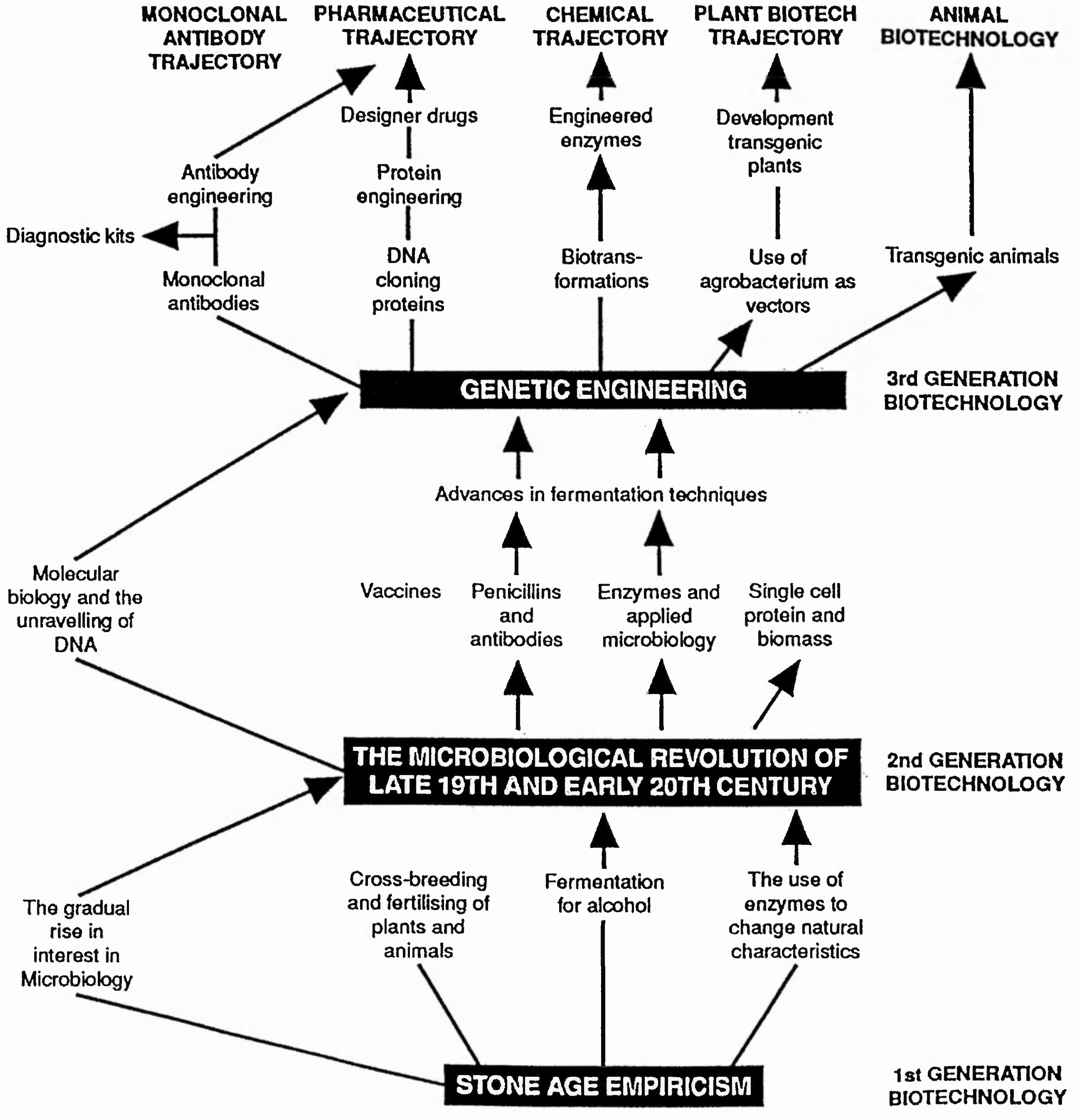


Table 4.1 Ranking of economic significance of several generic technologies

	Biotech.	Materials	Space	Nuclear	IT
Characteristics favouring or retarding diffusion					
Range of new products and services	4	4	2	2	9
Improvements in costs or technical attributes of existing processes, services or products	3	4	2	1	9
Social acceptance	5	9	6	3	9
Strength of private industrial interest	3	6	3	2	10
Sectors of application	4	4	2	2	10
Probable employment impact in 1990's	2	2	1	1	10

notes

a A value of 10 represents the highest ranking value and a value of 1 the lowest

source: OECD, 1988

Table 4.2. Customers for Biotechnology Firms' output

Output	*Customer*
Information	Other companies; public sector; laboratories; specialist libraries
Processes, R & D	Manufacturing companies, public utilities (private/public)
Drugs and Therapeutic products	Patents via GPs, consultants, public health care system or private medicine and insurance schemes
Veterinary drugs	Farmers and animal owners via vets
Diagnostics	Patients (over the counter or via public or private health care system); independent laboratories (private or public); GPs; hospital laboratories; police via own or independent labs
Genetically engineered seeds and plants	Farmers (directly or via private or public agricultural institutes)
Bioherbicides and pesticides	Individual consumers (via retailers, gardening clubs etc.); institutional landowners; gardening businesses; farmers
Foods	Food processing and marketing firms. Individual consumers via retailers; catering companies; catering services in schools, hospitals, workplaces (sub contracted or integrated public or private)
Animal foods	Farmers and animal owners via retailers and wholesalers
Food additives and processes	Food processing firms, farmers
Waste treatment processes and micro-organisms;	Water and Sewage companies and other public utilities ; construction firms who provide new waste treatment plant complete with biotechnology based products
Fuel alcohol and other Energy	Energy supply companies, networks of petrol garages; local biological sources of energy government, manufacturing companies.
Educational kits	Schools, education authorities
Intermediates, enzymes reagents	Manufacturing companies, public utilities, labs, feedstocks,

source: Walsh et al,1991.

Table 4.3 The most recent biotechnology therapeutics to go to trial

Indication	Company	Product	US status
		CSFs	
cancer	Cetus	Macrolin (M-CSF)	Phase I
bone marrow transplants,	Immunex	Leukine (GM-CSF)	New Drug Application (NDA) filed
neutropenia to secondary chemotherapy			
		Growth Factors	
wound healing	BM-Squibb/Oncongen	TGF-alpha	Phase I
chronic soft tissue	CalBiotech	Fibroblast growth factor	Phase I/II
nutritional/growth disorders	Genentech	Insulin-like growth factor	Phase I
venous stastis, diabetic leg and foot ulcers	Synergen	Human rDNA basis FGF	Phase II
		HGHs	
pituitary GH deficiency in children	Novo Nordisk	Norditropin (rDNAsomatropin for injection)	NDA filed
long-term growth failure due to inadequate endogenous GH secretion	Serono Labs	Saizen (rDNA somatropin for injection)	NDA filed
		Interleukins	
cancer immunomodulator	Sch-Plough	rDNA human interleukin-4	Phase I
		Monoclonal Antibodies (MAbs)	
lung, colon, breast, ovarian cancers	BM-Squibb/Oncogen	Chimeric L6	Phase I
breast cancer	BM-Squibb/Oncogen	Radiolabelled L6	Phase I
cancer	Cetus	Anti-LPS	Phase I
sepsis	Cetus	Immunotixin	Phase I
septic shock	Chiron	Anti-tumour necrosis factor	Phase I
Pseudomonas infections	Cutter	Anti-pseudomonas	Phase I
clinical sepsis	Cutter	Anti-TNF	Phase I
colorectal cancer	Cytogen	OncoScinct CR103	NDA filed
ovarian cancer	Cytogen	OncoScinct OV103	Phase III
prostate cancer	Cytogen	OncoScinct PR356	Phase I
adenocarcinoma	Cytogen	Onco Ther 130	Phase I
B-cell lymphoma	IDEC Pharmaceuticals	Murine MAbs to human B-cell lymphomas	Phase III
malignant melanoma	IDEC Pharmaceuticals	Murine MAb against murine MAb to melanoma-associated antigen	Phase I
iv treatment of myeloid leukaemias	ImmunoGen	Anti-B4-blocked ricin	Phase I/II
iv treatment of B-cell leukaemias and lymphomas	ImmunoGen	Anti-B4-blocked ricin	Phase I/II
ex vivo treatment of autologous bone marrow and reinfusion in acute myelogenous leukaemia	ImmunoGen	Anti-B4-blocked ricin	Phase I/II
colorectal cancer	Immunomedics	ImmuRAIT-CEA	Phase III
lymphoma	Technicione	LYM-1	Phase II
solid tumours	Technicione	TNT	Phase I
T-cell malignancies	Xoma	XomaZyme-CD7 Plus	Phase I
		rCD4s	
ARC, AIDS	Genentech	CD4-IgG	Phase I
		Vaccines	
melanoma	BM-Squibb/Oncogen	BMY-35047	Phase I
herpes simplex 2, genital herpes	Chiron	Herpes vaccine	Phase I
hepatitis B	WyethAyerst	Adenohepatitis B virus vaccine	Phase I
		Other	
heart and kidney failure	CalBiotech	Auriculin (atrial natriuretic peptide)	Phase II
cervical ripening	Genentech	Relaxin	Phase I

Source: SCRIP 151/3, May 9-11, 1990 p.32

Table 4.4 Project development dates for 31 selected vaccines

Disease	by 1990	1990–96	1996–2000
Chicken Pox		✔	
Cholera		✔	
Coccidiomycosis (valley fever)		✔	
Cytomegalovirus	✔		
Dengue			✔
E. coli enterotoxins			✔
Filariasis			✔
Gonorrhoea			✔
Hemophilus influenza Type B	✔		
Hepatitis A	✔		
Hepatitis B	•		
Herpes Simplex 1 and 2	✔		
Influenza viruses A and B	•		
Japanese encephalitis virus		✔	
Leishmaniasis			✔
Leprosy		✔	
Malaria		✔	
Meningitis	✔		
Parainfluenza	✔		
Pertussis		✔	
Rabies	•		
Respiratory Syncytial virus		✔	
Rotavirus	✔		
Schistosomiasis			✔
Shigella (dysentery)			✔
Streptococcus Group A		✔	
Streptococcus Group B		✔	
Streptococcus pneumoniae		✔	
Trypanosomiasis			✔
Typhoid fever	✔		
Yellow fever	•		

• vaccine already developed (but may not yet be licensed)

Source: Genetically Engineered Vaccines - a worldwide study on market opportunities for new vaccines in healthcare and veterinary medicine Copyright 1987 Technology Management Group, Bio/Technology vol. 5, November 1987.

Table 4.5 Clinical Diagnostic devices using biotechnology

More than 400 clinical diagnostic devices based on the new biotechnology are used in clinical practice today This table lists some examples.

Product description	Company	Technology
Pregnancy testing kits (Clear-blue, launched 1985)	Unipath	Monoclonal antibodies
Ovulation monitoring kits	Unipath	Monoclonal antibodies
Ovarian function profile (OVEIA)	Boots Celltech	Enzyme linked Immunosorbent Assay (ELISA)
AIDS diagnostic kit (Wellcozyme)	Wellcome	Monoclonal antibodies
Hepatitis diagnostic kit	Wellcome	Monoclonal antibodies
Legionella rapid assay	Bioscot/ Boots Microcheck	Monoclonal antibody
Salmonella rapid detection	Oxoid	DNA probe
DNA genetic fingerprinting	Cellmark (ICI)	DNA probe
Myosin LI. Early diagnosis of heart attack	Yamasa Shoyux	Monoclonal antibody
Intestinal and pancreatic cancer detection	Centocor	Monoclonal antibody (detection of glyco proteins)
Helico G (Helicobacter pylori kit)	Porton Cambridge	Ulcer diagnosis
Uristat. Detection of urinary tract infections	Shield Diagnostics	ELISA
Diastat. Detection of auto antibodies in systematic autoimmune rheumatic diseases	Shield Diagnostics	ELISA
Tandem E PSA Detection of prostate specific antigens for diagnosis of prostate cancer	Hybritech UK	Monoclonal antibody

Source: NEDO (1991): New Life for Industry. NEDO, London

Table 4.6 Some examples of the impact of the new biotechnology on the production of chemicals

The new biotechnology has already contributed to the production of some chemical products, resulting in purer products and more efficient processes. This table gives a few examples.

Product	Company	Application
3-hydroxyisobutyrate 3-chloroisobutyrate	Kanegafuchi	Chiral products for manufacture of cardiovascular drug
S-2-Chloropropanoic acid	ICI	Chiral product for a range of herbicides
Isopropylidene glycerol	International Biosynthetics	Pharmaceutical intermediate used in manufacture of Beta blockers
Benzene cis-dihydrodiol	ICI	Chemical intermediate used in manufacture of plastics
Polyhydroxybutyrate (PHB) and polyhydroxyvalerate	ICI	Copolymers for production of 'Biopol' a biodegradable plastic
Carotenoids produced by genetically modified Erwinia uredovora	Kirin brewery (Tokyo)	Traditionally produced chemically. Used in food production & synthesis of vitamin A
Phenylalanine fron E. coli	Biotechnica International	One of the precursors of the sweetener aspartame
Muconic acid	Calgene	Used in polyester & polyamide synthesis
Citric acid	Pfizer Sturge	Food flavouring additive

Source: NEDO (1991): New Life for Industry. NEDO, London.

Table 4.7 Some food improvements due to biotechnology

The impact of biotechnology on food manufacture is mainly in the area of food ingredients, particularly enzymes. This list provides a few examples. A number of food products that are under development are also listed

Product	Company	Application
Genetically modified bakers yeast	Gist Brocades	First modified food organism cleared for food use in UK March 1990. Reduces period of leavening in bread manufacture
Chymosin produced by genetically modified yeast	Gist Brocades	Cleared for food use in UK January 1991. Replacement for calf rennet for manufacture of cheese
Chymosin produced by genetically modified fungus	Christian Hansens Laboratorium	Cleared for food use in UK May 1991
Chymosin produced from genetically modified *E. coli*	Pfizer	Approved in US, Belgium & Australia. This product is still under consideration for UK clearance
Accelase	Imperial Biotechnology	Accelase is a natural enzyme system produced from food grade organisms which reduces time of cheese maturation *not cleared for food use in the UK*
Savorase	Imperial Biotechnology	An enzyme system used to produce natural flavours from casein, whey & soy *not cleared for food use in the UK*
Novamyl	Novo-Nordisk	An enzyme designed to enable bread to stay fresh longer. Available in Denmark since January 1991 *not cleared for food use in the UK*
VegiSnax	DNA Plant Tech	Crispy raw vegetable snacks *not cleared for food use in the UK*
Genetically manipulated tomato	ICI	A tomato with improved keeping properties is currently undergoing taste trials
Genetically manipulated brewers' yeast	Brewing Research Foundation	Currently being tested

Source: NEDO (1991). New Life for Industry. NEDO, London.

Table 4.8 Some examples of the new biotechnology on the environment

This short list describes a few environmental products either commercially available or under development.

Product	Company	Application
Xylanase	Novo-Nordisk	Facilitate separation of lignin & cellulose fibres in paper & pulp industry, thus avoiding the use of chlorine
Proteases	Novo-Nordisk	Hair removal in leather industry eliminating use of lime and sodium sulphide.
Cyclear	ICI	A fungal cell preparation for cyanide detoxification.

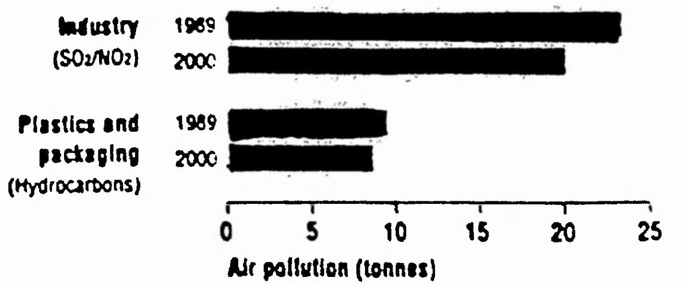
Bioremediation

Major environmental projects using biotechnology require services, consultancy and monitoring which can only be provided by specialised companies A number of these are listed here.

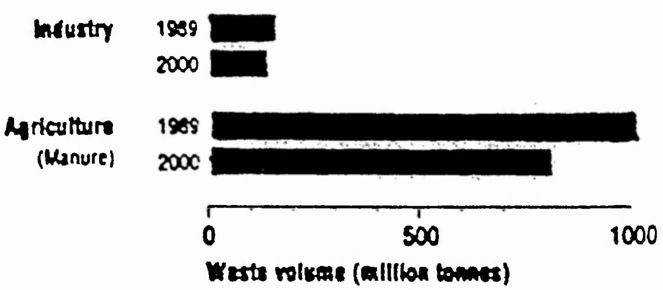
Company	Project example
Biotreatment Ltd (Cardiff)	Greenbank gasworks site Lancashire. First land decontamination project in the UK and one of the largest projects of its type in Europe.
Land Restoration Systems Ltd (Slough)	Treatment of 7000 cubic metres area on refinery site in Germany. Hydrocarbon concentrations were decreased by 90% over a 28 week biotreatment period.

Source: NEDO (1991): New Life for Industry. NEDO, London.

Table 4.9 Predicted reductions in pollution due to biotechnology from major sources in Europe (Year 2000)



Note The pH value of acid rain is predicted to change from 5 to 5 6 by the year 2000, which represents a drop in acidity



Source: NEDO (1991). New Life for Industry, NEDO, London.

Table 4.10 World Market for biotechnology products in 2000

Market size of world market for biotechnology products (ecu)	
Present	By year 2000
5.1 billion	over 83.3 billion

source: SAGB, 199O.

Table 4.11 Share of Various Market Sectors going to Biotechnology

Market sector	% of this market that will be occupied by biotechnology derived products by the year 2000
Instrumentation	50
Food	20
Pharmaceuticals/Healthcare	18
Average all markets	8
Chemicals	6.3
Agriculture	3.3
Environment	1.3

source: SAGB, 1990

Table 4.12 Comparison between European and US Biotech Markets

Europe		United States
485	Total number of companies	1,311
80 %	Employ fewer than 50 employees	75 %
70 %	Located in 4 countries/regions	74 %
45 %	Founded after 1986	36 %
20 %	Therapeutics	42 %
22 %	Other Healthcare	26 %
16 %	Ag-bio	8 %
22 %	Industry Suppliers	15 %
20 %	Chemical, environmental and other	9 %

source: Ernst and Young, 1995

Table 4.13 Geographical distribution of companies listed in Genetic Engineering News (1992)

Country	No. of Companies
United States	602
United Kingdom	64
Canada	38
Germany	20
Australia	16
France	12
Switzerland	10
Sweden	9
Netherlands	8
Belgium	6
Japan	4
Denmark	3
Austria. Brazil, Finland, Ireland, Israel, Italy, Luxembourg, Republic of China	2
Columbia, India, New Zealand, Norway, Singapore, Spain	1

source: GEN, 1992

Table 4.14 Location of biotechnology companies listed in GEN in the United States (1992)

State	No of companies
California	138
Masachussets	73
New York	52
New Jersey	49
Maryland	40
Pennsylvania	35
Wisconsin	21
Texas	19
Illinois	17
Connecticut	14
Virginia	11
Washington	11
North Carolina	10

notes: States with less than ten companies were not enumerated.

source: GEN, 1992

CHAPTER FIVE

THE GLOBAL POLITICAL ECONOMY OF THE BIOTECHNOLOGY INDUSTRY

1. INTRODUCTION

At the end of the last chapter, it was concluded that the characteristics of the biotechnology sector reflect the dialectical nature of globalisation, whereby on the one hand, products and markets are highly globalised, and on the other, the industry is highly embedded within its national environment. In this sense, in the biotechnology industry, a national and global orientation tends to occur simultaneously. Continuing the empirical exploration of the argument that the labour market for high-technology workers is locked into the production system, itself articulated through its relationship with the global industrial system, this chapter now turns to a specific exploration of the comparative development of biotechnology in the United States and Europe. The specific task of this chapter is to argue that the United States has gained leadership in the knowledge, production and financial structures for the biotechnology industry which has enabled the American state to gain competitive advantage in biotechnology, as reflected in its ability to attract the best knowledge, labour and foreign capital. In so doing, American hegemony in biotechnology has enabled US firms to set the 'rules of the game' in terms of the development of an emerging global biotechnology industry. Conversely, despite its early strengths in life sciences, European biotechnology has not developed at the pace originally anticipated. As it is shown here, governments can no longer be successful in promoting technological competitiveness in an industry such as biotechnology simply by allocation of more and more resources for R&D and creating more highly skilled labour. Moreover, innovation polices tend to be more strategic and more selective as in the United States (and Japan). When examining the state (and the supra-regional level) there are three sources of structural power relating to biotechnology development in Europe: knowledge, control of investment and access to finance.

This argument is explored through a discussion of the global political economy of the biotechnology sector and aimed at answering the question: why some nations have developed more than others? The argument advanced is that Europe has failed to capitalise on its early scientific advantages through a failure to commercialise biotechnology applications. This enabled other competitors to gain early advances in the sector. In addition, within Europe, certain organisational and institutional issues and the overall impact that these have on a new technology have had a direct bearing on the development of biotechnology, which are indicative of wider problems confronting the whole European integration project. This argument is highlighted by contrasting the European experience with that of the United States where governments have taken a strategic role in developing mechanisms and policies to support the development of the sector and the development of the biotechnology industry.

To illustrate this argument, the chapter is organised as follows. The dominance of the US in the biotechnology sector can be understood in relation to its position in the 'knowledge structure' for biotechnology. In part, this outcome can be linked to levels of Federal government investment in cancer and medical research which led to technological 'spillovers' and the development of a dynamic biotechnology small firm sector. The next section goes on to argue that European governments have been far slower to react to the potential of biotechnology, although the European Commission was quicker to react and has attempted to create a Europe-wide technology strategy. However, this strategy has been constrained by a lack of consensus between the European Union member states on how to both promote and regulate the sector revealing deeper social and cultural divides within the European Union. The lack of cohesion on issues relating to regulations for example, has created fundamental obstacles for European competitiveness in the global economy, resulting in many European firms seeking collaborative ventures with American dedicated biotech firms, with the loss of valuable knowledge, skills and capital.

The following section then goes on to consider broader macro economic problems facing the overall economic development of the European biotechnology sector and considers to what extent there has been a 'biotechnology revolution'. Indeed, there is substantive evidence to suggest that the global biotechnology sector has not developed at the pace originally envisaged as a consequence of the problems facing the commercialisation of biotechnology activities. It is argued that European biotechnology firms are facing a shortage of finance, extended lags in developing new products, a forecast level of demand that has failed to materialise, and the lack of the complementary skills, assets and technologies necessary for successful commercialisation of the technological knowledge that they already have. This discussion concludes by arguing that in terms of European competitiveness, the future economic impact of biotechnology depends not only on the expansion of demand but also on the existence of the appropriate conditions within which demand can be articulated and met. From a policy point of view and in relation to the broader concerns of this thesis, this raises a number of questions concerning the appropriateness of the current policy trend towards supply-side policies.

2. STRUCTURAL HEGEMONY IN BIOTECHNOLOGY: THE UNITED STATES

There is a growing perception among industrialists, investors and policy makers that the United States is the world leader in the global biotechnology industry (OECD, 1989; Sharp, 1989; Thomas, 1993; Russell, 1990a/b; SAGB, 1990; CEC, 1993). This is marked by the number of 'knowledge activities' dominated by the United States. For example, as indicated in the preceding chapter, the biotechnology industry is dominated by a preponderance of American dedicated biotechnology firms (DBFs) with far fewer start-up firms in Europe and the existence of local mileux in biotechnology around Massachusetts, California and New York. Additionally, Orsenigo has shown that the United States controls strategic biological data-bases and has the highest number of publications per annum (Orsenigo, 1989). Furthermore, analysis of patenting activity during the 1980s shows the pre-eminence of the US in genetic engineering and tissue culture (OTA, 1984). This is combined with domination over the lingua franca of the international scientific community, greater levels of investment from both public (charitable) and private sources and a more favourable regulatory conditions offering firms based there at a distinct advantage over competitors.

The influential position of the United States in accessing and controlling biotechnology knowledge, know-how and skills has enabled firms located there to benefit from the best strategic alliances and financial investments and attract the best skilled labour (see next chapter). In this sense, the United States has a powerful, hegemonic position in the biotechnology industry which creates a number of opportunities for the state in terms of wealth generation activities and for the competitiveness of firms. An important implication of this is the advantages available to firms located in the US for control and access to information, finance and labour. This supports the central theme of this thesis that knowledge-based activities are now critical to economic development. Thus, in high-tech activities as biotechnology, the competitiveness of firms and the structural competitiveness of states for attracting foreign capital has been greatly enhanced by leadership in 'the knowledge structure'. The importance of dominance in the knowledge structure for biotechnology and for power relations more widely for *shaping* the sector are discussed below. The discussion then goes on to consider *why* the United States occupies this position in the global biotechnology industry.

2.1 The knowledge structure and biotechnology

It was previously argued that one way to understand the role of knowledge activities in economic development is through the concept of 'structural power' and in particular, hegemonic power in the 'knowledge structure'. The debate in relation to hegemony in international relations is beyond the scope of this thesis. However, the concept of hegemony in new IPE is closely associated with the work of Cox (1981) and Strange (1991). In brief, hegemony is seen as bringing together both the coercive and consensual elements of power. Although the novelty of this approach compared to most of the mainstream lies in the attention it gives to the role of ideology in establishing and maintaining a hegemonic world order, it does also theorise the objective elements of power which lead to the capacity for the exercise, ultimately of coercion. As argued in chapter two, Strange's non agency based account takes an eclectic view of the global political economy which moves away from the parameters of the nation-state, ideology and class and in this sense is a more helpful theoretical starting point for understanding power in knowledge-based activities such as biotechnology. This is particularly useful for understanding the position of the United States in the global biotechnology sector.

This theoretical position was explored in chapter two. To recap briefly, structural power confers '..the power to decide how things shall be done, the power to shape frameworks within which states relate to each other, relate to people, or relate to corporate enterprises'(Strange,1988, p.25). In conventional economic thinking, knowledge is described as having strong characteristics of a public good (Dosi et al, 1988). But, as Strange notes, knowledge and know-how is not 'truly a public good in the sense that the term is used by economists, for the value of the supply to those already holding the knowledge may well be diminished when it is communicated to others' (Strange,1988, p.118). In this sense then, early access to knowledge is key to leadership in the knowledge structure. But, more importantly, leadership in the knowledge structure confers power to 'determine what knowledge is discovered, how it is stored and who communicates it by what means to whom and on what terms' (Strange, 1988, p.117). Consequently, power and authority are conferred on 'those occupying key decision-making positions in the knowledge structure' (Strange, 1988, p.117). Those who are entrusted by society with the storage of knowledge, the generation of more knowledge, and those who control 'in any way the channels by which knowledge, or information is communicated' (Strange, 1988, p.117) have power in the knowledge structure.

Thus, leadership in the knowledge structure in contemporary global political economy has led to three important developments. First, competition between states is increasingly becoming 'a competition for leadership in the knowledge structure' or a place at the leading edge of advanced technology; second, there is an increasing asymmetry between states as a consequence of access and control of technical knowledge as political authorities attempt to acquire and accumulate knowledge and access to it. Finally, more than any other of the four structures (production, security and finance), change in the knowledge structure 'is bringing new distributions of power, social status and influence within societies and across state borders'. Thus power is passing to 'the information-rich instead of the capital rich' (Strange, 1988, p.132-133).

What are the implications of these broad developments taking place in the world economy? Dminance in the knowledge structure has significant implications for the distribution of power and resources in contemporary production systems. For example, not least in the opportunities created for the hegemon to set the 'rules of the game' in the competition for world market share and determine *cui bono* questions (who gets what and how). Since it is generally accepted that economic systems have become more knowledge intensive, the knowledge structure is a useful organising framework for understanding the locus of power in contemporary capitalism. As I argued previously, this concept is not without flaws and at best, offers an organising framework for understanding 'power' in a world system whereby knowledge and business are transnationalised. Drawing from the theoretical argument advanced in chapter two, it was suggested that in addition to taking a structural approach to understanding contemporary economic activities, equally, a meso level analysis is required for understanding the interaction between structure and agency before answering such questions as *why* some nations are more competitive in certain sectors than others. Taking this theoretical approach therefore, this question is examined below in relation to the global political economy of biotechnology development.

2.2 The historical development of biotechnology in the United States

In the previous chapter the development of sciences related to the new biotechnologies and the pre-eminence of the European life sciences, especially in Britain, was discussed. An important question, then, is why a stronger biotechnology industry emerged in the United States and not in Europe? There is a good case for arguing that US hegemony in the sector is directly linked to the industrial strategies pursued there by US agencies throughout the 1980s which has secured its pre-eminent lead in biotechnology. Returning to the argument of chapter two, in the contemporary global industrial system, there is justification for selective and strategic targeting of industries. For example, *strategic industrial policies* on behalf of the Federal State has played a major role in securing leadership in biotechnology for the United States. Research by Borrus et al (1986) explores the initial strong US market position in the semi-conductor industry in relation to federal government support for military research. Equally, this could be applied to United States market position in biotechnology. Sharp argues that the emergence of a dynamic small firm sector in the United States is directly linked to US government policy (Sharp, 1992). Government research expenditure combined with private sector cancer research spending, much of which funds leading institutes such as the Wistar Institute in Philadelphia, and the Harvard Medical School, have made a substantial contribution to US leadership in the fields of genetic engineering, immunology and molecular biology. Thus as with micro-electronics, the US intellectual superiority in biotechnology stems from the catalyst provided by federal funding not in this case from military and space research, but from medical and biological research and above all, for cancer research (Sharp, 1991).

It can be argued therefore, that government support is a major factor contributing to US success in biotechnology. The levels of expenditure have by far exceeded other potential competitor states. For example, in the US, government funding of the life sciences in 1987 was over five times that of Japan, France and Britain. This is set out in table 5.1. The amount spent on the life sciences as a percentage of the total science budget was at least 15 per cent greater in the US than in the other countries. Thomas and Sharp note that the American National Institute of Health (NIH) expenditure alone has contributed substantially to the expansion of biotechnology in the US (Thomas and Sharp, 1993). For instance in 1982, the United States federal government support of directly funded related biotechnology work and the National Institutes of Health (NIH) (genetic manipulation, hybridomas, MABs, enzymes) amounted to $380 million (OTA, 1984), however, pathology and immunology are very closely related to biotechnology and some spin-off from the overall NIH budget of £3.5 billion has been inevitable. Further Federal spending on research for biotechnology is channelled through the National Science Foundation whose overall budget amounted to $1.2 million with over $53 million of that on research directly related to biotechnology (OTA, 1984). Thus between the NIH and the NSF, Federal Government spending reached approximately $400 million. In 1993, the US President's budget was over $US 4 billion (Walsh and Galimberti, 1993). Comparative figures from public sector funding of biotechnology

R&D support this view (figure 5.1). Although it is difficult to disaggregate biotechnology related R&D, these data clearly show the US leads by a wide margin. Within Europe, R&D spending on biotechnology has been concentrated in Germany, France and Britain, totalling over £600 million during 1988-89. By contrast, Spain and the Netherlands were estimated to have each spent only £5 million over the same period.

The emergence of American hegemony in the knowledge structure for biotechnology can also be related not only to public sources of investment through research budgets, but, equally, through the availability of privately supplied venture capital for small firms. The US and to a lesser extent Britain are distinguished by specialist venture capital funds that provide seed and start-up finance for innovators. Following the success of the semiconductor firms in Silicon Valley, US venture capitalists have been keen to invest funds in another new, high risk, high-return technology. America has by far the world's largest venture capital market and in 1995 $7.5 billion was injected into 1,600 small, young companies (Caulkin, 1996). The largest Biotechnology Investments Ltd., supported by the Rothschild fund, was capitalized at US $200 million in 1991 with 75 per cent of this investment in the United States (Thomas and Sharp, 1993). In comparison, only 25 per cent is located in Europe, most of which is in Britain with six funds specializing in biotechnology reaching an investment of over US $1 billion since 1980 (Thomas and Sharp, 1993). Within Europe, it is clear that Britain has the most active venture capital market, providing two-thirds of the continent's venture capital.

However, this is still considerably smaller than in the United States with Caulkin arguing that Britain provides a pale imitation of the US model of investment. This is supported by research that suggests many European venture capitalists abandon young high-technology firms (Caulkin, 1996). Indeed, as is discussed in more detail later in this chapter, one of the main impediments facing biotechnology is the lack of long-term investment to finance new innovations.

These very substantial funds in the US have led to the development of the high quality laboratories which in turn have attracted the best qualified and experienced scientists and provided a fertile environment for the development of dedicated biotech firms. However, it has also been argued that the success of the biotechnology sector in the United States is due to the specific power of the 'innovative milieu' around clusters of firms based in the cities of New York, California and Boston (Willoughby, 1996). The idea of the innovative milieu has been under represented in the English language literature. This literature describes local industrial complexes based on flexible specialisation and vivified by network relationships, but places great emphasis on intangibles such as attitudinal environment and complex interplay of cultural factors (religion, technically progressive values and so forth.,) as substrata for political openess (for example, see Lagendijk, 1996). According to this view, the prime determinant of the location of business is not based on external locational factors as key forces underlying the biotechnology industry such as the presence of a pool of highly skilled labour, favourable regulatory regime and institutional richness. Moreover, it is based on the founder of the company and their specific choice of location. The problem with this argument in terms of understanding the development of the biotechnology industry in America is that it fails to recognise the role of federal money in supporting the initial spin-outs (primarily university academics turned entrepreneurs) of dedicated biotechnology firms from medical and research institutes in the first place. Thus, Willougby's conclusions that regional development policies aimed at attracting biotechnology foreign capital to locate in specific localities will be fruitless given the specific innovative milieu, fails to recognise the strategic role of government in developing the biotechnology industry in the United States. Indeed, this role of government raises a number of questions concerning the overall accuracy of the innovative milieu concept in relation to the development of biotechnology clusters in the United States.

Knowledge and Power in the Biotechnology Industry

If, then, as it has been argued in this section, the United States dominates the knowledge, production and financial structures for the world biotech sector, what are the implications of this outcome for the development of the sector in other countries or supra-regions? One consequence of hegemonic leadership in the biotechnology sector is the power conferred to shape developments within the sector, thus for influencing the relations between firms and states. Leadership in the knowledge structure through early market entry has enabled US firms to deeply influence the 'rules of the game' within the industry and dominate the forms of spatial relations between dedicated biotechnology firms and large multinational corporations seeking new knowledge in the field. This has manifested at a number of levels and can be understood by drawing on the tenets of the new trade theory. For example, the American State has secured a large share of the rent-yielding firms operating in the sector, not to mention the overall positive economies derived from generating, accessing and storing knowledge, know-how, and skills in biotechnology advances. The long term benefit of securing external economies is the creation of a self-sustaining cycle of development whereby barriers to entry are quickly raised, the hegemon has secured and embedded its privileged position in dominating the industry. In terms of creating greater wealth, by securing a large share of the rent-yielding industries, high returns are generated for society because in addition to direct earnings (for example, American federal investments in cancer research) innovation generates the knowledge which provides 'spillovers' in terms of benefits to capital and labour being employed elsewhere, such as new spin-out firms. The implication for US firms is that they have greater choices: they can attract the best alliances (discussed later), the best foreign capital thus they can offer the most attractive career prospects and salaries. Overall, this concentration of skills, know-how and knowledge offers an attractive supply base to potential inward investors.

Another factor relating to power in the knowledge structure and the ramifications that this has for understanding the pattern of behaviour in the biotechnology sector is in relation to the development of a 'safety regime' for biotech research and development.

The general perception is that the value system for biotechnological products is more favourable in the United States than in Europe, marked by a less onerous regulatory environment (Russell, 1990a). New techniques in genetic manipulation (cf. section 5.5 in pervious chapter) have enabled biotechnologists to develop a wide range of agricultural products, ranging from plants that are resistant to herbicides to micro-organisms that can be used to control pests. Apart from the host of technical issues about the manipulation *per se* of living things, and general concerns about science being 'out of control', there is some public concern about the organisms themselves spreading uncontrollably as in the case of Dutch Elm disease and myxomatosis.

However, overall levels of public concern in the United States appear less vociferous than in Europe. For example, this is marked by the American response to bovine somatotropin (BST) (Hoyle, 1994).[1] BST is injected into cows to increase milk yield. In November 1993, the US Food and Drug Administration approved the biotechnology company Monsanto's new BST product, *Posilac* after 12 years of development, which has been more controversial in Europe (*see later*). Equally, there has generally been widespread acceptance of the first genetically manipulated food - a tomato called 'Flavr Savr' developed by the biotechnology company based in California, Calgene, which

---

[1] BST is the term used for taking small amounts of impure pituary hormone extracted from dead cows and injected into live ones to increase milk production. A number of conerns have been expressed about the safety of this method on human health. Although there have been a number of concerns expressed in *The New York Times* a commissioned study to assess the safety and likely market impact of BST, has been produced for the Clinton White House entitled *Use of Bovine Somatotropin (BST) in the United States: Its Potential Effects* which stated that'there is no evidence that BST poses a threat to humans or animals' (Hoyle, 1994).

guarantees a longer shelf life by improving durability during transportation, which has began to reap large dividends to the company with very little consumer opposition to date (The New Yorker, 1993). However, some restaurants across America have indicated that they will not serve genetically altered foods (The New Yorker, 1993).

Whilst traces of resistance do exist in American society, they appear more contained and less pervasive at a political level than in Europe. The most comprehensive public opinion research on biotechnology in the US has been conducted by the Office of Technology Assessment (OTA, 1987). Genetic engineering was cited as making life better by 66 per cent of people but 52 per cent still through that genetically engineered products would represent a serious danger although only 12 per cent could cite a serious hazard associated with them. On ethical considerations, 68 per cent believed that creating hybrid plants and animals by genetic engineering was morally wrong but 80 per cent approved of specific medical treatments arising from genetic engineering. The majority of the population was prepared to accept fairly high risks to the environment for the sake of the potential benefits of genetic engineering but, 32 per cent were opposed to the field testing of genetically modified organisms in their own community and 20 per cent would not approve of such testing under any circumstances. Only 42 per cent approved of large scale commercial application of genetically modified foods. The OTA reported that:

> 'A relatively wide-spread general sense that a serious danger from genetically engineered products is at least somewhat likely exists in the population, and is somewhat independent of education or information about the products' (OTA, 1987, quoted in Grindley and Bennett, 1992, p13).

However, in comparison to Europe, these elements of resistance filter less into the American political process. As Tait remarks, public concern is probably just as strong in the United States as it is in Europe, but the regulators there seem more prepared to take the risk of ignoring it. While both the European Commission and British Government are engaged in the writing of regulations to protect the environment aimed at avoiding future problems, - the American strategy is a 'just-in-time' approach (Tait, 1982) where problems are dealt with as and when they arise. It is noteworthy, that the USA President's Council on 'Competitiveness Report on National Biotechnology Policy' with Vice President Dan Quayle as its chairman, made no reference in February 1991 to the importance of, and need for, public awareness and understanding of biotechnology in a document which sets out US policy for the next decade.

However, it is the perception among industrialists world-wide that the regulatory environment for biotechnology is less onerous in the United States, with its 'just-in-time approach' that is important in terms of influencing spatial relations in the biotechnology industry. Indeed, there are significant implications of this for understanding the political economy of the development of the biotechnology sector. For example, as a direct consequence of this perception concerning regulations, a number of non-American firms have set up R&D facilities in the United States in order to benefit not only from the rich science base (for instance, Bayer, Hoechst, Sandoz and Boehringer) (van Tulder and Junne, 1987; Financial Times, 19 December, 1991) but, equally, from the more relaxed regulations (Russell, 1990a). The important point here concerns the process of domestic political decision-making. Powerful global forces have meant that in countries where a biotechnology industrial lobby is appearing, states have been compelled to relax stringent regulations on biotechnology research and development because the loss in terms of new innovations and the potential wealth from them, are too high. Thus the consequences for long-term economic development of retaining high-technology investments are so important that governments are compelled to keep strategic industries and accommodate them. Such structural pressures were demonstrated by recent events involving Gensyme where lengthy regulatory procedures in Massachusetts threatened the state's position as the global biotechnology centre. The public agencies in Boston responded by allocating ombudsmen to take biotechnology firms swiftly through the regulatory procedures. The deal was made extra sweet by Massachusetts state authorities sanctioning tax breaks for Gensyme (Financial Times, 9 May 1994).

In this sense, national systems of innovation within the global industrial system have been confronted with a complex trade off between, on the one hand, powerful global economic forces and on the other, domestic political pressures and national social forces. To summarise this section, the importance of the new trade theories for this thesis and for understanding arguments related to knowledge and skills and European biotechnology competitiveness is that they offer an alternative paradigm raising alternative questions than conventional wisdom in relation to what governments can and cannot do in the global economy to support high technology innovations. The general line of argument from this perspective is that causality can take both directions: governments can take the initiative to influence the composition or output of trade (as in the case of the United States) or can feel forced to respond to external changes, which as I show has been the case of Europe.

The discussion now turns to understanding the factors that have shaped the pace of economic development in the biotechnology sector in the European countries. As I show, the pace of biotechnology development needs to be understood in relation to the political choices and decisions that have shaped the economic development of the industry. In many ways, the biotechnology market in Europe demonstrates how the market is socially constructed through institutions, norms and behaviour that exist in the different countries. For example, the lack of consensus and common ground within the European Union towards developing a common policy for promoting and regulating the biotechnology industry has had a major impact on the pace of economic development. In this respect, and in direct comparison with the United States, a very different story emerges which reveals that leaving biotechnology to the market place (especially when other nations are pursuing strategic policies) and the failure to develop the relevant institutions necessary for supporting high-technology development and investment, has had the result that the European biotechnology industry has failed to develop at the pace originally anticipated during the early 1980s. This is explored below.

3. THE EUROPEAN BIOTECHNOLOGY SECTOR

> 'The recent increase in biotechnology products is only a beginning. It is clear biotechnology will have a strategic significance in dealing with some of the major challenges facing the developed and developing world, such as food, health, environment and population growth through new vaccines,...drought resistant plants.., and making certain plants unattractive to traditional predators thus reducing the need for pesticides...'
>
> (Commission of the European Communities, 1991, p.1)

In the 1990s, the hope that biotechnology will be a key technology for the future development of the European Community is regularly cited by the European Commission. The aim of this section is to examine the overall development of a nascent European biotechnology sector and consider some of the constraints facing the economic development of the sector. European biotechnology can be seen not only in terms of issues surrounding its promotion, but equally, in terms of safety as well. In contrast to the United States, domestic pressures from within certain member states have created a series of problems for the regulation of the biotechnology industry which, at times, has conflicted with the demands of industrialists to promote the sector internationally and to follow in the American footsteps to create a less onerous regulatory regime.

Furthermore, there are a number of endemic problems facing the competitiveness of European biotechnology which are explained by the failure to develop the necessary institutions, a Europe-wide technology policy and long-term investment. This, I argue, is related to more fundamental problems concerning political integration within the

European Union and, the enduring nature of national value systems and institutions which have slowed down, in certain instances, the emergence of a Europe-wide biotechnology strategy. In this sense then, understanding the economic development of the European biotechnology industry reflects a number of common political and cultural problems inherent to the overall European project. It also reflects the tensions within nation-states themselves to respond to domestic pressures and, simultaneously, respond to the pressures of competing on a global market. These issues are examined below.

3.1 Building a Community wide Strategy

Interestingly, national governments in Europe have been far slower to react to the 'biotechnology revolution' than the European Commission (Cantley and Nettancourt, 1992). During the 1980s, the European Commission proposed biotechnology as a key technology for the future economic development of Europe. Under the auspices of the Forecasting Assessment for Science and Technology (FAST) programme, undertook a review of national assessments of the new biotechnologies (on this see Sargeant, 1982).

In addition, the European Commission has been greatly influenced by important lobbying organisations. For instance, there has been an important lobby on behalf of the industrialists (Walsh and Galimberti, 1993) which has argued that the sector has fallen behind the United States. And, the academic community, who for a long time, have been concerned that many of the scientific discoveries of third generation biotechnology orginated in Europe (and, especially Britain), but are now being exploited abroad.[2]

Despite support for it, developing a Europe-wide strategy has not been without problems. The main drive behind Community policy for promoting biotechnology has been how to create a transnational technology community and, at the same time, respect the principles of national sovereignty over education policy (Magnien and de Nettancourt, 1993). This is compounded by a panoply of interests within the European Union in relation to the biotechnology sector. In contrast to the United States, where the Biotechnology Industry Organization (BIO, Washington) is the identifiable single voice for bioindustrial interests, every European company has many representational routes to European bodies in the European Union. One of the reasons for this is directly related to the concerns that are raised through biotechnology development. Thus, there are national bioindustry associations, a European umbrella of national bioindustry associations, loose fora of biotechnology interests, federations of scientific societies, national sectoral associations and their European counterparts and direct memberships in European industry groups (Mahler, 1994).[3]

---

[2] For example, the Senior Advisory Group on Biotechnology represents large companies and their interests relating to policy, particularly as regards regulations. In the case of academia, the European Federation of Biotechnology is primarily an academic network which has vigorously lobbied for the support of the European Commission for biotechnology research funding and projects. The UK Interest Group Working Party on Biotechnology Education has also been influential in shaping thinking as regards the manpower supply into the industry and this is discussed in detail in the next chapter.

[3] Ten major European bioindustry lobbies are *National associations*: Organibio (Paris, France); Association of Biotechnological Industries in Denmark (FBID, Copenhagen); Belgian Bioindustries Association (BBA, Brussels); Netherlands Industrial and Agricultural Biotechnology Association (NIABA,

Promotion of biotechnology : Developing the supply-base and problems of cohesion

Where there have been initiatives at the European level, they have primarily been targeted towards improving the supply-base, for instance, creating transnational mechanisms for translating scientific discoveries from the academic research laboratory to commercial activity; improving the uncertainties around scaling-up laboratory work into large scale commercial production; accessing information; improving and creating transnational training systems and increasing the debate concerning the role of governments in creating an environment in which these things can happen (Walsh et al, 1991). Much of the lead came from the European Commission under the auspices of the Community Framework Program (Magnien et al. 1989). Biotechnology policy, therefore, cannot be divorced from overall EC technology policy. Under this title a number of sub-programmes have been established and these are set out in table 5.2.

Leidschendam); Asociacion de Bioindustrias (Barcelona, Spain); Assiobiotec (Milan, Italy), BioIndustry Association (BIA, London). *European level* The European Secretariat of National Biotechnology Associations (ESNBA, Brussels). *National (nonassociational) forums of biotechnology* : These do not have quite the same status of national associations, but are looser aggregations of national interests. Examples are in Sweden, BioResearch Ireland and Germany. *The European Federation of Biotechnology* representing the interests of scientists and bioengineers. This organisation played an important agenda setting function in representing biotechnology interests in the EU before industry organisations stepped in. *Sector associations* European sector associations with biotechnology interests include the Association of Microbial food Enzyme Producers in Western Europe (AMFEP); the European Council of Chemical Industry Federations (CEFIC); Confederation of the Food and Drink Industries (CIAA); Association of plant breeders (COMASSO); European Crop Protection Association (ECPA); European Federation of Pharmaceutical Industry Associations (EFPIA); European Federation of Animal Health (FEDESA); European Federation of Manufactures of Animal Feed Additives (FEFANA). An umbrella organisation of the sectoral associations listed above and SAGB (*ibid)* is the Forum for European Bioindustry Co-ordination (FEBC). *Specialised biotechnology platform* Yeast Industry Platform (YIP); Green Industry Bioindustry Platform (GIBIP).

The evolution of community sponsored biotechnological research and development was anything but a linear process. The attribution of EC funds to the programmes followed a discrete pattern with peaks in 1985 and 1990-91. Each budget allocation was attached to a specific multiannual programme. Give or take some margins of error through conversion into yearly expenses, the extreme between 1982 and 1991 is fairly apparent. The table is obviously an oversimplification of EC thinking behind the policy, nonetheless, it does provide a basic insight into areas that were given more weight than others at the time.

In brief, most of these programmes have attempted to set up a transnational flow of scientists between research centres, universities, and firms in particular, with the building of networks of scientific expertise which cut across national territories. The launch of BRIDGE was aimed at creating a 'network' of researchers and a 'technological community' through the t-project technology transfer mechanism (de Nettancourt, 1993). However, there are a number of problems facing the creation of a Europe-wide technology policy which are more directly linked to the overall political project concerning European integration. There is a vast literature discussing the European project and is beyond the remit of the specific task here (for example, for an interesting account of the development of the European project as a response to US supremacy after the Cold War see Servan Schreiber, 1979; and on the benefits of the Single Market see Cecchini; 1988; also see Pinder, 1991 and on the theoretical aspects of functionalism George, 1991). For instance, the political tensions within the European

Union member states in relation to devolving aspects of sovereignty, for example over education and training and the 'sharing of knowledge' along with general cultural diversity has an important bearing on why the European biotechnology industry has been slower to compete than in the United States.

Russell (1990b) argues that initial interest in these transnational programmes was slow. He identified two specific problems related to building a 'technology community' in Europe. First, developing a coherent technology community in a fragmented European Union as a consequence of divergent national interests and institutions, norms and values. Second, national priorities were and remain divergent, with particular countries adopting different policies and cultural attitudes towards the organisation of science and education and towards the regulation of biotechnology. Thus, as Russell notes, it is clear that 'nationally' orientated priorities in member states make transnational sharing of knowledge, as the Community programmes have tried to develop, quite problematic. Indeed, many of the individual governmental priorities for the development of biotechnology, as with any other major technological sector, have been concerned with developing a strong national base before embarking on a Euro-wide strategy. A recent example is the UK scheme for the promotion of biotechnology *Biotechnology Means Business* scheme (see *Waste Management*, 1995).

It is clear that the organisation of science and technology in Europe, in comparison to the United States, is highly fragmented consisting of sixteen national science and educational infrastructures and sixteen national priorities. This acts as a major disadvantage for the development of a common science and technological community for biotechnology (Walshe et al. 1993). Indeed, it is such institutional differences which contrast the organisation of science and technology in many European countries with the United States. In Germany a large proportion of the highest quality research is concentrated in the Max Planck Institutes while applied research is undertaken mainly in the government-funded GBF (Gesellschaft für Biotechnologie Forschung) laboratories. In France, most research is undertaken in the publicly-funded CNRS (Centre national de Récherche Scientifique), INSERM (Institut National de Santé et Récherche Medicale) and INRA (Institute National de Récherche Agronomique) institutes. In such environments the full-time institute-based scientist is often unable to engage in private research. Comparatively, Britain is closest to the American model where, for example, medical research is organized in universities as well as institutes with the former playing a substantial role in the life sciences (Sharp, 1985; 1989). Strange has also commented on the culture of the university in Europe compared to the United States, arguing that the European institution has traditionally been associated less with the business community and more with radical and polemical thinking (Strange, 1987). Overall, these institutional differences as regards learning institutions in the European tradition are an important factor explaining differences between science and technology linkages in Europe compared to the United States.

The organisation of science and technology within Europe may also be one reason for the poor rate of small start up dedicated biotech firms in Europe. Sharp comments that in failing to develop a dynamic small firm sector (as in the American economic model of development), Europe has failed in biotechnology to develop a mechanism for transferring scientific discoveries from the laboratory and into industry (Sharp, 1992) Clearly, the pattern of biotechnology development in Europe is closer to the Japanese than the American experience.[4] Although substantial differences between European

---

[4] Whilst I do not deal with the Japanese industry here it is worth mentioning that in comparison to the United States, Japan's strength in biotechnology lies in the fermentation industry and it is the largest corporations which are developing and exploiting these strengths, rather than small companies. When new biotechnology techniques were being developed in the United States and to a lesser extend Europe, Japan was slow to recognise their importance and further impeded their application by imposing severe safety rules on any experiments. The result was that by the end of the 1970s, Japan lagged some five to six years behind the United States. Since this period, it has been making a determined effort to catch up and through link-ups between Japanese and American companies, particularly with larger start-ups and a substantial training doctoral and post-doctoral students abroad mainly in the United States. For example, in January 1983, 196 Japanese including fifteen from leading industrial countries, were working at the National Institute of Health in Washington DC. This was double the number of any other country, India with 97, being the next highest, followed by Italy, (91), the United Kingdom (69) and France (52), (US Government Intragency Report, 1983, p.B76a). The primary executive agency for 'big science' in Japan is the Science and Technology Agency The STA established a specialist committee for biotechnology (Committee for the Promotion of Life Sciences) and in 1981 its budget for research amounted to $210m, although only $24m of this went to strictly defined biotechnology (Rogers, 1982). The STAs research programme concentrates on medical aspects of biotechnology (particularly genetic manipulation) and longer term projects on protein synthesis and fully automated bioreactors. The Ministry of Trade and Industry (MITI) represents the industrial interest in biotechnology and its emphasis is to a greater extent on the practical applications of new techniques. It is responsible for the Federation Research Institute at Tsukuba Science City. In 1981 it declared biotechnology to be an 'industry of the future' and inaugurated a $110 m ten year programme of research and developments with three main areas of interest : bioreactor development ($43m); rDNA (particularly its application to industrial processes - a further $43m budget) and large-scale cell culture ($24m). Some forty Japanese companies are joining MITI on this programme through the linked research association - companies such as Mitsubishi Chemicals, Mitsui, Kyowa, Hakko, Ajinomoto, Takeda, Sumitomo. MITI also has an interest in biomass energy with a budget of over $7m per annum. Abrahams (1994) argues that one of the main reasons for a relatively small biotechnology sector in Japan is due to low R&D spending, which is reflected in the number of scientists working on R&D (for example, Merck has 1,700 scientists in research alone excluding development, Takeda has 1,200 in R&D combined, Sankyo has approximately 1,300 , Dalichi employs 600 researchers and 130 scientists in development.) Japan's real strength lies in its company sector in the number of companies showing awareness of and involvement in biotechnological activities and in the resources devoted to R&D. A 1982 survey by MITI of 200 corporations showed 157 with an R&D programme in biotechnology already underway (JETRO, 1982). Total research expenditures of the firms involved amounted to $203 m with 27 per cent of this being concentrated in the food industries. In the drug industry, interest has focused on rDNA, cell fusion techniques and monoclonal antibodies while in the chemical sector enzyme technology and downstream processing gained concentrated effort. The food industry showed interest in downstream interest in fermentation technology and downstream processing although a large number of firms claimed activity in

countries exist, in general, it has been governments and large corporations who are providing the lead with the start-up firm playing a smaller role. This has had two implications for the development of a Europe wide strategy in biotechnology.

First, the concentration of biotechnology development in the hands a few major players in the chemicals and pharmaceuticals sectors have inhibited the development of a transnational technology community in Europe. Much of the biotechnological interest and R&D in Europe still sits with the large chemical and pharmaceutical giants, such as Novo, Bayer, ICI, Hoffmann-La Roche, Ciba, Feruzzi, BP, Shell, Nestle and Unilever (Sharp, 1991; Walsh and Galimberti, 1993). Whilst some have benefited greatly from European Community programme money, one of their principal interests is the safeguarding of commercial secrecy, thus the philosophy of 'sharing knowledge' does not sit comfortably with them. Furthermore, their markets and interests are already global and their collaborations are not necessarily bounded territorially in Western Europe - many have already relocated to the States to acquire new biotech knowledge (van Tulder and Junne, 1987).

Second, European firms were slow to respond to developments taking place in the life sciences, not making their serious investments in third generation biotechnology until

---

the rDNA field. Aware of their deficiencies in rDNA and cell fusion the Japanese drug industry has been actively seeking links with foreign competitors and in particular have sought links with major American drug companies and some of the new specialist biotechnology firms. But it is the application of genetic engineering to its traditional strengths in food and fine chemicals that is important to the Japanese (Yoshio, 1995).

the early 1980s, despite explorations in the 1970s, and when the establishment of DBFs were at their height (Sharp, 1991). Thomas and Sharp (1993) argue that by that time, dedicated (American) biotech companies, such as Amgen, were already established and many, moreover, had at least one successful product and were further strengthened by collaborative ventures with larger firms. Although only limited profits were to be made from first generation protein drugs (for example, interferons), by that time, it was clear biotechnology had radically altered the route to drug discovery. In addition, Walsh and Galimberti observe that had the large corporations relied entirely on in-house R&D and building up the new capability from scratch, the established firms would have had to make the commitment of investing in new facilities and recruiting staff from a very wide range of disciplines in what was quite a distinct area from their traditional knowledge base, and this with no clear idea at that stage which ones (if any) they would pursue further. Instead, they made alliances with external sources of the new technology (academic researchers and DBFs) which was not only a lower risk strategy than building up the necessary competencies, but also a faster one. These alliances have primarily been with non-European companies (see below).

Furthermore, corporate R&D spending in Europe has traditionally been much less than in the United States. For example, the top ten European biotechnology companies shown in table 5.3 spent a total of US $63.3 million in 1990. According to Thomas and Sharp, this represents just 13-14% of the total R&D commitment by the top ten US biopharmaceutical companies. Amongst the European firms, only Celltech (UK), British Biotechnology (UK) and Plant Genetic Systems (Belgium) approached spending levels of the American group. The European small firms taken together resemble Amgen (US) both in terms of R&D expenditure and manpower (Hodgson, 1992). Amgen employs approximately 1179 personnel while the European firms together employ approximately 1398. However, when revenues for 1990 are compared, Amgen was very much more successful. The company achieved revenues of US $381.2 million while the European firms only managed an average of US $9.2 million per company (Thomas and Sharp, 1993).

In summary, the lack of homogenous interests across the member states and firms has made the idea of a technological community very difficult to sustain in reality. Mahler (1994) has continued this theme, arguing that the lack of co-ordination between member states on biotechnology efforts and co-ordinated views on technical aspects is a major obstacle to European biotechnology development. On this, Greenwood and Ronit (1994) argue that a supra-national regional lobbying organisation is necessary across Europe to match the Biotechnology Industry Organisation in Washington, United States to represent a common consensus on bioindustrial interests. Perhaps one of the most important issues confronting a Europe-wide technology policy is regarding the regulation of the biotechnology industry. The following section discusses the problems of developing a European wide regulatory regime for biotechnology.

4.2 Regulating Biotechnology: National Systems And The Role Of Social Forces

> 'Who the hell do the scientists think they are that they can take federal tax dollars ... and do research work that we then cannot come in and question?'
>
> (Alfred Vellucci, Mayor of Cambridge, Massachusetts, 1976, quoted in Cantley, 1987, p.1)

In chapter two, it was argued that despite the popularity of the globalisation thesis, the national environment still has a major role in influencing the pace and types of developments taking place within a society. An examination of the role of social forces in the European biotechnology sector supports the complex view of globalisation developed earlier: on the one hand, the shrinking of the world economy and the homogenisation of certain dimensions of it, and on the other, the re-vitalisation of certain localising tendencies. The theories of Robert Cox on world systems is useful for understanding the role of social forces in the economic development of a sector as biotechnology (Cox,1982). Cox argues that there are various state forms which derive from different state/society complexes which remain a crucial level of analysis. In addition, he incorporates into his thinking world-systems theory and the traditional historical materialist concerns with social forces, especially Gramsican concerns with ideas and ideologies as sources of power (Cox, 1982). This analysis emphasises not only structural transformation and the implications that this has for world order, but, equally, it recognises the power of social forces and ideologies and the specific influence that these key forces have on influencing political and economic choices. This argument is empricially explored below in relation to powerful interest groups and their role in shaping economic and political outcomes relative to the European biotechnology industry. The aim of this discussion therefore, is to return back to the overall theoretical argument in chapter two concerning the necessity of a systemic approach to industrial policy which takes into account the territorial structure of production and its relationship with the global industrial system.

In any society, the advance of science and its technological applications are under some degree of social control. Where science and technology demand significant resources, or their applications threaten established interests, their further development will depend upon social consent. The former Director of the European Commission Concertation Unit for Biotechnology Eductation (CUBE) set up under the auspices of DG XII[5] Mark Cantley notes that this consent is readily given, if science and technology are seen as important to competitive capability or where there are obvious benefits to society. Where the relevance is less obvious and their impacts unforseeable (i.e. because long term or indirect), the consent (and resources) will be less readily obtained; and where they rouse significant apprehension or threaten established interests - economic, social, intellectual or other - the necessary consent and resources may be replaced with outright opposition (Cantley, 1987).

---

[5] CUBE grew out of the FAST programme. With no funds to give out to projects, it did have a budget of one million ECU's to cover the collection, analysis and distribution of information with a view to developing biotechnology opportunities. In particular, it acted as a secretariat for the Commission's Steering Committee set up in 1984 which has attempted to provide the Commission with a supranational lead to the promotion of European biotechnology, also serving to harmonise regulations on biotechnology safety. CUBE has, however, since been disbanded.

These general observations described by Cantley, apply with particular force to biotechnology because of its pervasive effects in many sectors, and builds on recent discoveries as subversive as those of Galileo or Darwin. On the one hand, there are positive popular perceptions of traditional fermented foods and of the more recent triumphs of sanitation and medicine over disease. On the other, there is concern about unfamiliar and little understood technologies such as genetic engineering, and still more so about the juxtaposition of such novelties with the familiar processes of birth and procreation, and the ethical, religious and cultural values associated with identify, privacy, human (and animal) rights, and the nature of man.

As it was discussed in chapter four, for many, elements of biotechnology bring issues of accountability, ethics, military and possible terrorist use. While biotechnology promises some cures for some illnesses at the same time it brings potential risks for new illnesses. It can be an environmentally sensitive technology bringing alternatives to pesticides and fertilisers reducing the amount of chemicals released into the environment, yet, it can also be an environmentally threatening technology with the release of genetically modified organisms threatening the delicate balance of the biosphere (Russell, 1990a). As a consequence, the biotechnology industry has attracted wide spread debate within Europe guided by a number of transnational pressure groups. The impact of these movements on the pace of economic development of this sector cannot be ignored and need to incorporated into an analysis of the development of biotechnology in Europe. The role of cultural values and public perception and biotechnology is discussed below.

Public Perception and the political process in regulating biotechnology

In terms of policy, the role of social forces in shaping the pace of biotechnology development has become recognised by European policy makers as a key strategic determinant of its development. The European Commission's communication to the Council of Ministers and the European Parliament in April 1991 entitled *Promoting the Competitive Environment for the Industrial Activities Based on Biotechnology within the European Community*, states:

> 'biotechnology suffers from a bad image amongst policy makers and the general public....Although some of the expressed fears seem exaggerated they are, nonetheless, of great political influence. It is imperative therefore that problems of public acceptability, and ethical questions raised be recognised and dealt with' (CEC, 1991, p3).

In this respect, European governments are faced with the challenge of both promoting biotechnology on the one hand, and on the other, balancing the pressures of the industrial lobby to decrease regulations with the demands of social groups and their concerns about the new biotechnologies. As a means of developing a Europe-wide agenda on this, the European Community has attempted to undertake a co-ordinating role in relation to creating a 'safety regime' in biotechnology (Russell, 1990b). The main issues of safety are first, the use of genetically modified organisms (GMOs) in enclosed manufacturing systems and the products from such systems and second, the planned release of genetically modified organisms in agricultural and environmental applications. The main problem, however, in creating regulations is that there is a lack of scientific knowledge about the problems involved in releasing GMOs into the environment under many possible conditions. Tait argues that traditionally, European regulations designed to protect the environment were often reactive measures (as the United States) (Tait, 1992). However, concerns about the new biotechnologies have now begun to attract wide-spread attention across the European media about science and scientists being 'out of control' (Hughesman, 1994).[6] These adverse opinions prompted a new approach by the European Commission to protect the environment: the so called 'precautionary principle' with both the European Commission and the British Government drawing up legislation aimed at avoiding future environmental problems.

The rationale for regulating biotechnology, it is argued, is to protect the Community against unwanted effects that might be associated with the release of genetically engineered organisms into the environment and the consumption of food, drugs and other drugs and other products based on the technology, of which there are major international disagreements. Regulations are also required on ethical grounds, to resolve disputes (or at least to arrive at a consensus acceptable to the majority) about the moral desirability of genetically exploiting certain life forms, and especially in cases where human beings are concerned, as in the prevention of genetic diseases.

---

6 There is a vast sociological literature on bioethics. However, I would suggest that far more influential, are the popular sources regularly cited through the press and media with book turned block-buster film Jurassic Park by Michael Crichton, on this see Dixon, 1991; 1989; Budd, 1993.

The Commission observed that the possibility of environmental release extended across many applications such as pesticides, herbicides, nitrogen fixation, plants and animals resistant to pests and diseases, adapted to extreme meteorological conditions or scarcity of resources, degradation of toxic chemicals and oil spills, it stated:

> 'Not only known or predicted traits of the organism (such as pathogeneticity) may raise questions but also the publicity of ecological cycles and interactions, and undesired transference of novel genetic traits to other species (i.e. pesticide resistance of a crop passed on to a weed). This makes it necessary to proceed with the releases in a careful manner' (CEC, 1988, p.2)

In this light, the Commission has adopted a case-by-case approach to environmental release. The nub of the Commission's approach is to require notification of all work to be made to a national competent authority following effective monitoring and control of the correctness of the classification and of the containment measures applied. For example, until the EU's Council of Ministers (CoM) first prohibited BST sales within the EU in April 1990 to allow the EC to gather more evidence relating to safety and efficacy of the product. The EC then persuaded the CoM to extend the BST moratorium to December 1993. However, the EC told the CoM that it was unable to complete its study and proposed a seven year ban on BST sales which the CoM rejected. However, the recent US decision to go ahead with BST sales has left European industry in an unfavourable position and under severe pressure to do the same. Furthermore, the EU's Internal Market Council (IMC) have drafted a proposal to regulate novel foods and novel food ingredients that contain genetically modified components. However, the new patent rules to protect biotechnological innovations do have the full backing of all the EU member states such as Denmark, Spain and Luxembourg who have all signalled their opposition.

Regulations concerning the patenting of human life forms are still in negotiation. The EC proposed an amendment in 1992 that would ban patents for biotechnological inventions considered contrary to public policy or morality and that concerns parts of the human body *per se*. However, there is no consensus over whether the human body should not be patentable with some states disagreeing over whether human DNA sequences are patentable (Ward, 1994a). Recently, the EC also unveiled its amendments to its proposal to regulate novel foods and novel food ingredients containing genetically modified components. This area has received a number of changes during the last decade, and the most recent amendment is that additional labelling requirements may be needed to ensure that consumers are aware that consumers are aware of the differences between conventional foods and so-called novel foods and novel food ingredients. However, the EC shied away from calls to introduce a requirement to have technology-specific labelling of foods containing genetically modified components. Although, some states such as Germany already have introduced such a criteria. The launch of the genetically modified tomato to European markets has met with demands from consumer interest groups to do the same (The Observer, 18 August, 1996). Indeed, it is the issue of deliberate release of gentically modified organisms (GMOs) that is attracting world wide attention and within the community members there are wide differences ranging from Germany which has banned the release of GMOs to Italy, which has no specific regulations at all.

Indeed, the real problem facing the development of a Europe wide regulatory environment for biotechnology, is related to the wide divergence between national attitudes across the member states, differences which have, to date, been strongly reflected in the development of regulations on biotechnology. This difference in national situations is shown in table 5.4. The UK Advisory Council on Science and Technology (ACOST) summarised the situation:

> 'Public perception and governmental response will be of paramount importance in setting a regulatory framework and determining the rate and direction of the diffusion of the technology. The power of public feeling must not be underestimated. Consumer resistance and fears for safety and pollution for example can seriously encumber commercial prospects' (ACOST, 1990, p.9).

In countries where the Green movement and the Church carry significant popularity, pro-biotechnology lobbies have frequently met with fierce opposition on ethical grounds. In Germany and Denmark in particular, public opinion had a profound impact on government policy towards biotechnology (Cantly, 1987). The regulations which emerged during the 1980s were regarded as particularly stringent. The power of certain social forces in Germany led to a successful campaign by the Green movement for a lengthy regulatory process before companies set up laboratories for scientific research in biotechnology (Financial Times, May 9 1994). In Denmark, field trials of genetically engineered plants were prohibited until 1991.

Furthermore, domestic social forces are combined with transnational pressure groups in relation to genetic engineering which have had a major impact on European decision-making on how to regulate the biotechnology sector. For instance, following a successful lobby by the industrial interest groups for less stringent regulations, Greenpeace announced that it was to adopt genetic engineering as one of its main campaign issues for the 1990s. Even if the industry's actions did not lead directly to the Greenpeace decision, they could have reinforced any existing feelings against biotechnology, making it easier for Greenpeace to rally support around the issue (Tait, 1992).

Another illustration of the power of interest groups in shaping the pace of the economic development of biotechnology is in the case of the flavr savr tomato in Europe. It is unlikely that consumer demand for this product will be as high as in the United States (The Observer, Aug.18, 1996).[7] Active campaigning against the Flavr Savr tomato has already begun, particularly by the anti-biotechnologist activist, Jeremy Rifkin whose transnational lobby has found support among different areas of environmental politics - organic food consumers, biodiversity activists - who are against recombinant DNA and the notion of genetically altering food produce.

---

[7] For example, Calgene recieved substantial investments from Campbell Soup to produce the flavr savr tomato and owns the patent on the PC gene. Jeremy Rifkind's lobby 'Pure Food Campaign' in December, 1992 sent a letter to Cambell threatening to boycott the company unless Cambell disassocated itself from genetically engineered products. In January, in a letter to the *Times*, James Moran, the director of public relations at Cambell said, 'Cambell does not market bioengineered products and has no plans to do so.. Before any such use was contemplated, we would have to be assured that such use has full governmental apporval and strong consumer acceptance.' The New Yorker remarks that the impression that many observers got from this sequence of letters was that Cambell was so worried for fear of the stigma of rDNA would damage its reputation for wholesomeness that it gave into Rifkin's demands.

Overall, public opinion in European countries where biotechnology is more developed appears more adverse to the technology. A public opinion poll on biotechnology was carried out in March 1991 through the European Commission Eurobarometer survey interviewing 12,800 people. The survey of European attitudes towards biotechnology revealed the 'risk perception' and 'awareness of application' were both greatest in Germany and Denmark while Greece, Portugal and Spain were among the lowest. Although a large majority think new technologies will help to improve their lives, only 49 per cent think biotechnology will do so while 11 per cent think it will makes things worse. This latter proportion ranges from 2 per cent in Portugal and 4 per cent in Spain to 19 per cent in the Netherlands and 24 percent in Denmark (Eurobarometer, 1991). Studies show that in countries where there was less information from non-governmental sources, public support for biotechnology was higher than in countries where there were powerful interest groups against biotechnology (Eurobarometer, 1991). Interestingly, the public show a general distrust for scientists with both scientists and industrialists featuring low in public opinion surveys on the believed reliability of information sources (Grindly and Bennett, 1992).

Overall, the development of a European biotechnology industry is balanced between on the one hand, the interests of the pro-biotechnology lobbies and on the other, transnational pressure groups and domestic social forces. Tait summarises the stalemate facing biotechnology promotion and regulation:

> 'So industry faces two possible outcomes, neither of which is particularly desirable. Lobbying may produce less restrictive regulations, but public opposition may still impose other costly delays, and could even erode markets for new products. Or, lobbying may fail to achieve any significant change in the regulatory system, but will even so alienated public opinion' (Tait, 1992, p.49).

Clearly, public opinion in Europe has had a negative affect on the development of the biotechnology industry. The European Commission has been keen to act on this adverse trend and has published a number of discussion documents and popular articles explaining biotechnology (for example, *The public and biotechnology* published by the European Foundation for the Improvement of Living and Working Conditions and *Biotechnology for All* by the Concertation Unit for Biotechnology Education (CUBE) in 1991). In this respect, the economic development of biotechnology, especially in the agriculture and healthcare sectors has become inseparable from domestic political forces. This also demonstrates the extent to which politics and economics have become inseparable entities both have a direct impact on market development.

The discussion here on the role of public opinion in the overall equation of biotechnology economic development also illustrates the dialectic of globalisation. In practice, it is clear that different regulatory environments and the different attitudes prevailing in public or government circles do feature strongly in influencing the location of investment and of product launches. This is a contributory factor for American dominance in the biotechnology industry. The movement of biotechnology capital, for instance, will be greatly influenced not only by the scientific and industrial base available in different countries, but also, on the congeniality, or otherwise of the local climate to development, which, in turn, will depend upon the degree to which its successful socio-economic integration is achieved (Grindly and Bennet, 1992).

To summarise, it is probably inevitable that European biotechnology will develop its potential eventually, simply as a consequence of the commercial advantage given to the industries based on it. In addition, clearly the global environment creates pressures on states to meet the requirements of industry. In this sense, in the long run, the development of biotechnology is likely to go ahead, as in the case of Germany, where the forces of globalisation have compelled the German state to relax many of its stringent regulations because of the consequences of losing more R&D activities in the longer term (Financial Times, 9 May, 1994).

4.6 Conclusions

Collectively, the Community is very aware of its weak competitive status compared with the United States. For European industrialists, the issue is clear. Having discussed the biotechnology as a 'revolutionary' technology, there is great concern that investors and policy makers in Europe might loose any sense of urgency in relation to 'catching up' with the United States, which Europe will need to do if it is able to gain the economic benefits of the biotechnology revolution when it does happen. The industrialists argue Europe's loss of competitive advantage in information technology relative to the US and Japan, must not be repeated with biotechnology. However, the interpenetration of international economic imperatives to relax regulations in Europe combined with domestic political imperatives has made the business of promoting biotechnology in Europe a highly complex policy area. Furthermore, the assortment of biotechnology provisions in Europe initiated from the national, intergovernmental and supranational levels that in the rapidly changing field there is no overall consensus on the Community role. National programmes are often to be protected from duplication and information sharing, and companies are cautious with respect to collaborative exercise, but acknowledge the need for them.

Where there have been policies for promoting biotechnology in Europe, they have primarily focused on developing the supply base. However, as I have argued theoretically hitherto, such policies will be inadequate in the knowledge-based economy. The discussion now moves on to examine key factors that must be necessarily included in any analysis of the biotechnology sector, and more widely, industrial policies aimed at promoting the supply-base. In terms of biotechnology development and the role of the state there are three key sources of structural power - knowledge, of which has already been discussed, control of investment and access to finance. In addition, there are a number of issues related to the organisational and institutional fabric underpinning the development of a European biotechnology sector which have a direct bearing on the structure of demand which is under-developed along with inadequate institutional development. This relates to my theoretical point in chapter three concerning human capital. Investments in skills and training will have an ineffective impact of the performance of firms if levels of demand are under developed for certain products.

4. INSTITUTIONAL ORGANISATION

4.1 The Biotechnology Myth?

Despite the initial euphoria surrounding the 'new' biotechnology, this review of the sector shows a less optimistic picture. Indeed, the emerging consensus among academic writers is that biotechnology is nowhere near as far advanced as microelectronics and information technology, which are regularly cited as the basis for a new techno-economic paradigm with revolutionary growth potential (cf. chapter four, table 4.3). Many of the academics seeking government funding and entrepreneurs seeking venture capital have exaggerated the speed of biotechnology development. In reality, the application of third generation biotechnology is still in its infancy as a laboratory technique let alone commercial stage and the impact of biotechnology has been largely concentrated in the healthcare sector. Furthermore, the overall industrial impact of biotechnology remains low. Thus while the potential impact of biotechnology on industrial manufacturing is estimated to be revolutionary, to date the technology still remains very much in rudimentary stages of growth with few biotechnical products available on markets. Many biotech firms have not yet or nor are they about to produce a saleable product or generate profits. For example, at present the health care sector, by far the largest beneficiary of biotechnology, has very few biotechnical products actually commercially available. Table 5.5 lists some products of 'new' and 'intermediate' biotechnology commercially available and table 4.5 (previous chapter) shows clinical diagnostic devices using biotechnology. One of the main problems facing dedicated biotech firms is the length of product development. Figure 5.2 shows the length of time for the commercialisation of some biotechnology products can take up to twenty years. To be explicit, nearly 20 years after some major breakthroughs in biotechnology, it is still difficult to forecast the eventual output or value of commercial applications.

The result of this time lag from the laboratory to the market place, combined with the uncertainty surrounding the completion of products passing all clinical trials, has had a major impact on investor confidence (Green and Burt, 1994; Green, 1994). For example, the fortunes of the biotechnology industry reached a high watermark in 1991-92. The main reason for this was the success of Amgen, a Californian company started in 1980 and a recipient of large amounts of investment. However, the recent failure of a number of hyped companies which witnessed their drugs fail in the last stages of clinical trials also lead to collapsed share prices and investor pessimism spread across the sector (King and Murphy, 1996; Kuper, 1996) By 1990, only six dedicated biotech firms were making any profit in the USA and many of the UK firms, the most advanced European country in biotechnology, have yet to produce a product or generate a profit (Walsh and Galimberti, 1993).

By the mid 1990s, the lack of products to yield cash income and the lengthening estimates of how long it would take to get new products to market, combined with production problems of scale-up, downstream processing and marketing continued to characterise the industry. This has been particularly pertinent to the European biotech industry. In its annual survey of the sector, Ernst and Young predicted that over 24 European leading small biotechnology companies will run out of available funding over the next two years unless they sourced new forms of finance (Ernst and Young, 1994). For this reason, a number of small companies have begun to opt for abandoning the production of their own products due to the costs involved with many moving from research into supplies for specialist equipment, chemicals and so forth and into diagnostics where developments in monoclonal antibodies have provided products and finance (Hone,1994). Another strategy open to them was to enter agreements with established firms in order to gain access to their funds and their complementary assets, sharing biotechnology expertise in return.

An important question then, is why has biotechnology not delivered at the pace that was originally envisaged during the early 1980s? Part of the answer lies in the problems discussed earlier in relation to developing a Europe-wide agenda for biotechnology. However, part of the problem is institutional, such as the overall level of demand for biotechnical products and problems associated with the financial structures for funding high risk technological activities. These are discussed below.

4.2 Demand side factors

The first issue relates to overall levels of demand for biotechnology-related products. The OECD (1989) has argued that it remains an open question whether or not biotechnology will form the basis of a new techno-economic paradigm like those based on electric power or synthetic materials, with major economic impact on most branches of the economy. The outcome - the degree of biotechnology's future success or failure, and its eventual economic impact - will depend decisively on demand for its products, even though demand was not a major stimulus to the birth and emergence of biotechnology as a new field.

As I showed in chapters two and three, in the neo-classical version of market behaviour, demand plays no explicit role. However, in biotechnology the structure of demand conditions is directly affected by national macroeconomic policy which in turn affects the composition of trade. In this sense then, demand is not merely a feature of the external environment in which firms and governments operate and in that sense 'separate'. Walsh et al (1991) have argued that both firms and governments play an active role in contributing and shaping that demand. For example, technical expertise does not necessitate market success. An example of this is ICI, who spends 5% of its R&D budget on biotechnology, has been working in the field since 1960s, yet its hope of achieving 5-10% of its sales from biotechnology-based products and processes by the 21 st century is seen as optimistic. It has recently shut down its plant for manufacturing Single Cell Protein (SCP), one of the first commercial applications of biotechnology since antibiotics. ICI describes SCP as a technical success but market failure. After US$ 200 m investment, manufacturing stopped in 1983. The price of raw material methanol had gone up and the price of soya, the raw material for competing products had gone down so that SCP was no longer commercially worthwhile (Ratledge, 1992).

Overall, there is very little in the academic literature about the active creation of demand for radical new innovations. Ratledge (1992) has observed that the success of *Quorn* (a SCP product as a result of a joint venture between ICI , Rank Hovis and McDougall and Sainsburys) led to a sophisticated marketed product aimed directly for the consumer market. The organism used, a strain of the mould *fusarium graminearum* is grown on sugar, by hydrolysing starch which is cheaper than sugar and when harvested is capable of being 'texturised' so that it can be blended by food technologists into a variety of meatless products. Such products are attractive to vegetarians and also consumers who are prepared, and able, to pay the required price for such a product. The main point of this is that this process is only sustainable in a society that can afford to pay for an alternative food source such as the affluent industrialised societies of the northern hemisphere. Drawing on the flexible specialisation thesis, it is clear that changing consumer demand in an affluent society has created market opportunities for some biotechnological processes. Thus opportunities in the bulk industries are more fortuitous than those that depend on structural changes in the world system. In this sense, many potential innovations await changes in the market, such as the oil price rise, political developments in the Middle East, drought, climatic changes, environmental crises in the balance of political forces world-wide can all have some influence on the shaping of demand.

Another factor influencing levels of demand for biotechnological products is culture. In August, 1995, the biotechnology company Imtran announced that genetically engineered pig hearts have been transplanted into monkeys with encouraging results of short term survival. This was deemed to be a considerable scientific advance for improving the success rates of human heart transplants. The object of the Cambridge Group as represented by Imtran has been to breed a herd of pigs so genetically engineered that the immunological reaction of a primate to pig antigens is much diminished. This raises a number of ethical questions concerning the use of animal organs in humans.

In the earlier chapters, I argued that demand and institutions play a central role in market development and illustrated this through the national systems of innovation debates which have broadened the concept of technology to include institutions to explore the role of national institutions, norms and procedures and the entire system of national political arrangements (legal, social, defence, labour market relations) and so on as a source of explanation. Johnson (1992) comments that the wide range of institutional factors which impact on innovation include: communication and interaction within firms (through forward, backward and horizontal linkages); user-producer relations; the institutional infrastructure (including education and training and incentive systems); co-operation and consensus; demand-side factors (dealing with the appropriation of the benefits of innovation) and formal institutions concerned with searching and exploring, such as universities and R&D departments. In this sense then, and as I have argued previously, there is a strong argument in favour of government intervention not only in relation to the supply-side factors, (for example investing in human capital for improving the competitiveness of firms), as the extreme globalisers contend, but also for an industrial policy based on the production system as a whole where policies are predicated on the recognition that growth is not constrained by factors such as the supply of labour, but by the overall structure of demand.

4.3 Financing biotechnology

The second dimension inhibiting the development of a dynamic European biotechnology industry is linked to the funding arrangements for high risk innovations. The whole question in Europe how to finance young, high tech innovations is a recurrent theme underpinning the transformation of Western European societies into ones that are highly competitive in the global economy (Hutton, 1995). Overall, Europe has failed to deliver the necessary funding institutions required to take scientific advances from the laboratory and to the commercial market place (Caulkin, 1996). This has been particularly the case for the nascent biotechnology industry with the intention of many dedicated biotechnology firms to become fully integrated pharmaceutical companies and therefore become self-sustaining corporations occurring in very few instances. The real problem facing the attraction of finance to new biotech firms are first, the lack of commercial success of biotechical products (Green and Burt, 1994; Clarke, 1995); second the scepticism of the investment sector to support an industry that is surrounded by adverse public opinion (resulting in low levels of demand) and a longer time than anticipated for development work; and third, the financial structure in Europe for investing in new innovations. These issues are discussed in more detail below.

One of the real problems underlying access to finance, it is argued, is related to the inherent problems of long term investment in high technology industry in Europe, and the nature of the financial structures for high tech investment. In 1993, UK venture capitalists invested only 12 per cent of their funds in technology related firms compared with 33 per cent in 1984 (Caulkin, 1996). As regards start-ups, according to the European Venture Capital Association, new equity or start up capital, amounted for less than 5 per cent of lending in 1994. Caulkin argues that in Britain, venture capital is a misnomer, with very few venture capitalists prepared to invest in high technology firms, preferring 'development capital/management buy out industry'. Even in Britain, where a venture capital market is said to exist, it is argued that venture capitalists are 'risk-adverse' (Caulkin, 1996) and prefer to re-invest into mature industries. As regards the British economy, Hutton argues that the persistent lack of financial investment into high technology is a major structural impediment to long term economic growth and is related to the overall functioning of British institutions (Hutton, 1995). In 1993, UK venture capitalists invested only 12 per cent of their funds in technology related firms compared to 33 per cent in 1984. While just 7 per cent of European funding went to computer related companies, the figure was 24 per cent in the US (Caulkin, 1996).

Why are European venture capitalists less prepared to take risks like their American counterparts? Caulkin argues that this is linked to three reasons. First, the poor record in the last cycle; institutional investors, who historically provide most of their funds now prefer to place their money on more secure investments. Second, is the lack of 'junior' markets on which high-tech stocks can be floated, allowing venture capitalists to make their exit. Interestingly, during 1995, capital markets for biotechnology looked more assuring with the biotechnology industry beginning to show far more investor optimism, with the industry having its best year during 1995 since 1992 when share prices almost doubled over the summer months (Green, 1995). For example, biotech companies raised $2.25 billion through public and private routes, venture capital and pharmaceutical companies which represents according to merchant bank Burrill and Craves, more than was raised in the previous four quarters combined. However, the more recent experience of the British Biotech second share flotation has curbed any great future optimism for the industry when the largest single fund-raising exercise by the British biotech company ended in disappointment when only half the shares in British Biotech have taken up their rights to new shares. The decision of so many investors to shun the £143m rights issues means that half the stock being issued will be left in the ownership of sub-underwriters (King and Murphy, 1996).This is despite the company (and sector leader) main products marmiastate, a drug which might be able to treat most cancers entering phase III clinical trials and potentially reaching the market in 1999. The rights issue disappointment is the latest in a series of recent setbacks for the biotechnology sector. Flotations by biotech and drug companies such as Cambrio, Alizyme and Therapeutical Antibodies have raised less money than initially intended, with Cambrio postponing its debut by one month (Kuper, 1996). A third factor, is the unwillingness in Europe to underwrite some of the risks of high tech investment for the sake of wider returns to the economy as a whole. In contrast, the US adopts an interventionist position, with a range of measures supporting investment in risk advanced technologies and firms. Although, France, the Netherlands and Germany encourage early-stage investment, the UK does not. In addition, unlike the Federal States of America, there is no Europe-wide scheme.

The result of these handicaps - poor track record, lack of clear exit route and absence of institutional underpinning - is that lenders often compensate for risk by demanding high returns, compounding the chances that the new firm will take off in the money markets. In addition, on top of surrendering a much higher proportion of equity for the privilege of venture capital than for corporate backing, venture capital supported start-ups are much more likely than others to not be successful - partly because of the high returns demanded, partly because lenders spread their expertise too thinly, and partly because the best entrepreneurs are smart enough to seek their investment elsewhere.

4.4 Where to next? The shape of things to come

In this climate of inadequate financial provision in Europe, biotech companies have been seeking funding from larger companies through the creation of strategic alliances. It has been estimated that mergers and acquisitions are likely to be the dominant trend in the biotechnology industry during the next decade (Green, 1994; Ward, 1994c; Ernst and Young, 1995; Drake and Brown, 1995; Barley et al, 1992). The favourable position of US firms has enabled them to capture the best strategic alliances. For the large firm there is much to be gained from this arrangement in terms of access new information and 'know-how' without undertaking R&D in-house and thus 'buy-in' the expertise. However, there is a deeper question concerned with the overall development of the sector as a consequence of mergers and acquisitions. These issues are discussed below.

Large Firms : Access to information and know how

As I have argued, access to information and know how is a major locus of power in the global political economy. In the case of biotechnology it is fundamental, forming the direct link to the interderminate, yet, vibrant connection between the science and the technology of molecular biology. Mastering this link can pose severe constraints for corporate activity due to the rapidity of technological change. It is argued that small firms are far more dynamic and innovative than large companies as a consequence of their organisational flexibility (Storey, et al 1989). This has been particularly the case in biotechnology innovations in the United States (Sharp, 1991). Thus as Barley et al (1992) have argued one rationale for licensing or forming strategic alliances is that relevant technical knowledge is more efficiently obtained by direct access to research conducted elsewhere (Tietelman, 1989). Van Tulder and Junne (1987) have argued a similar reason for European multi-national firms opting to form strategic alliances with American, rather than European small firms. Sapienza (1989) argues that in a technology driven industry the emergence of a new technology can trigger changes in the associated market structure and in the nature of competitive forces. Biotechnology has precipitated such a paradigm shift in the ethical pharmaceutical industry, and one consequence is a proliferation of R&D collaborations. He argues that this is taking place at the same time that global competition is intensifying and that biotechnology has become a tool in the geopolitical strategies of the major industrial nations. Even those firms which have had market success (i.e. Genentech, Amgen; Celltech; Cetus) succeeded in marketing products only after entering various kinds of agreements with large established firms.

Small Firms: access to finance

If established corporations are motivated to form alliances for a window of opportunity and access to new knowledge, small firms have been motivated to form alliances for financial reasons. This type of arrangement has taken a variety of forms including the licensing of technology. The high barriers to entry to markets such as costs of clinical trials has meant that many small firms often require assistance from the larger firms to overcome barriers to entry or to sub-contract products out for clinical trial. This has led to many small firms forming strategic alliances with large pharmaceutical companies. As they do not have the resources to mount clinical trials and market their products on a world wide basis, this arrangement offers one alternative. Examples of strategic alliances in the healthcare sector include, Merck, Sharp and Dome's agreement with Genetech and Chiron; Hoffman La Roche's licensing agreement with Cetus and the Genetics Institute, Smith Kline Beecham's alliance with Nova Pharmaceutical Corporation; Proetus and American Home Products; Celltech and Bayer (for an extensive list of global-wide strategic alliances in the biotechnology sector see Ernst and Young, 1995 p.46-50). Similarly, small biotechnology firms have sought marketing agreements with larger companies with international distribution and sales networks to gain access to established practices and global markets (such alliance formation has been discussed elsewhere in other sectors as an emerging trend see Ohmae, 1990; Reich, 1991; Dunning, 1991; Bhartlett and Ghosal, 1990; Livingstone, 1991). Other alliances have focused on manufacturing agreements which are attractive to small firms without production facilities. Thus in commercial terms, it has been common place for small firms in biotech to broker scientific and technical expertise in exchange for access to larger firms' financial resources, marketing expertise and manufacturing capabilities (Barley et al 1992).

Market Power

There is considerable debate concerning who gains from these partnerships (see Drake and Brown, 1994; Biotechnology Business News, 1991; Thomas, 1993). One argument is that large multinational corporations were late to enter the biotechnology field. When they did, this largely precluded the autonomous development of the independent biotechnology firms (Walsh and Galimberti, 1993). Furthermore, these firms used their market power to negotiate alliances with the small independent firms in order to appropriate technological knowledge generated by both small firms and the public sector (Walsh et al 1991). To date, several small firms have been bought up by larger firms such as Genentech by Hoffman La Roche; Glaxo has taken over Biogen's European lab; Bayer bought Molecular Therapeutics together with Molecular Diagnostics, while Rhone-Poulenc has bought Connaught Biosciences. There is a concern that, as a result of this process, the innovations of biotechnology may be lost along with the 'newness' and 'uniqueness' of the biotechnology community. While there are a variety of forms of alliances between small firms and larger ones, Barley et al (1991) show that in the United States, regardless of specificity, strategic alliances in biotechnology generally involve the exchange of knowledge for money. The implication of this relationship is that often the exchange requires some degrees of autonomy such as determining its own research and development, to gain access to markets with high barriers to entry. For many small biotech firms, the compromise may forestall bankruptcy, merger or acquisition. It is also noted that collaborative agreements represent a shift in institutional boundaries in which R&D is located creating a collaboration between a large firm and small vulnerable one forming a new form of hierarchy (Amin and Dietrich,1991). As Walsh and Galimberti note, even the most successful of the dedicated biotech firms - Genentech, Amgen, Cetus and Celltech - only succeeded in marketing final products as a result of various kinds of agreements with large established firms.

This tendency has led to the concentration of market structures and the globalisation of technology and industry through high technology networks of alliances (Ohmae, 1990, Dunning, 1991 and Bartlett and Ghosal, 1989) which transcend national boundaries. Walsh et al (1991) have analysed how these structural changes across national borders contribute to the phenomenon of globalisation. The implication of this for global political economy is that biotechnical research and knowledge is concentrated into the hands of a few large players. European multinationals recognise the advantages to be gained and continue their trend towards preferring American rather than European vertical integration, inter-firm co-operation and collaboration. This is shown in table 5.6. This raises many important spatial questions concerning the nexus of technical knowledge and expertise and wealth creation opportunities for Europe.

4.3 Conclusions

To summarise this section, the result of an under developed structure of demand, uncertainty around biotechical products at all stages of clinical trials and the costs involved, has led to a lack of confidence on the part of the investors in the overall speed of return on their investments. This raises a number of important questions in relation to developing industrial policies to support the sector. The trend towards strategic alliances, mergers and acquisitions may in the long term preclude the autonomous development of the independent biotechnology firms. Indeed, the future of dedicated biotech firms in Europe remain uncertain, as the case of the recent British Biotech share issue shows.

5. CONCLUSIONS

The aim of this chapter has been to chart the development of a global biotechnology sector. US leadership in the sector, it was suggested, is closely linked to the industrial strategies pursued there in the early stages of biotechnology. This gave the United States control over the most important resources in relation to high technology industries: control over the means of production, along with access and storage of knowledge and, importantly, the power to exert influence on the emerging 'rules of the game' in the global biotechnology industry in relation to global biotechnology research.

This chapter also reinforced the earlier argument of this thesis that there can be no doubt that national borders are being eroded through the internationalisation of both business and technology a situation which has been reinforced through the emergence of supra-national research programmes in Europe. Still, as I have argued hitherto, despite this trend, the case of biotechnology demonstrates that it is useful to consider the national system of innovation (and even the emergence of a future supra-national system of innovation in Europe) although both institutions and national borders have taken on a certain degree of discretionary character. Moreover, when looking at the state, there are three main sources of structural power relating to high-technology development: knowledge (control and access), control of investment and access to finance. The latter two can be to some extent controlled or developed, as I have argued here in relation to investment in European biotechnology, but, the creation of a global economy have eroded much of this control. However, as it has been argued hitherto, the knowledge resources within a country can to a considerable extent be controlled through national efforts in education and training.

However, the main point to emerge from this chapter relates to the overall understanding of industrial policy and high technology development for a sector such as biotechnology in Europe. As I have shown through this examination of the sector in Europe, whilst the creation of knowledge resources is one dimension of supporting the biotechnology sector, the specific dynamics of the industry are such that the role of social forces, demand and institutional organisation have an important bearing on the pace of economic development. According to Walsh and Galimberti (1993), to commercialise biotechnology in Europe, firms needed a network of doctors, farmers, ecologists, agricultural experts, nutritionists and others prepared to carry out tests on the efficacy and/or safety of drugs, food additives, new crops, agrochemicals, waste treatment systems, diagnostic kits and enzymes and later to recommend them to final end users. They needed well established relationships with regulatory authorities and licensing bodies, in order to negotiate the test required for new products to be approved, to steer the product through the regulatory process and in some cases to agree the prices to be charged and the conditions under which the product would be used.

In this sense, the future economic impact of biotechnology depends not only on the expansion of demand, but also on the existence of the appropriate institutions within which demand can be articulated and met. Consumers buy products, but, their expectations are shaped and their choice limited - in some cases decisively determined - by intermediaries who exercise their professional judgements, and by the effects of a series of government regulations.

The main conclusion to emerge from this discussion then is that governments can no longer be successful in promoting technological competitiveness by allocation of more and more resources to R&D and to education and training. Particularly, within a global environment whereby other competitors are pursuing innovation policies which are highly strategic and selective. I have also shown that in the case of developing a competitive European biotechnology industry, the role of demand has a major, if not central role, in its overall success. This raises a number of questions in relation to the overall policy in Europe as regards the development of the supply base and the need for more highly skilled labour to enter into the new biotechnologies. Thus, the next chapter turns to focus on one aspect of supply side policy: developing the skills and training of the labour supply. This is explored through a case study of a European Commission funded initiative in the area of education and training in biotechnology where, as I show, skills shortages have been *perceived* to be a critical factor preventing the development of a European biotechnology sector. This, along with the previous chapter examined in detail the overall characteristics of the biotechnology sector and the state of the industry at present. This discussion has been necessary because as I go on to show in chapter eight and in support of my thesis, my research findings suggest that firms in the sector are not facing critical labour market problems. From this perspective, this has major implications for the way in which we understand policies relating to economic growth more widely and industrial strategy. In this sense, the discussion now returns to the core argument of this thesis - that skills and training issues are only one dimension of the complex equation contributing to the economic development of a knowledge-based industry such as biotechnology.

Table 5.1 Breakdown of national expenditures on academic and related research in the Life Sciences 1987 *

	Expenditure						
	UK	FDR	France	Nether	US	Japan	Average
Life Sciences	864	1,483	1,116	313	7,285	1,261	
	30.9 %	36.7 %	34.7 %	32.7%	48.9%	33.7 %	36.3 %

Notes a Expenditure data are based on OECD 'purchasing power parities' for 1987, circulated in early 1989.

b This represents an unweighted average for the six countries (ie national figures have not been weighted to take into account the different sizes of countries).

Table 5.2 European Company Commitments to R&D in 1990

Company	FY spending ($M)	Change from last FY (%)	Versus Revenue (%)
Agricultural Genetics	6.6	0.0	236.0
BioEurope	1.6	15.0	60.0
British Bio-Technology	11.2	51.5	294.0
Celltech	15.8	56.0	49.0
Innogenetics	6.2	13.2	73.1
Mogen	1.5	21.0	107.0
Oxford Glyco Systems	2.5	25.0	NA
Plant Genetic Systems	8.1	12.0	182.0
Porton International	5.4	-11.0	22.0
Xenova	4.5	59.0	194.0
Total	63.3	NA	NA
Average	6.76	26.2	73.4

Source : adapted from Hodgson, 1992.

Table 5.3 Ten years of biotechnological research and development in the European Community

Year	Metamorphoses	Funds allocated (Mecus)
1982	technology-driven	BEP (7)
1983	global strategy	
1984	industrial R &D Advisory Committee	BEP (8)
1985	transnational criterion	BAP(55)
1986	European laboratory Without Walls	
1987	industrial consultation	
1988	model harmonisation contract	BAP (20)
1989	knowledge driven	
1990	industrial participation	BRIDGE (100)
1991	targeted projects	BIOTECH(164)

Source: Magnien and Nettancourt, November (1991) 1.0 Mecu = US$ 1.22 million

Table 5.4 Summary of national situations

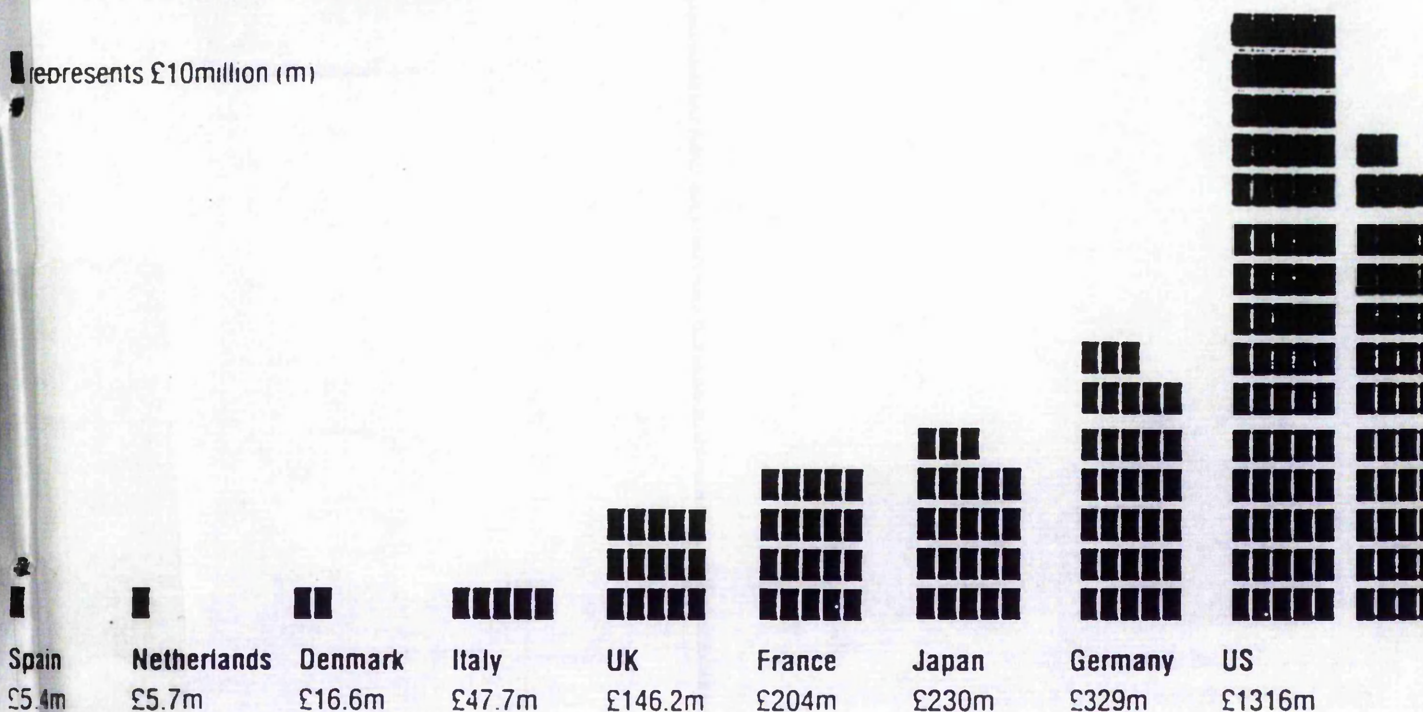
	OPPOSITIONS	PUBLIC RELATIONS	LEGISLATION	EDUCATION
BE	One public interest group : no great impact (Vita Vitalis, related to similar Dutch group); farmers organisation: neutral 'wait and see'.	no concerted actions	Re Biosafety rec DNA : only for deliberate releases of GMOs ? Approval : 11 field tests of transgenic plants; large field trial of rec vaccinia - rabies vaccine	
DK	Left political parties, environmental and consumer organisations; issues : transgenic animals only for improving health, BST rejected	Government (TA, public information), Novo-Nordisk : community information	Gene Law (1986), amended (1989); first transgenic plant trial (1990); workforce (trade unions)	Genetic engineering; education service for secondary schools
FR	Not strong : Amis de la Terre (Green Party)	Programmes : ORGANI-BIO, ADEBIO, CHEMIE ECOLOGIE, French government (new association DESCARTES :biotechnology and ethics)	Re Biosafety rec DNA : only for production, not for R&D; but R&D committees have been informed	COMETT courses; biotechnology in schools as part of national obligatory curriculum, chapters on biotechnology in text books on biology
D(W) .	Green Party fundamentalists, majority of trade unions (except Chemistry Trade Union)	Government, Industry	Delayed Gene Law, moratorium proposal for deliberate release of GMOs; no licence for rec human insulin factor (HOECHST); first field trial with transgenic plants in 1990.	Biosafety Course System (DECHEMA); TV programmes; teachers' programmes, booklet with transparencies

NL	Small public interest groups; Young Agrains, environmentalists, religious groups; issues : BST, patents on organisms, companies in agro-biotechnology projects in developing countries, deliberate release	Gov: NIABA/NBV/Advis Cte Biotech: PR strategy plan 1989; Gist Brocades; RABO Bank : biotechnology Forum plan; (NOTA): deliberate release, transgenic animals	rec DNA work in General Environmental Safety law (licences for projects, facilities)	School video course (NIABA/Gist-Brocades/Biology teachers' Assoc.); rec DNA GMT video course
CH	Basler Appell gegen Gentechnologie :biosafety re closed systems and environment	SGCI (standpoints) pharma industry	Re closed/open systems: in preparation	
UK	Not strong but increasing: Green Alliance, Patent Concern; issues : biodiversity, bioethics, biotechnology in third world countries	Dept Trade and Industry; BioIndustry Assoc; CIBA Media Resource Service, layman's publication	Implementation of EC directives on contained use and deliberate use of GMOs in Environmental Protection Bill/Act	Biotechnology in schools as part of national curriculum; National Centre for Biotechnology Education (NCBE).

source : European Federation of Biotechnology , 1990

Figure 5.1 Public Funding of biotechnology

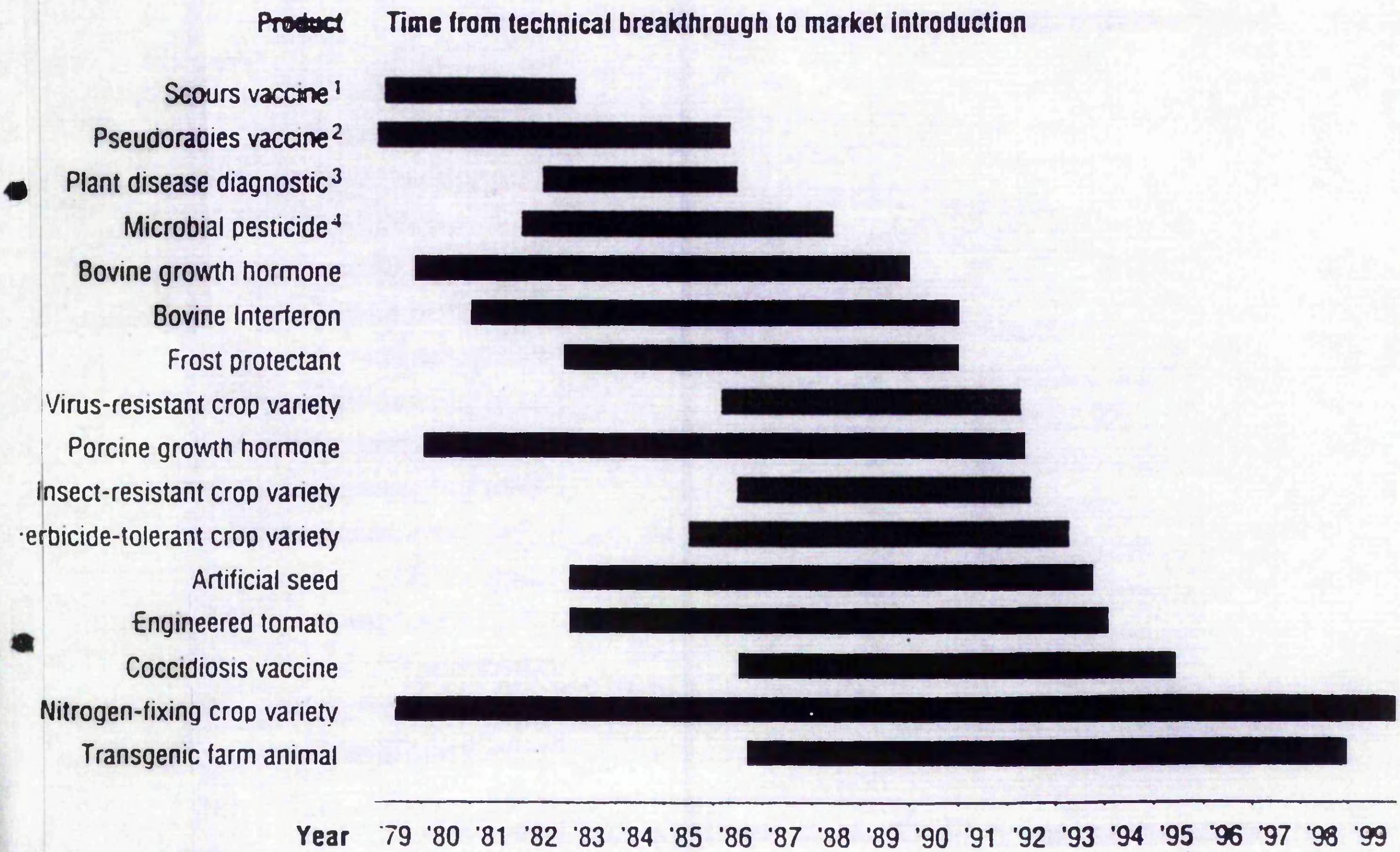
Figure 1 Public funding of biotechnology



NB Figures are for different base years between 1986 and 1989 but mostly 1988–9

Source *Developments in biotechnology* 1990. ACOST

Figure 5.2 Time to commercialisation



1 MAb-based passive vaccine
2 Recombinant vaccine
3 MAb-based: for turfgrass diseases
4 Biofungicide for cotton

Note The timescale suggested has slipped as a result of legislative and environmental problems

Source *Decision resources* an Arthur D Little Affiliate. 1989

Table 5.5 Some products of 'new' and 'intermediate' biotechnology commercially available

	Products	Manufacturer	Information
Diagnostics	AIDS diagnostic kit	Wellcome	Used in diagnosis of AIDS in clinics & bloodbanks
	DNA genetic finger printing	Cellmark (ICI)	Forensic uses: Confirmation of genetic links in immigration & criminal cases
	Helico G (Helicobacter pylori kit)	Porton Cambridge	Diagnosis of ulcers
Pharmaceutical	Human insulin produced by genetically modified bacteria	Genentech/Eli Lilly	Diabetes treatment. Overcomes problems of supply, and infections associated with porcine & bovine sources
	Erythropoietin (EPO)	Amgen	Treatment for anemia in kidney dialysis patients
	Hepatitis B vaccine	SKB, Merck	Until recently vaccination against Hepatitis B was not available
	Human Growth Hormone	Genentech	Used in the treatment of dwarfism
	Tissue Plasminogen Activator (TPA)	Genentech	Used for the dissolution of blood clots
Agriculture	Bovine somatotropin (BST)	Monsanto Hoechst	Increases milk production in cattle
	NEMASYS	AGC	Formulation of insect parasitic nematodes Controls black vine weevil in protected ornamentals
	Straw stubble digester	Cytozyme	Enzyme based substance which encourages the rapid breakdown of cellulose in soil
Food & drink	Chymosin produced by genetically modified yeast	Gist Brocades	Rennin substitute used in cheese making. Eliminates problems of supply and infections from animal sources
	Quorn	Marlow Foods (ICI)	A meat alternative. This product is produced by traditional fermentation
	Salmonella rapid detection kit	Oxoid	The use of this detection system greatly reduces the risk of distribution of contaminated food stuffs
Biosensors	Glucose sensor	Medisense	A pencil like instrument which measures blood sugar levels. Specifically for home use
Chemicals	Phenylalanine from *E coli*	Biotechnica International	One of the precursors of the sweetener aspartame
	Polyhydroxybutyrate (PHB) and Polyhydroxyvalerate	ICI	Copolymers for production of 'BIOPOL', a biodegradable plastic
Environment	Cyclear	ICI	A fungal cell preparation for cyanide detoxification
	Xylanase	Novo Nordisk	Facilitates separation of lignin & cellulose fibres in paper & pulp industry, thus avoiding the use of chlorine
	'Lipolase' (detergent enzyme)	Novo Nordisk	Fat-splitting enzyme

Source: NEDO (1991). New Life for Industry. NEDO, London.

Table 5.6 Acquisitions of North American Companies by European Firms

Year	Purchaser	Acquired Firm	Area
1986	BP Nutrition (UK)	Edwards J. Frank and Sons.	Plant Genetics
1987	Glaxo (UK)	Biogen	Therapeutics
1987	Feruzzi (IT)	CPC Int	Plant Genetics
1987	Montedison (IT)	Plant Cell Rest Ins	Plant Genetics
1987	Pharmacia (Swe)	Electro-Nucleonics	Therapeutics
1987	SDS Biotech (Swe)	Techamercia	Therapeutics
1988	Novo Industri (DK)	Zymogenetics	Therapeutics
1988	Biodor (CH)	Calbiochem	Speciality Chemicals
1988	Ciba Geigy (CH)	Cooper	Therapeutics
1988	Hoffman La Roche (CH)	*Biogen	Therapeutics
1989	Bissendorf (D)	Biosciences	Diagnostics
1990	Porton Int (UK)	Hazlton Labs	Reagents
1990	Inst Merrieux (FR)	Connaught Biosciences	Therapeutics
1990	Hoescht (D)	Gene Trak Systems	Diagnostics
1990	Culltor (Fin/ Eastman Kodak (US)	Genencor	Therapeutics
1990	Hoffman La Roche (CH)	Genentech	Therapeutics
1990	Schering AG (D)	Codon	Therapeutics
1990	Schering AG (D)	Triton	Therapeutics

source: Walsh and Galimberti, 1993

CHAPTER SIX

UNDERSTANDING BIOTECHNOLOGY LABOUR MARKETS: A CRITICAL ASSESSMENT OF RECENT STUDIES

> 'Although the European labour market is currently more of a concept than a reality, it is true that some specialised European-wide labour markets are developing. However, movement within professional groups remains limited, despite the progress being made to encourage mobility by ensuring the mutual recognition of diplomas and professional qualifications'.
>
> (Vaso Papandreou, Commissioner, Commission of the European Communities, 1990, p.2).

1. INTRODUCTION

In chapter three, it was argued that understanding the labour market for highly skilled workers in sectors such as biotechnology is more complex than the conventional labour market economics perspectives suggest. The labour market forms but one part of the broader production system and in this sense, labour market outcomes are shaped by a wider range of factors inherent within the overall macro economy, the industrial structure of the sector and institutions.

This chapter now moves on to discuss the specific perceptions that have been formed in relation to the role of scientific labour and the economic development of the biotechnology industry. As argued in chapters one and two, scientific labour is now seen as critical to the economic well-being of advanced industrialised societies and, consequently, the wealth of nations. In this sense, 'human capital' and 'knowledge' have become primary factors of production. Significantly, debates concerning the economic development of the European biotechnology industry have frequently cited the supply of scientific labour as crucial for its development. Indeed, it is widely believed that the success of biotechnology depends to a great extent, if not critically, on the skills and insights of the workforce (Spinks, 1980; Senker and Faulkner, 1991; OECD, 1988; CEC, 1993; IRDAC, 1991; Bryce et al 1989). In addition, the biotechnology industry represents one high-value sector that has been singled out as facing critical skill shortage problems (CEC, 1993; IRDAC, 1991;1994; Bryce et al 1989; Blanchere, 1983).

This chapter (and chapters seven and eight) addresses the theoretical questions raised so far and tests the hypothesis that the labour market for highly skilled workers in globalised sectors, is more complex than conventional thinking. This chapter shows through a review of studies undertaken on biotechnology labour markets that increasing the supply of highly skilled labour will not resolve some of the inherent structural problems within the imperfect labour market for biotechnology workers, which are more adequately explained by the structure of firms, demand conditions and the macro economic environment that has direct bearing on the range of choices available to firms in their recruitment and training strategies, in short by what is called here an institutionalist approach. The aim of this chapter therefore is to review critically labour market knowledge relating to biotechnology. Previous investigations of biotechnology labour markets have concentrated on the aggregate levels of supply and demand for scientists and technologists, and the idea of the flow of knowledge or 'brain drain' from one nation-state to another. In these studies there is a general failure to relate the labour market to the overall science policy debate, of which scientific labour forms a central role. Instead, the labour market is analysed as a self-contained entity without connection to the broader economic structure of this industry which in turn limits our understanding of how labour markets operate in this sector.

The organisation of this chapter is as follows. The first section discusses the conventional wisdom of the problems facing biotechnology in relation to skills and training. The second section then reviews the literature and studies in relation to these labour markets. The third section critically reviews this 'knowledge' and argues that the labour market has been examined and discussed as a self-contained entity and there has been a general failure to locate 'the labour market' within a wider political economy, particularly in relation to the structure of firms, the specific and unique character of biotechnology and the imperfect nature of the labour market. The chapter concludes by developing my earlier observations in chapter three about the need to situate any analysis of labour market activity within an understanding of the overall production system.

2. PERCEPTIONS OF THE BIOTECHNOLOGY LABOUR MARKET IN BRITAIN AND AT THE EUROPEAN LEVEL

The following section discusses the general perceptions which have been formed about the biotechnology labour market. This discussion draws in particular from debates and reports undertaken in Britain and by the Commission of the European Communities. The reason for focusing on Britain lies in the influential role of British industrialists and academics in shaping agendas for biotechnology in the area of skills and training requirements at the European level. This is discussed in more specific detail in the following chapter on the case-study of a British initiative funded by the European Communities COMETT programme called BEMET (Biotechnology in Europe, Manpower, Education and Training). However, the task here is to review the more general perceptions around the biotechnology labour market that have been formed in Britain and at the European Commission. One of the reasons for British interest in 'skills-shortage' related issues stems from the long-standing concern of British academics and industry keen not to repeat mistakes made in the 1970s (*cf.* chapter four). The British Biotechnology interest groups were all too aware of their failure to capitalise and patent achievements in monoclonal antibodies, now noted as a disastrous event in British science that led to a case of 'discovered in Britain but exploited abroad'. During the 1980s, the academic community in Britain pioneered an important 'interest group' specifically set up to represent organisations and industries related to biotechnology activities and to lobby on behalf of their members for improving the supply of scientific labour. But, as argued in the previous chapter, recognition of the potential of biotechnology for revitalising traditional manufacturing industries and more importantly creating strategies to *pro-actively* promote the industry was primarily led at the European level by the European Commission during the early 1980s. As a result, the EC commissioned a number of studies in relation to perceived skill shortage problems in high-technology sectors such as biotechnology.

2.1 Britain

The United Kingdom was one of the first European countries to address the issue of skills shortages in the biotechnology sector and bring this to the attention of public agencies. Over a decade ago, the British government was prompted into action by the Spinks Report (1980) (see ACARD, 1990) and a series of Select Committee hearings in the House of Commons in the Spring and Summer of 1982 (House of Commons, 1982) which served as the forbearer of other Parliamentary Select Committees on the subject of competitiveness in biotechnology such as the House of Lords Select Committee on Science and Technology in 1993. One of the main areas of weaknesses identified by these Committees was the supply of highly qualified labour and the increasing skills shortages facing the industry.

Specifically, the Report recommended that the government recognize the significance of creating an adequate supply of highly skilled personnel as an industrial strategy for competitiveness in high-technologies such as biotechnology. Similarly, the government was urged to foster a climate conducive for transferring leading basic research into industrial applications. Sharp (1985) comments that the result was somewhat disjointed set of initiatives which, nevertheless, in total, constituted a relatively coherent 'strategy'. But if both the government and public were new to biotechnology, universities and industry were not; indeed Britain's relative strength in biotechnology stems from these two activities. In 1989, the concerns of the academic community in relation to maintaining a competitive edge in the Life Sciences vis a vis the United States, which was beginning to develop a dynamic small firm sector by the mid-1980s (*cf.* chapter five), were demonstrated in a letter to *The Independent* by R.J Elllis, Professor of Biological Sciences at the University of Warwick and colleagues at the Universities of York and Dundee (June, 19,1989). They wrote:

> 'The manpower crisis is the single most crucial factor which threatens the success of biological sciences in both industry and academia...Morale is very low, particularly among junior scientists, which reflects the poor esteem in which higher education and research are now held by many in this country..' (quoted in *Bio/technology*, Vol 7, Aug 1989 p.761)

The letter was supported by 118 heads of academic departments and more than 1,000 senior academics and industrialists, claiming that poor prospects in academic research and the lack of career structure were promoting many post graduate and post doctoral scientists either to gravitate to other professions or change country (*Bio/technology*, Vol 7, Aug 1989). In addition, the establishment of the UK Interest Group Working Party on Biotechnology Education in 1988 at the request of the British Co-ordinating Committee for Biotechnology (BCCB), signalled the importance BCCB attached to labour market related issues. This initiative is turned to in more specific detail in the following chapter.

2.3 The European Commission

Since the 1980s, numerous national investigations have been undertaken which have directly linked industrial competitiveness in biotechnology to highly developed educational infrastructures (IRDAC, 1991; 1994; Blanchere, 1983; Prais, 1981; Bryce et al., 1989; Bryce and Bennet 1990; CEC, 1994; Realising Our Potential, 1993; Bangemann, 1995). The idea that highly skilled workers contribute to overall economic prosperity has also been accepted in European Union policy debates. The perceived crucial role of generating new knowledge in contemporary industrial societies has led to the emergence of the 'skills gap' agenda which has been recognised as a critical challenge now facing European governments. Discussion is centred on how Europe is failing to capitalise on its intellectual capital through an inadequate science and technology infrastructure. One important focus is how to create an adequate supply of skilled labour for high value activities to engender economic competitiveness in strategic industries such as biotechnology. This is reflected in current policy debates at the European level and mirrored in the general tone of at least the UK government on the subject of increasing skills and the training of the workforce generally (CEC, 1993; Realising Our Potential, 1993).

After an initially slow governmental response in Europe relative to the United States, biotechnology began to generate wide-spread political interest in terms of its wealth generation possibilities, and especially its potential for new employment opportunities. A number of reports were published during the 1980s arguing that Europe, traditionally strong in the life sciences, was failing to capitalise on its academic expertise in this area. One of the crucial factors continually cited for the failure of European economic development in the biotechnology industry was the shortfall of highly skilled workers entering the biotechnology industry. The European Federation of Biotechnology (EFB) which had been formed in Interlaken in 1978, formed a range of working groups. In 1980, the Education Working Group of the EFB brought together people from all over West and East Europe to produce a report (1983) edited by Henri Blanchere, about the manpower and training implications of the expansion of the biotechnology based industries. The 1987 OECD study *Structural Adjustment and Economic Performance* argued unequivocally that inadequate labour force qualifications were acting to slow down economic growth in Western Europe. This was followed by the IRDAC *Skills Shortages in Europe,* Reports published in 1991 and in 1994, which asserted that investment in R&D might fail to produce the expected benefits due to a lack of qualified people. It also stressed that European competitiveness would be threatened if careful attention was not paid to education. These developments are discussed in more detail below.

The general themes characterising this debate can be categorised into two broad areas. First, there is the perceived 'skills gap' challenge to the future development and competitiveness of strategic, knowledge-based industries such as biotechnology. Second, the question of how education and training policy may contribute to economic growth in these knowledge-based sectors through human resource development. The Commission of the European Communities Working Party *Guidelines for Community Action in the Field of Education and Training* (1993), summarises their position in relation to the role of human capital and European economic competitiveness in knowledge-based sectors:

> 'Over the past few years a growing consensus has emerged throughout the European Community as in other parts of the world, that so-called 'human or intangible capital' is the most vital resource of advanced economies, without which the natural endowments of nations, their financial power and fixed capital will become dwindling resources. This is not only a question of men and women acquiring new skills and knowledge but also of the vital need to develop the capacity to organise and innovate' (CEC,1993b p.2).

A number of reports on economic development in the European Union have argued that investments in skills and training are essential for the future welfare of many sectors as a direct consequence of rising demand for highly skilled workers as traditional manufacturing becomes more knowledge-intensive. Biotechnology, is regularly cited. For instance, one report entitled *European Education and Training, Human Resources and Competitiveness* (1993) linked scientific and technological R&D programmes to the overall issue of the adequacy of both the numbers and the education and training of highly skilled scientists, engineers and technicians. Similarly, studies such as those carried out by the Industrial Research and Development Advisory (IRDAC) Committee to the European Commission (1991;1994) have argued that a number of skill deficiencies across the European Union particularly in knowledge based sectors (especially in biotechnology) have developed and impede competitiveness. In the reports, IRDAC argued that European industrialised societies were experiencing structural problems in the creation of highly skilled labour as a consequence of the pervasive nature of generic technologies. In 1991, IRDAC reported that:

> '..there is evidence that the higher investment in technological R&D ... might not produce the expected economic benefits due to the lack of qualified people both to develop and exploit advanced and innovative products and processes. .'

The Report went on to say:

> '...if sufficient attention is not given to the skills shortage problem, in particular in areas of technological advance, Europe's competitive position will be threatened." (IRDAC, 1991, p 1) .

Furthermore, the report suggested that Europe in general had fallen behind Japan in the application of new technology in production especially in mature and traditional industries. It was also suggested that Europe had only recently begun to develop a multidisciplinary science of manufacturing and to give its study sufficient attention in university and research. This was compounded, according to IRDAC, by unfavourable demographic trends in Europe, in particular a falling birth rate and an ageing population. This, it was suggested, endorsed the need to reassess training policies to shift emphasis on retraining, as Japan, for the optimal use of human resources or, the concept of a life time of training. In comparison to Europe:

> '...Japan produces more engineers per head of population than any other Western country : Europe overall produces less than half per head.... [and] participation rates in school age until 18 are at much higher levels than Europe (95% of young Japanese are in full-time education up to the age of 18; in Europe this is often less than 50%)' (IRDAC, 1991, p3).

In addition, the European Round Table of Industrialists have argued for education and training to be considered to be one of the main pillars of the future development of the European Union and European social partners and, employers and trade unions have placed the question of skill and qualification needs as one of the highest priorities on the agenda of the social dialogue at the European level (CEC, 1993). Priority, it is asserted, should now be given to education in public policy as the basis of a 'qualifications for all' policy objective. Inherent in much of the debate, therefore, is how to create more highly qualified workers in sectors characterised by skill shortages and improve training systems to be more responsive to the market.

To summarise, the general perception at the European level, is that the biotechnology labour market is characterised by skills shortages which are a potential limiting factor in the ability of a state to develop and exploit biotechnology (Waite et al, 1989; Bryce et al 1989; ACOST, 1990; CEC, 1993; Atkinson, 1990; Boosveld and Van Der Kwaak; 1992; Enzing, 1991; Bevan et al, 1987; Cardiff and Claessens, 1994). However, a closer review of a number of studies of biotechnology labour markets suggest that skills shortages are but one dimension of the overall labour market problem facing biotechnology development. These studies suggest that increasing the supply of advanced skilled labour is one dimension confronting policy-makers for improving 'knowledge, 'know-how' and 'skills' - and in most instances is confined to highly specialised skills areas. Additionally, these studies indicate that a generic policy of increasing the supply of scientific labour for improving the pace of economic development of the new biotechnologies is not necessarily the most effective one. The biotechnology labour market is difficult to define and is rapidly changing as a consequence of macro economic conditions' for instance, changes in the structure of demand; changes in investor confidence levels; R&D strategies pursued by public agencies and large corporations; inherent structural problems of creating a mobile labour force within the European Union. The next section then discusses these issues and seeks to answer the questions: how can a biotechnology labour market be defined? Can skill shortages be forecasted? What, if any, is the overall relationship between the labour market and the industrial structure of biotechnology, public sector policies and general macroeconomic forces?

3. A REVIEW OF BIOTECHNOLOGY LABOUR MARKET STUDIES

There is limited detailed knowledge on biotechnology labour markets. One of the inherent problems facing an analysis of the 'biotechnology labour market' is its structure. In chapter four, it was argued that biotechnology can be characterised as an inter-disciplinary activity requiring scientists and technologists across a range of biosciences and bioprocess skills (also Blanchere, 1983; Bevan et al, 1987). These skills cut across academic boundaries and according to Pearson (1987) are better regarded under three broad skill groups, genetic engineering; hybridoma technology and associated activities and bioprocess technology. Since biotechnology is multidisciplinary a wide-range of skills are required from its work-force. This is illustrated in table 6.1.

Table 6.1. Multidisciplinary skills base of biotechnology

Technical :	(biochemistry; microbiology; fermentation technologists; molecular genetics; pharmacology; animal sciences; plant physiology; immunology; protein engineering; biocatalysts; bioelectronics; biochemical engineering; bioinformatics ; immunology)
Commercial:	(management; marketing; public relations; sales; administration; regulatory affairs).

The workforce is divided into two categories 'core', technical workers - research and development scientists, engineers for production and quality control experts and 'commercial' workers - management and marketing expertise, public relations skills and skilled lawyers in intellectual property rights. The importance of research and development is represented in the spread of the workforce which clearly favours the 'core' workers category. Analysing the biotechnology labour market therefore is highly problematic given that there are no defined boundaries as to what constitutes a 'biotechnology' worker. At present, the term 'biotechnologist' does not correspond to any meaningful reality and to search for a specific expert is misleading (Blanchere, 1983). It is more useful then to understand the biotechnology labour market not as a discipline nor a science, but as an activity to which specialists belonging to a diverse range of disciplines make their contributions.

According to a study undertaken by McCormick and Goodstein (1993), the 'average' biotechnologist is approximately 43 years of age, has 13 years of experience in the industry and eight years in a company. The 'average' biotechnologist earns $85,175 a year.[1] The qualification levels of the respondents were high, with nearly three quarters holding doctorate degrees. The idea that these sets of workers are highly motivated by their work which was discussed in chapter three, was also identified in the study. McCormick and Goodstein (1993) commented that these sets of workers were highly motivated by their work. Research was deeply enjoyed - 'the thrill of unmasking nature, the intellectual freedom and challenge, the practical satisfaction of methods development'. The academic respondents mentioned the satisfaction of teaching; commercial scientists the deep satisfaction of seeing a project through to commercialisation and particularly prized the virtue of bringing projects in on time and under budget. Overall, there were high levels of work satisfaction.

Given the inherent problems of defining the biotechnology labour market, the discussion now turns to a review of contemporary 'knowledge' on biotechnology labour markets.

---

[1] It is worth noting that in the survey by McCormick and Goodstein, nearly 95 per cent of the respondents were from the United States and Canada, the rest from Europe. In this sense then, the survey findings on the 'average' biotechnologist are more appropriately applied to the United States and Canada than to the average biotechnologist world-wide. Over 81 percent of the respondents held technical jobs - researchers (55 per cent); research managers (29 percent); process developers (8 percent) or technical consultants (5 percent). Non technical top management accounted for another 5 per cent of the total, and non science specialists (i.e. in law, finance, information) accounted for another 14 per cent).

3.1 Labour market structure

McCormick and Hodgson (1993) studied over 208 employers world-wide, recruiting for biotechnology-related activities. Over 44 per cent of the responses indicated that new jobs would be created in the longer term with an estimated 19 per cent increase in the overall size of the workforce. The majority of the workforce will be concentrated in healthcare with growth in bioprocess design, bioinformatics and facilities engineering. Table 6.2 shows the pattern of employment according to these trends.

The concentration of the workforce in R&D activities and in health care demonstrate how the sector is still in relatively infant stages of commercial development and in addition how the bulk of investment, at present is directed towards molecular biotechnology and flowing into pharmaceuticals and especially human therapeutics. These are commercial areas that are beginning to use biotechnology techniques and commericalise their products and are thus at a more advanced stage of market development (*cf.* chapter four for an analysis of biotechnology activities and their market development).

In a survey conducted by Ernst and Young (1995) European biotech companies are clearly more optimistic about the near-term future than in the United States. According to the report, although 10 per cent respondents to the 1995 US Ernst and Young survey indicated that one of their most significant actions over the next two years will be to lay off large numbers of employees. No CEO responding to the European Survey anticipated such action.

Table 6.2 Distribution of jobs in biotechnology by sector

Industrial Focus	%
General pharmaceuticals	22.4
Human therapeutics	47.2
Human diagnostics	4.3
Animal therapeutics	1.6
Total pharmaceutical	75.5
Agriculture	5.7
Bioprocess engineering	3.9
Instrumentation and supply	2.5
Informatics systems	2.3
Textiles	1.6
Basic Research	1.6
Food and beverages	1.6
Medical devices	1.4
Chemicals and enzymes	1.1
Environment	0.9
Finance	0.5
Education	0.5
Biomaterials	0.5
Exhibition organising	0.2
Energy	0.2
Law, patent, technology transfer	0.2
total	100

source: McCormick and Goodstein, 1993

In addition, it was considered that most of the pivotal business decisions made by European CEOs in the past 12 months involved expansion through hiring more people, increasing capacities and positioning the company for future growth. On this basis, it was estimated that the macro-economic impact of biotechnology in Europe will result in a 1 per cent growth in employee numbers among industries that use biotechnology. Among the start ups, this is estimated to be even more dramatic: staffing levels are expected to rise by 6 per cent a year to the end of the decade (Ernst and Young, 1995).

Biotechnology contrasts with other new technologies such as IT where generally tertiary education and especially undergraduate study provide the basic training while higher level and more specialised skills are developed in industry. As I showed in the previous chapters, biotech firms are generally small firms employing less than fifty employees and are highly dependent on the universities and public research centres along with postgraduate training to produce the required skills and 'know-how'. In addition, while there is a need for individuals to have a good grounding in basic life sciences, equally there is a longer term training element. Employees in the biotechnology industries also require highly specific disciplinary training (Connor et al, 1993). In this sense, and following the conclusions of chapter four, the industrial structure of biotechnology characterised by small firm activity and its dependence on knowledge-activities has accentuated the dependence of biotech firms on the public sector for accessing skilled labour, new knowledge and know-how and for up-dating skills.

The qualification profile of scientific labour working in biotechnology related activities continues to be very high and is estimated to estimated to continue increasing (Bevan et al, 1987; Connor et al, 1993; Ernst and Young, 1995; McCormick and Hodgson,1993; Bryce et al, 1989). The labour structure in industry and research centres emphasises primarily PhDs or post doctoral scientists together with graduate level staff recruited as higher level technicians (Bryce et al, 1989; Bryce and Bennet, 1990). The only exception has been for biochemical engineers with specialist qualifications (Bevan et al, 1987). Bevan et al revealed over-recruitment of PhDs into first degree level posts and for most organisations taking part in this investigation the high skills profile of recruits reflected the genuine need for specialist skills and knowledge which could only be resourced at this level. Overall, the study revealed that recruiters were highly dependent on the public sector for higher education for the initial training of post-graduate and graduate recruits, an increase in demand for labour was predicted however this 'expansion':

> '....will be characterised by extensive competition for a wide range of specialisations with skill shortages in some discrete areas but juxtaposed with over supply in others' (Bevan et al, 1987, p.6).

The investigation pointed to caution in estimating trends in the biotechnology sector. Similarly, Connor et al, (1993) argue that the dynamic nature of biotechnology makes it particularly vulnerable to changing skills demands with resultant time lags between the providers and users of biotechnology skills. In the context of postgraduate training where there are long lead times, it has been suggested that the dynamic and inter-disciplinary nature of the discipline makes predicting future skill needs and selecting priorities particularly problematic (Connor, et al 1993). Bevan et al (1987) argue that there are inherent problems in forecasting skills shortages in the biotechnology sector for a number of specific reasons. First, the rapidity of technology change and new firm formation and the mix of skills required. Second, changes in the R&D investment strategies of established firms could also have a major effect on demand trends, as could significant investment from the USA and changes in public expenditure. Third, longer term trends favour a continued increase in demand for highly qualified labour and this could lead to a widening range of recruitment difficulties for certain specialist skills at PhD and post-doctoral levels. This would be particularly exacerbated by changes in training policies and the rising costs of training students in these areas. Finally, it was pointed out that the decreasing proportion of permanent core staff responsible for supervision of research students in research centres themselves could act as a major constraint to increasing the throughput of research students in publicly funded research centres (Bevan et al, 1987).

According to Bevan et al, (1987), in general career opportunities are dominated by industry, with few openings in research centres or higher education. In industry the increase has involved both the establishment of new firms and expansion of indigenous firms. This has been more than offset by the contraction or closures of a small number of commercial organisations withdrawing from novel activities. However, in the United Kingdom the increase in employment opportunities has been most marked in research centres and institutions where the emphasis has been entirely on post-doctoral scientists working on short-term contracts. Bevan et al found that the increase in research centres and institutions employment in the UK, is partly due to the increased tendency on the part of employers to out-source work (Bevan et al, 1987). By discipline area, recent studies have indicated there has been a sharp growth in demand for genetic engineering skills (Bevan et al, 1987).

Another popular argument in relation to scientific labour markets generally is that scientists are leaving Europe to go to the United States, or elsewhere that can offer more fortuitous rewards (Atkinson, 1990; Pearson, 1989). It has been argued that this is particularly pertinent in Europe, with a flow of scientists and technologists in biotechnology leaving to work overseas. In 1984, a survey of the number of workers having left the UK to work overseas (primarily the United States) has been in the order of 250, representing perhaps 15 per cent of the total number currently employed in the UK. Whilst this loss was considered not to have a significant impact on many individual organisations, it was seen to be an important reduction in the UK's pool of biotechnology expertise (IMS, 1983). The survey revealed that the flow included a number of senior biotechnologists who left in mid-career due to a perceived lack of opportunities in the UK. A factor further constraining their return, and that of more junior staff overseas, would be the need to take a fall in salary and living standards, the poor business/industrial environment, or lack of funds for research. A number of people also commented on the difficulties either learning about UK vacancies or attending interviews and relocating costs (IMS, 1983). One post doctorate commented:

> 'many scientists leave the UK with the intent of returning. The later realisation of lack of accessibility to the UK job market, because of the distance, expense and lack of opportunities, leads them to seek foreign employment for economic reasons. It becomes increasingly difficult to reverse the process of time' (IMS, 1983, p.34).

However, in a more recent study of biotechnology labour markets for the Science and Engineering Research Council (1987), Bevan et al concluded that the brain drain problem had lessened and was now principally focused in younger scientists for whom new opportunities existed in higher education and with the growth in demand in industry offering more opportunities in the UK for experienced people. The slow down in growth and the maturing of biotechnology in North America has also been reducing the demand for migrants. Another article commented on how negative immigration of scientific workers was being more than offset by a net import of skilled labour (*Nature*, 1993). Indeed, where it does take place, the globalisation of labour markets is generally perceived to be positive factor underpinning the development of science and technology (*New Scientist*, 1989). Bevan et al argued that short term contracts in research centres and higher education, relatively low morale and poor facilities were important factors in recruitment difficulties. Furthermore, problems acquiring the desired skills were largely confined to highly specialised posts, usually at a senior level, were the quality not the quantity of applicants tended to be the problem (Pearson, 1987).

4. A CRITICAL REVIEW OF SKILL SHORTAGES AND THE BIOTECHNOLOGY LABOUR MARKET

There are a number of observations that can be discerned from this discussion of biotechnology labour markets. These are treated here in this section and then returned to in the next chapter in relation to the empirical research of biotechnology European firms' perceptions of the labour market. First, however, given that the 'skill shortage' debate has attracted so much attention, it is noteworthy to briefly consider what is meant by the term. Robinson (1996) argues that skill shortages can be said to exist when firms are facing difficulty in recruiting to fill vacancies because of a shortage of suitably qualified or skilled labour. However, skill shortages overlap with, but are not the same thing as, recruitment difficulties or hard to fill vacancies. Skill shortages only matter if they seem likely to have a significant impact on firms with the consequence that they may therefore be causing upward pressure on pay. For example, firms may face recruitment problems for a variety of reasons. First, there may not be enough labour with the necessary formal skills or qualifications to fill the jobs available. These are the 'true' skill shortages. Obvious examples would be schools unable to recruit teachers with maths or science qualifications or, manufacturing firms unable to recruit qualified engineers or technicians.

Second, there is another type of skill shortage which is not related to formal skills and qualifications. Many firms often complain that even when individuals present themselves with the formal qualifications, they are sometimes seen to lack the 'personal transferable skills' necessary to secure recruitment, that is, they are perceived to lack motivation or interpersonal communication skills or some other personal characteristic. Third, individuals may have the requisite formal qualifications to fill a job, but not the necessary recent experience. Fourth, some jobs may be relatively unattractive, for example, because of unsociable hours or poor pay, so that firms' recruitment difficulties reflect these features of the jobs on offer rather than a shortage of suitably skilled labour. Finally, some employers have lengthy recruitment procedures or unrealistic recruitment standards so that their recruitment problems are 'home-grown'.

The distinction between these types of recruitment difficulties is very important because many of the surveys commonly quoted in the media actually refer to the incidence of recruitment difficulties as reported by firms, but are often misrepresented as referring to the incidence of skill shortages as if recruitment difficulties and skill shortages were one and the same thing. Clearly they are not. There are several reasons other than a shortage of suitably qualified labour for firms experiencing recruitment difficulties, as I show in the following chapter on the biotechnology sector.

The observations that can be made from this review of labour market literature on biotechnology are as follows. Skills-shortages are highly *specific*. Previous skills shortages in investigations in British biotechnology during the early 1980s (IMS, 1983) show them to be relatively small scale and selective rather than widespread. More recent research (Connor et al, 1993) found that although in general there was no evidence of supply problems, there were considerable shortages of highly talented individuals entering industry. In addition there was a general perception among employers that quality of PhD output was falling. Furthermore, it was argued that while biotechnology depends on various disciplines and has its roots in basic science (biochemistry, microbiology and bioengineering), long term solutions lie in broad improvements to the science base of the nation-state. Although a full analysis of the science base was not undertaken by the authors (Connor et al, 1993), a major criticism of Curran and Lovering with regards to overall analyses of scientific labour markets (Curran and Lovering, 1994).

This methodological point resonates with my argument in chapter three concerning the need for developing a broad analytical approach for understanding the role of the labour market in sectors such as biotechnology. To repeat briefly, the argument advanced was that large investments in training are unlikely to solve problems, or compensate for an inferior product, or a defective part or malfunctioning equipment. To this can be added, demand-side factors such as a general low demand expectation within the economy and low demand for certain products. Drawing on the insights of institutional labour market theories, training requires evaluation as part of the overall organisation of the firm and its production system: the process of training, the organisation of work, the design of the product, the use of capital and the company's macroeconomic performance, which is heavily influenced by macroeconomic policies, effecting the level of unemployment and the variability of product demand. Over time, macroeconomic policy affects the composition of the jobs being formed which in turn determines the skills and attitudes that are created in the workplace as well as the rate at which education embodied in new entrants is put to use in the labour market.

This leads to the second observation on the specific influence of macro economic forces. For example, as I have argued in chapter five, the biotechnology sector is characterised by a number of factors (knowledge, demand and finance) which not only need to be incorporated into any analysis of the economic development of the sector, but will also have a direct bearing on labour market outcomes. For instance, the skill shortage argument as a major factor impeding the economic development of the sector is only one contributing factor in the overall development of biotechnology. Indeed, in the United States where the biotechnology industry is more mature, the financial problems facing small biotech firms aiming to continue of lengthy clinical trials has had a major impact on the sector (discussed in the previous chapter). For instance, evidence now suggests that American biotech firms are beginning to lay off workers (Ernst and Young, 1995). The implication of these 'down-sizing' trends in the United States for Europe is that it raises doubts about the efficacy, in the long-term, of creating policies based around increasing the supply of scientific labour for improving the economic competitiveness of the sector.

The next observation relates to theoretical points made in chapters one, two and three concerning the conceptualisation of markets and the intractable relationship between the political and economic domains. It was argued that the market is an institution, comprised of a host of subsidiary institutions which interact with other institutional complexes in society; the economy is much more than a market mechanism. It includes the institutions which form, structure and operate through, or channel the operations of the market. In this respect, it is not the market but the larger economy which effectively allocates resources (Samuels, 1987). Taking institutional labour market approaches, the institutional arrangements of a society, the organisation of the industry, the relationship between the firms and governments, the legal framework within firms and workers operate are all taken as relevant factors in any labour market analysis. Implicit in this approach is the intractable relationship between politics and economics. Politics is the means by which economic structures, in particular the structures of the market, are established and in turn transformed. Economic structures and processes are the results of political interactions and they are generated by competing socio-political interests in particular economic and institutional settings (Stubbs and Underhill, 1994).

From the labour market studies discussed above, the relationship between biotechnology economic development and the national scientific and educational infrastructure is clearly a crucial one. As a technology-push industry, the dynamism of biotechnology activity has depended on public sector knowledge 'utilities'. (By this, I am referring to the development of biotechnology in the United States that was spurred on by the spillover effects of cancer and medical research. Additionally, by the number of spin-out biotech firms from public funded research institutes. In this sense, the economic development of biotechnology is intimately bound to the political environment surrounding the organisation of education and science for the production and delivery of academic research, post-graduate training and up-dating. Consequently, biotechnology is particularly vulnerable to the political decisions concerning the organisation of science. The development of biotechnology therefore is intractable from the political realm - which both shapes and conditions the labour market and the science base.

The fourth observation concerns the whole area of forecasting skills needs in the biotechnology sector due to diversity of needs and macro economic conditions. The current assumption among policy makers that future employment will necessitate an increase in skill levels (see The Labour Party, 1996) reaping economic dividends to the wider economy, is suspect not least on the grounds that there is no real certainty about the types of skills required in the future given that demand conditions are variable (see Bailey, 1991). In addition, as I show in the next chapter in the case-study of employer's skills and training requirements in the biotechnology sector, few companies reported concerns about skills shortages. Most companies are however concerned with investment and demand problems in Europe, along with general problems of access to information about the labour market relying on imperfect tools for recruiting staff such as personal networks. As I argued in chapter three, institutional theory implies that there are broader concerns in the labour market which Hutton has noted when he states:

> '[w]hat happens in the labour market .. is dependent upon factors outside workers' control .... the origins of their problems lie in what has happened in the financial system, to investment and to the character and level of economic activity it has generated. In short, most of the economic cannonades of the past decade and half have been firing at the wrong target' (Hutton, 1995, p.242-243).

By conceptualising the labour market in this way, institutional theory recognises that government plays a necessary part in creating the structure within which the economy functions and is largely responsible for labour market outcomes. The institutional structure, created and preserved by government, provides a social order, a set of social and work roles, ensures social reproduction and provides a system of value through the creation and enforcement of rule and custom.

This leads to the fifth observation that despite efforts to create a European 'Laboratory Without Frontiers' by the European Commission, the labour market still remains within the legal jurisdiction of the nation-state. The national customs, norms and modes of behaviour which are inherent within national labour markets translate into barriers to the free movement of scientific labour across the European member states. Earlier in chapter two and three, it was argued the labour market for 'symbolic analysts' - or advanced scientific labour is an elite market which is not only conditioned by global macroeconomic forces, but is equally shaped through powerful *national* institutions. Although it is widely argued that within the contemporary period of globalisation, the state has less control over ideas and knowledge, (for example, as I have shown through my earlier discussion in chapter two on 'the knowledge structure' and in chapter five in relation to the globalisation of the biotechnology industry), it is clear that in relation to labour, the state still remains the controller of its borders and thus the movement of people across them. This point was explored in chapter two and is again returned in the concluding chapter (eight). Despite the rhetoric of globalisation, labour mobility is less prominent than the ideology of free market forces assumes. The implications of this for the development of European biotechnology is that there are still many barriers to the free mobility of scientific labour across the so called Single Market. As I show in the next chapter, the heterogeneous labour market for biotechnology together with the disparity of education and training systems in the member states has been a critical factor impeding the flow of scientific labour around the European countries.

Finally, the structure of the biotechnology industry as a new and dynamic sector is a major influence on the shape and dynamics of the labour market. Boosveld and Van Der Kwaak (1992) have argued that biotechnology requires earlier 'human resource management.' They argue that biotechnology is unlike other sectors in the sense that it is multidiscplinary and technology-driven, requiring people from vastly different backgrounds, often with a gulf in outlook between them. They point to how biotechnology is characterised by continuous, rapid change and considerable risk with biotechnology businesses seldom growing organically with growth funded by income from product sales but by venture investment. The result for the business of the pressures of returns to investors is that staff are acquired quickly with the business up and running in a very short time. Thus the acquisition of staff can be rapid and perhaps unconsidered. The main point from this analysis is the implications that Boosveld and Van Der Kwaak have for recruitment strategies in biotech firms. They argue that human resources comes into its won during a period of 'bulk hiring'. They suggest that emerging companies tend not to be very selective when recruiting large numbers of staff. Typically, they employ to satisfy immediate needs forfeiting future potential. The task of the day has priority over balanced build-up of the department or the entire organisation. One common mistake therefore, is to employ overqualified and thus expensive labour. Another is to employ someone who is overly specialised and inflexible: a career scientist, for instance could clearly perform the immediate tasks and duties but might balk at moving into a management role that would mean compromising scientific aspirations. There is no scope in most biotechnology companies for the dual track, scientific management career ladders that are common in the pharmaceutical industry. Another problem is the recruitment of former colleagues. Many supervisors try to reduce labour market uncertainty by recreating an old work environment:

> '..Too often old friends become burdens, expecting more, expecting privileged from larger companies or industries or universities' (Boosveld and Van Der Kwaak, 1992, p.874).

5. CONCLUSIONS

The aim of this chapter has been to discuss studies undertaken to assess what is meant by a 'biotechnology labour market' and to review critically the perceptions developed hitherto in Britain and at the European level. What is significant about these labour market studies is that they demonstrate that the labour market for biotechnology is not adequately explained by aggregate levels of supply and demand and that the market necessitates closer evaluation within the overall context of the system of production for biotechnology. This, therefore, raises questions concerning contemporary thinking on the politics and economics of education and training as a focal point of economic strategy for high-technology industry. The problem with this policy conclusion is that it may privilege the economics of education and training at the expense of addressing other dimensions of the production system which impede economic development. Furthermore, as I show in the next chapter in my empirical research of the biotechnology labour market, it is certainly not clear that skill-shortages are as wide-spread as conventional wisdom on scientific labour implies.

The next chapter turns to a direct case-study of a European funded evaluation of biotechnology labour markets according to the perceived needs of firms operating in the biotech sector. With respect to my argument, I show in chapters seven and eight how skills and training issues in the biotechnology sector gained salience in European policy circles during the late 1980s and early 1990s. Taking a specific case-study of European firms, I show that the labour market for this sector is more complex than the labour market economics 'orthodoxy' implies. The empirical evidence suggests that a range of *institutional* factors underpin the functioning of this labour market, in conjunction with broader production and knowledge structures that underpin the global political economy. These factors are then explored as a more adequate explanation of the patterns, imperfections and outcomes of developing labour markets which may also reveal more about the political economy of knowledge based industries.

CHAPTER SEVEN

SKILLS SHORTAGES OR INSTITUTIONAL FAILURES? A CASE STUDY OF EUROPEAN BIOTECHNOLOGY LABOUR MARKETS

1. INTRODUCTION

This chapter now turns to the case-study of biotechnology firms in Europe and their perspectives of the labour market for biotechnology. The aim of this chapter is to support the thesis that the relationship between skills and training and the economic performance of firms and overall GNP is a more complex relationship than the assertion that increasing the supply of highly skilled workers and increasing the investments in education and training will inevitably improve the competitiveness of firms and nations in a global economy. Instead, the labour market is more appropriately understood as an institution, comprised of a set of norms, behaviour and routines, themselves constructed through social structure (networks of personal relationships); processes of cognition (different forms of rationality); culture (different forms of understanding); and politics (the way in which training systems and related institutions are shaped by the state and class forces). The argument advanced is that competitiveness necessitates a broader analytical approach that takes into account the broader structure of the firm, the macro economy and their relationship with the global economy. This context is critical in understanding the continuing fragmentation and diversity of the European biotechnology labour market.

This argument is empirically supported through the following sections. The first discusses the raison d'être for the pan-European investigation of skills needs in biotechnology firms. This is followed by a brief discussion of the organisation BEMET (Biotechnology in Europe, Manpower, Education and Training) under the EC COMETT initiative set up to undertake this task. The discussion then moves on to review the main findings from this investigation. These are divided into a number of sub-sections. The first sub-section shows that in accordance with the overall description of the biotechnology sector the pervasive nature of the technology and the preponderance of small firms. The next demonstrates the high level of skills of workers. The third sub-section reveals that the 'skills deficit' in biotechnology is not as wide-spread as it is widely implied, however future levels of demand in the next section still remain high for workers. The research is then discussed in relation to more contextual issues surrounding biotechnology labour markets. These findings reveal national differences and problems facing small firms for accessing knowledge on the labour market and for recruiting widely. Training is then discussed and an uneven picture of access to training activities is revealed in countries which has some bearing on the overall relevance of the national system of innovation. The 'brain drain' phenomenon is then shown to be less problematic for firms, and in many instances, the movement of scientific labour is considered to be a positive development. In the final sub-section, it is shown how the overall empirical findings support the overall hypothesis advanced in this thesis, that the relationship between human capital and competitiveness is part of the broader structure of the production system, which is discussed in relation to the system of innovation and the structure of power. The survey was designed to protect the confidentiality of the respondents and therefore firms will not be identified by name.

2. THE UK INTEREST GROUP WORKING PARTY ON BIOTECHNOLOGY EDUCATION

This section briefly discusses the findings of two influential meetings and published reports by The UK Interest Group Working Party on Biotechnology Education in relation to skills needs in the biotechnology industry. The overall conclusions from these two reports suggested that biotechnology in Europe is suffering from a shortage of suitably qualified staff which in turn was impeding the economic development of the sector. In turn, this represented a major obstacle for European competitiveness in the sector. In short, the reports urged national and European public agencies to address this issue. The main conclusions from these reports are discussed briefly below, along with the recommendation to the European Commission to fund a Europe-wide study of the skills requirements of European biotechnology firms and an assessment of biotechnology course provision across European institutions.

2.1 Manpower and Training Needs in UK Biotechnology (April 1989)

The creation of the UK Interest Group Working Party on Biotechnology Education in 1988 at the request of the British Co-ordinating Committee for Biotechnology (BCCB), signalled the importance BCCB attached to labour market related issues. The inaugural meeting was held on 4 April 1989 entitled *Manpower and Training Needs in UK Biotechnology*.[1] The aim of the Interest Group was to liaise through the Biochemical Society and its Education Group with the European Federation of Biotechnology and its Working Party on Education in Biotechnology. One of its primary functions was to identify potential training needs in biotechnology for the future. The intention then, was that the Interest Group would liaise at the European level with the European Federation of Biotechnology, an overarching body overseeing activities in biotechnology. The *Manpower and Training Needs in UK Biotechnology* conference held in 1989 grouped policy-makers, academics and industrialists to discuss the issue of skills shortages in the biotechnology industry in Britain. The Chairman of the conference, and a Director of a leading British Biotechnology company summarised the issue of the meeting:

> 'The fact that there has been a decline in potential manpower as witnessed by the recent demographic trends, together with an increased demand for scientific manpower in biotechnology, have created a shortage. It is very clear that we are already, and going to be increasingly, short of trained people, probably at all levels.' (Bennet and Bryce, 1990, p.20)

In this sense, then, the general theme of the meeting was that the *supply* of labour for biotechnology was not meeting demand. A number of observations were reached

1 A list of participants at this meeting are included in the appendix to this chapter.

concerning the current trends in the supply of labour. It was suggested that several adverse trends gave reason for serious concern about the labour supply situation for biotechnology in the 1990s. These included, the demographic decline in the number of school leavers; the decline in the number of first degree graduates continuing with postgraduate study; the increasing competition for graduates from other sectors of the economy; the decline in the proportions of first degree and PhD graduates entering industry as scientists and the difficulties experienced by institutions in making suitable short-term research posts (Bryce et al, 1989).

The meeting enabled a number of insights to be drawn about the labour market for biotechnology. These are treated briefly here. First, biotechnology in relation to its skills and training needs is uniquely characterised by a number of factors:

- it is multidisciplinary
- it is an enabling technology used in a wide range of industrial sectors and technological contexts
- the high skill and qualification levels of its staff
- its dependence on higher education institutions and research centres for advanced level training
- the limited transferability of skills between sectors
- its rapid and recent commercialisation

(Bryce et al. 1989, p.4).

Second, it was identified that considerable increase would be anticipated by industry for scientific updating, conversion training, induction training of new personnel and awareness training for non-scientific staff. It was suggested that high and unsatisfied demand for training specifically designed for biotechnology in key areas of management functions (marketing, design, quality, business planning, patenting, and financial and information systems). The number of advanced courses was considered to be more or less sufficient, rather the need for cost-effective courses closely or flexibly designed for their specific purposes including open and distance learning courses.

Third, the meeting proposed that adequate provision for biotechnology in school curricula and in public information was essential if the population as a whole could have an informed understanding of its benefits and regulation to encourage both the development of biotechnology and students making it their career choice.

Policy Recommendations

A range of policy recommendations were forwarded as a consequence of the meeting. There was a general call for training systems to be adaptive and responsive to the requirements of industry and that undergraduate training ought to provide a broad based knowledge followed with in-depth specialist knowledge about a subject. To attract students into postgraduate training more and adequate grants should be provided by public agencies at the national and European level. It was also recommended that industry took a greater , dynamic lead in the role of training by supporting more basic research and hence related post graduate training; becoming more involved in the teaching of undergraduates, by short term secondments of staff to higher education establishments and by the joint supervision of final year degree and postgraduate students. In addition, undergraduates ought to be encouraged to spend short periods of time in industry, for example during vacation periods and sandwich placements need to be increased (Bryce et al, 1989, p.5). Finally, it was recommended that a similar conference needed to be organised to address the same issue, but at the European level. It is not without significance that the perceptions amongst the UK Interest Group was that science constituted an 'international' scientific network and that a transnational scientific labour market existed thus it was necessary to address skills shortage problems across Europe.

2.2 Manpower and Training in Biotechnology for Europe (December 1989)

The subsequent meeting *Manpower and Training in Biotechnology for Europe* was held in Delft, the Netherlands in December 1989.[2] The overall discussion and findings did not markedly differ from those found in London. However, the real opportunity from the meeting was the co-ordination of European wide activities related to labour market issues through the umbrella organisation the European Federation of Biotechnology (EFB).[3] The general feeling was that this was a real opportunity for a

---

2 *ibid.*,

3 The European Federation of Biotechnology was founded in 1978. The aims of the EFB have been '...the integration and representation of scientists in biotechnology in all European countries by exchange of scientific and technological experiences; supporting of European activities in research and development and

transnational meeting of the European biotechnology scientific community, to address skills-related issues in the sector. Significantly, the published report (Bryce and Bennet, 1990) described the environment for biotechnology and skills and training requirements and related biotechnology development to the wider political context of the European project. The report states:

> 'Part of the current changes in biotechnology result from the widespread changes in the political climate. The European infrastructure in science is poorly developed at present compared with the USA and Japan largely because there are twelve separate national science policies among EC Member States. '(Bryce and Bennett, 1990, p.4)

In terms of actual labour market change, it was estimated that the numbers of employees in new biotechnology firms has increased from two- to ten- fold according to country in the period 1982-88, with an accelerating shift in emphasis from research and development to application and production which would continue. In relation to recruitment and skills and training, acute problems were said to exist in specific areas. The three main areas of concern highlighted however, were:

- the very significant decrease in the number of graduates proceeding to post graduate and post doctoral training;
- the major movement for training from southern European countries to the north due to the lack of facilities in the former;

---

the organising of international congresses and meetings..' (EFB Newsletter, June, 1993, *Bio\technology*). The aims behind the EFB are to act as an 'inclusive' body. Every scientist in biotechnology who is a member of a Member Society of the EFB would be eligible to become a 'personal corresponding member' of the Federation. The main purpose then was to build an overall forum for biotechnology in Europe.

- the variation between European countries in the training period for the PhD degree which inhibits mobility.

The meeting also concluded that an uncommon market for scientific labour existed and that national variations whilst rich in diversity, also act as structural obstacles to transnational labour mobility at a time whereby pressures to acquire highly qualified personnel is accelerating in particular regions.

Policy recommendations

The recommendations made were not dissimilar to those made in the first meeting in London. For example, first, it was recommended that the biotechnology industry should continue developing the interaction between academia and industry. Furthermore, industrial involvement in course design and course content should be encouraged with special emphasis given to postgraduate courses. Second, it was suggested that undergraduate training should be broadly based with specialism being taught only in the final stages. Resources and facilities in academic institutions for training should be improved and especially in regard to postgraduate training in southern Europe. Communication, team-working and social skills were also highlighted as important and necessary skills. For example:

> '[p]ersonnel trained in biotechnology must be able to operate as part of a multidisciplinary team. For this reason they should have training elements in management, marketing, financial and legal aspects, including intellectual property rights, as well as a sound basis in science and technology which in

> itself must inculcate multidisciplinary competence and attitudes' (Bryce and Bennet, 1990, p.5).

Third, it was recommended that the provision of short courses on a range of topics should be developed for updating and retraining of the workforce. In particular, training grants were cited as a mechanism for facilitating labour mobility. The harmonisation of qualifications across Europe, in particular the PhD training period also was recommended, along with a general improvement of the public perception of biotechnology:

> '[I]t is of crucial importance that the general public's understanding of biotechnology be encouraged and increased. This can only be achieved by sustained effort by all involved with biotechnology and by using as effectively as possible all appropriate means' (Bryce and Bennet, 1990, p.5).

Finally, following the overall theme of the Conference on European co-operation in skills related issues, it was recommended that projects should have a European scope in order to achieve a critical mass together with the other benefits of transnational ventures. It was stated that the Commission should be made aware of the collaborative network formed by the European Federation of Biotechnology, professional organisations and biotechnology industry throughout Europe and its willingness to be involved in a variety of initiatives. It was suggested that the close liaison between members should be maintained and that co-ordination between the European Commission and national initiatives should be encouraged further and developed. Thus a feasibility study, leading to a Europe-wide, comprehensive assessment of labour and training requirements and provisions for biotechnology was suggested to be intimated as soon as possible. The aim of this proposed study would be to include all sectors of biotechnology, levels and types of training and roles of biotechnology personnel throughout the industry. As part of the study, it was intended that an inventory of training and exchange opportunities throughout Europe with the same coverage would be constructed and effectively disseminated. It was recommended that the extended network of the European Federation Working Party on Biotechnology Education, the UK Interest Group on Education on Biotechnology, professional associations and industry were necessary partners for such a programme. Funding, it was considered, should be provided jointly by the European Commission and by the biotechnology industry, for example via the COMETT II programme. The principal objective of the COMETT programme (COMmmunity programme for Education and Training in Technology) was to provide Europe with highly skilled scientific and technical personnel through a broad range of measures including: short training courses in advanced technology areas; personnel exchanges between university and enterprise; the development of training materials which focus on open and distance learning (suitable for working people); training needs analysis within a region or particular technology sector. The first phase of the COMETT programme (COMETT I) covered the period 1987-1989 during which had budget of more than 50 million ECU was allocated to over 1,400 projects (Walshe et al, 1993). The second phase of the programme (COMETT II) runs from 1990-1994 with and estimated budget of 230 million ECU. COMETT has pursued the following objectives of: to pool experience and mutual expertise for the benefit of users; to accelerate the practical exploitation of R&D findings; to encourage the development and implementation of training activities which meet the real needs of industry. The COMETT Programme was launched in 1989 to promote co-operation between universities and industry concerning the field of technology and to address the needs of small and medium sized enterprises Definition of an SME varies from country to country however according to COMETT, an SME was defined as a company with no more than 500 employees. One of the objectives of COMETT was to target SME development through the vehicle of the University Enterprise Training Partnership (UETP). The UETP constituted the core of COMETT and COMETT II with 205 UETPs in total supported throughout the life of the COMETT programme. Located across the member states, the aim of the UETP was to act as a training consortia bringing together industry and academia with the primary function to identify training needs of a particular sector or region and to initiate training activities on a transnational basis (Walshe et al, 1993). In practice, therefore UETPs have organised conferences, student placements, personnel exchanges, training needs analysis of sectors and regions and short courses. One of the primary objectives of the COMETT programme, was to use the UETP as a vehicle for stimulating communication between small firms and university or other enterprises on a transnational scale across Europe. The idea behind this was that the high technology small firms was constricted by limited finances and little time to keep up with developments in science and technology. As a consequence, structured knowledge transfer (through training) was considered to be often non-existent. For the small firm, participation in the COMETT programme enabled them to access a Europe-wide network of technical knowledge more quickly than developing the relevant 'know-how' in-house. In particular the programme emphasised the development of multi media training packages and 'distance-learning' as a means of diffusing knowledge and skills around established networks.

To summarise, the raison d'être for the BEMET study originated from the UK Interest Group Working Party on Education reports that skills and training are a critical factor input into European competitiveness in the global biotechnology industry. The main tenet of these reports resonate with the discussion in chapter one on the expediency of improving a nations' structural competitiveness in a global economy through supply-side measures such as investment in skills and training. As I argued in chapter three, these ideas are not particularly new ones. However, the argument re-emerged alongside the rhetoric of globalisation and the role of government to act as a facilitator and the provider of supply-side policies. A discussion of project BEMET is turned to below.

3. THE UNIVERSITY ENTERPRISE TRAINING PARTNERSHIP BEMET (BIOTECHNOLOGY IN EUROPE, MANPOWER EDUCATION AND TRAINING 1990-1994)

The outcome of the European meeting was a proposal from the UK Interest Group to the European Commission COMETT programme to fund a three year sectoral investigation into the current and future skills requirements of firms in the biotechnology industry. In addition, a further investigation would identify the availability of training provision in biotechnology across West Europe. Thus, following a successful bid to the European Commission COMETT programme, in 1990 a sectoral, pan-European University Enterprise Training Partnership (UETP) called BEMET (Biotechnology in Europe, Manpower, Education and Training) was established. The UETP was a unique structure assembling industry, academia, policy and interest groups to co-operate on manpower, training and education issues. This in itself was unique in that it created a forum for discussion between different groups in biotechnology that previously did not have the resources to meet and discuss issues related to manpower and training on a European level. The organisational structure of UETP BEMET is shown in figure 7.1 and the primary aims of the UETP are shown in Table 7.1.[4] The training needs analysis (project BEMET) ran from 1990-1993 with the primary function of evaluating the manpower and training requirements of biotechnology firms and to review the current courses available for training in the area in higher education. Between 1990-93, project BEMET undertook a sectoral investigation of the training needs of biotechnology firms across Europe. There were a number of methodological problems for undertaking this investigation and these are discussed in more specific detail in the *Appendix*. The following section discusses the findings from this empirical research on the skills needs of biotech firms and how they relate to the overall perceptions on biotechnology labour markets according to the UK Interest Group Working Party on Education and to previous labour market studies discussed in chapter six.

---

4 The BEMET secretariat was held at The Biochemical Society in London and The Nottingham Trent University and managed by a pan-European Board of representatives from the UK Interest Group, the European Federation of Biotechnology Working Party on Education, Trade Associations, UETPs and the European Biotechnology Industry. The list of representatives on the steering board are listed in the appendix to this chapter.

The following section then seeks to answer the specific research question that BEMET was set up to explore: are European biotechnology firms experienced a skills deficit, if so in which areas and what are their training needs? The research indicates that the labour market is more complex than conventional theories relating to labour market theory imply, with a range of other factors critically impeding the functioning of a perfect labour market. It suggests that the market for highly skilled scientists and technologists is more adequately explained by taking the market as an institution, rather than a simple mechanism of exchange. At a deeper level, the research enquiry reveals the more specific problems for European firms in *accessing* scientific labour and why including cultural attitudes and national differences and inherent problems in the structure of biotechnology firms related to finance and training.

4. DISCUSSION OF SURVEY RESULTS

This section reviews the results of a pan-European survey of over 230 biotechnology firms. The organisation of this section is as follows. The first part describes the sample group of firms. It is argued that the sample constitutes a representative selection of biotechnology firms following the earlier description of the industry in chapters four and five. The next section shows the qualification profile of biotechnology workers as a set of very highly skilled scientists and technologists which follows my earlier argument in chapter two that contemporary production systems have become more knowledge-intensive. The third section moves on to discuss whether skills shortages characterise the industry. The research findings show that overall there tends to be an adequate supply of scientific labour for the general sciences, however skills shortages do occur in highly selective areas and for positions that are relatively new. However, firms are more concerned with the *quality* of applications, rather than *quantity* and this is discussed in the fourth part. The next section discuses the anticipated levels of demand for workers in biotechnology with the overall trend being upward. Section six looks at the training needs of firms - which tend to be in selective areas, particularly in management and in southern European countries - and the delivery and financing of training which reveals national differences. The discussion moves on to consider whether the brain drain is a reality or myth and reveals mixed perceptions, with finally a general discussion in relation to labour markets and the broader obstacles to labour market functioning within the European Union such as cultural differences and the problems challenging high technology small firms for recruiting from an enlarged global labour market.

4.1 Sample

Biotechnology activity is generally more concentrated in the northern European countries. The geographical distribution of companies in the sample group demonstrated this concentration of firms in the northern regions of Europe (figure 7.2). Across Europe, biotechnology firms are primarily located in the 'banana' of Europe, running from the South East of the UK, to northern Europe (the Netherlands, Belgium, northern France and Germany down into northern Italy). Table 7.2 shows the actual location of firms in countries. The sample size (239 firms) and the breakdown by country is shown in Table 7.3. As it was discussed in chapter five, there are a preponderance of biotech firms located in Britain and this is represented in the sample.

In chapter four, (*cf section 4.4*), biotechnology was described as a generic technology, driven by a set of rapidly, evolving and powerful techniques with a pervasive effect on industrial sectors. In addition, it was argued that the impact of biotechnology has been more profound on the health care sector as a consequence of public funding of cancer and medical research (*cf chapter five*). The pervasive effect of biotechnology across a broad range of manufacturing sectors was also discussed and categorised into healthcare, food and beverages, agriculture and the environment. The sample used for this investigation also demonstrates the broad range of commercial sectors where biotechnology firms can be found. Since the strongest impact of biotechnology has been in the health care industry, there is a preponderance of firms operating in this sector relative to the other commercial industries using biotechnology. This was represented in the sample group with over 30 per cent of the sample either fully engaged, or partially engaged along with other activities within the health care industries (see table 7.4). When analysed more closely, the dominance of the health care sector in individual countries is clearly marked, with the exception of Ireland, whereby biotechnology is more actively used in the food and beverages sectors (see figure 7.3).

As discussed in chapter four, the industrial structure of biotechnology is characterised primarily by a dynamic small firm sector. These dedicated biotech companies are generally 'spin-outs' from academic or publicly funded research centres, or established entrepreneurs seeking to exploit publicly funded research. In addition, however there are a number of companies using biotechnology (chemicals, pharmaceuticals, waste treatment, food processing and so forth) which are typically larger, often multinational type activities. Overall, the sample correlates with this description of the industrial structure of biotechnology, dominated (70 per cent) by small firms employing up to 100 employees, although of this, nearly 30 per cent employ less than 20 workers. The remaining 30 per cent of companies were primarily small-scale operations of larger, multinational corporations (see figure 7.4). The size of the biotechnology firms in this investigation also correspond with the earlier discussion on the market development of biotechnology and that most biotechnology companies are still engaged in earlier stages of research and development with very few, large-scale production activities and commercialisation activities as yet taking place within the sector (see figure 7.5). The preponderance of small firms is indicative of these R&D activities. In addition, when broken down by country, a large number of small firms are located in countries that have a more developed 'national system of innovation' in the life sciences, for instance in Britain, France, Scandinavia, and Germany (see figure 7.6). Overall, the larger firms in the sample are located in the southern European countries and Ireland. The next section discusses why biotechnology is considered to be a knowledge-intensive activity.

4.2 Knowledge-Based Industry: Qualifications and Skills Profile of Biotech Workers

Previous labour market studies have shown that the qualification profile of workers in the biotechnology sector favours highly skilled scientific and technical staff (*cf. chapter five*).

Over 200 companies (over 80 per cent) have Ph.D. qualified staff working in the firm, with the rest of the staff qualified at a post-graduate level or with highly technical qualifications corresponding to degrees. Overall, the qualification levels of staff were categorised into doctoral level, masters, graduate, diploma and technical qualifications. (The categories on the questionnaire did receive queries from firms given the disparity of education systems across the member states). The number of companies employing staff at these different levels demonstrates the importance of skills and qualifications to the industry (see figure 7.7). Breaking this down more closely, over 40 per cent of staff in Management and R&D hold Ph.D. qualifications, with over 40 per cent of staff working in the highly specialised areas of molecular genetics, pharmacology and immunology (see table 7.5). The next section discusses skills shortages in the biotechnology sector.

4.3 Skills Shortages in the Biotechnology Labour Market

In the previous chapter, it was shown that the widely held perception among policy makers, particularly in Britain and at the European level, is that there is a skills deficit facing the biotechnology industry. However, studies undertaken in the labour market indicate that whilst skills shortages occur - *these are highly selective and within specialised scientific areas*. The case study investigation reported here also revealed that skills shortages may not be as widespread as conventional wisdom on the economic development of the biotechnology industry infers. This is discussed below.

Selective skills shortages

Firms reported that the most widely recruited sets of 'skills' in the biotechnology industry was for scientific labour in biochemistry, microbiology and engineering and overall for staff working in R&D activities. The concentration of recruitment activities in these areas reinforces the assumption made by the UK Interest Group that employers search workers with a broad range skills base with specialisation coming later. In addition, the concentration of activities in R&D indicates the relatively infant stages of biotechnology economic development (see figure 7.8 and 7.9). The investigation also revealed that in the most popularly recruited scientific labour was relatively easy to recruit (for example, biochemists, microbiologists) with the exception of suitably skilled engineers and immunologists for the biotechnology sector (figure 7.10). As one firm based in Italy commented on the problem facing small firms competing with large firms for highly skilled labour:

> '..big companies are more attractive to highly skilled biologists, I am looking everywhere in Europe for skilled biologists in immunology and diagnostic techniques..' (Italian firm).

In addition, small firms tend to be highly specialised in specific areas and given that biotechnology is still a relatively new technology, small firms are likely to suffer from a shortage of highly selective skills. As one firm in Denmark commented, '.. small companies like us tend to be specialised and will always have problems..' Overall where recruitment problems were identified, they tended to be in the more specialised areas where biotechnology is still a relatively new and uncommercialised such as agriculture, the environment and fine chemicals. Thus it is clear that some sectors are more likely to suffer from skills deficits than others. For example, a large proportion of firms working in environment, agriculture, energy and fine chemicals (see tables 7.6 and 7.7) indicated that recruitment for of suitable staff for these sectors was problematic. This compares to the more established health care and food and drink sectors were skills deficits were far less marked for R&D (see table 7.6). One possible reason to explain this is that biotechnology activity is relatively more mature in these two sectors than in the 'new' commercial areas and that skills have been developed over a longer period of time.

However, the survey revealed that firms' concerns were far more heavily concentrated around recruiting suitable scientific staff with management skills to work in the commercial areas of the firm such as marketing and management (see figure 7.11). Indeed, the survey revealed that securing skilled scientists with managerial expertise did represent an acute labour market problem for the industry. As one Managing Director from a small Italian biotechnology company put it:

> 'Any particular problems as far as recruitment is concerned lies with technicians at all levels, however there are some real problems recruiting figures which have to link high level scientific background with managerial experience, most of all in those areas where in Italy industries have been involved for too few years to create a generation of scientists/managers' (Italian firm).

And on this issue, a firm in The Netherlands stated , '...I see no directed problems but the combination of businessman and scientist is hard to find..' Another firm claimed that there was an '...unawareness of high technology knowledge at the top management. Policy strategy is too much directed to short term satisfaction of shareholders..'

Recruitment Problems and Effects on Business

A number of firms indicated that the pace of R&D, motivation levels within the firm along with general business development had been effected by the failure to obtain appropriate staff. Overall, there were national differences concerning the effect of this on business. For instance, one small firm based in the Netherlands and using biotechnology techniques in the veterinary sector, commented on the problems recruiting for a new sector. As a relatively new sector for biotechnology techniques, the company had been largely unsuccessful in recruiting the necessary skilled veterinarians with the desired competencies. The following remarks were made concerning the costs of this to the company:

> 'It is mainly extra work for the remaining veterinarians in the staff - and because of this some biologists and agricultural trained MSc's are joining the staff instead of vets' (firm in the Netherlands)

Another small firm in Italy indicated that business had directly suffered as a consequence of unsatisfied recruitment needs with the Managing Director commenting:

> 'I can estimate that we have lost our potential business as a result of not being able to recruit skilled immunologists and sales and product specialists' (firm in Italy).

Other firms based in Italy also complained that R&D and production had slowed down as a result and in turn, *this was having a major impact on investments* into the business. Similar comments were made ranging from the slowing down day-to-day business and motivations within the small firm. For example, one firm in Britain stated:

> 'It is really difficult to assess but there may have been some affects on scientific standards and certainly on problems solving capabilities' (firm in Britain).

Personal contacts, networks and 'knowledge of knowledge'

In terms of how firms recruit, in the last chapter, labour market studies of biotechnology show that there is a general tendency for small firms to rely on personal contacts within the industry and rely on the national labour market. This was also found to be the case in this survey (see figure 7.12). One of the reasons for this is related to the time necessary to undertake recruitment (as Boosveld and Van Der Kwaak (1992) argue see chapter six). Equally, it is clear that small firms are *disadvantaged* in 'the knowledge structure' - in terms of accessing information on the labour market in comparison to large firms (cf. more generally chapter two; and in relation to the biotechnology industry, chapter five). Clearly in the case of the labour market for biotechnology, TNC's have greater information on the global labour market by virtue of their own scale and own internal labour market which is not territorially bound (see Salt, 1988). Although both large firms and small firms compete with one another for skilled personnel, small firms, however, frequently do not have the economies of scale necessary to recruit internationally or have access to labour market information. As one firm in Norway commented on small firms, '...they...will always need people with practical skills but I must emphasise the importance of knowledge - there is a need for information and short courses..' In comparison, clearly personal contacts are widened in a larger firm thus for larger firms recruitment in biotechnology appears to be easier. One large firm in the Netherlands commented on the relatively small numbers of scientists working in biotechnology and this made recruitment a relatively easy process, stating:

> 'Biotechnology in Europe is very well known group, many manpower supplies come out of this group from references and so forth. Recruitment is only by a few companies' (large firm based in The Netherlands)

And, in the investigation, only the large firms commented on how they would overcome potential skills shortage problems in their host country by looking out to global labour markets, stating:

> 'At Novo Nordisk we shall have to go to the USA and Japan to fulfil our needs for trained professionals in the future' (large firm in Denmark)
>
> 'We recruit from all countries including France, USA, Germany, Spain, Italy to meet our requirements' (large firm in Britain).

In comparison to small businesses, large firms have extended *trans*-national, internal labour markets from which to source their skills requirements. However, the transaction costs of entering global labour markets for small firms can often be too high. This raises an important issue in relation to the debates raised in chapter one and chapter two concerning Reich's argument about the globalisation of the labour market for 'symbolic analysts' in which he includes 'the biotechnologist'. The survey shows that small firms (which primarily make up the industry), recruit from personal networks and *national labour markets* using the national press to obtain staff. The implication of this finding for Reich's argument is that *the market for labour may be less global* than he assumes in his thesis.. Another implication of this for Reich's argument, which confirms my overall thesis, is that the labour market does not act as a *perfect market* whereby labour moves around freely meeting the demand needs of those prepared to pay the salaries that they so command. Instead, the labour market is highly *institutionalised* in the sense that it is governed by habits, norms and ways of recruiting specific to the culture and social structure of the firm or the entrepreneur. In addition , this creates a highly *imperfect* labour market for biotechnology, given that much of the recruitment is confined to 'knowledge of knowledge' - that is, the reliability of knowledge of those undertaking the actual 'searches' on where to look for specific skills, and the financial constraints imposed on small firms of being limited to a territory (national advertising) when the actual 'space' of biotechnology markets is highly transnational.

4.4 Future Levels Of Demand For Scientific Labour Entering The Biotechnology Industry

Conventional wisdom on supply of labour and the biotechnology labour market implies that the demand for biotechnology labour will increase during the next five years (Bryce and Bennet, 1989). The survey findings show that in 1993, the average biotechnology firm increased its workforce, with approximately 30 per cent doubling in size, with nearly 20 per cent more than doubling, and with only 20 per cent not experiencing any employment growth an less than 5 per cent decreasing the workforce (see table 7.8). When this is compared by country, only firms in Ireland (4 firms out of 12) experienced relatively large reductions in employment comparative to the rest of the European countries (table 7.9).

It is clear from the survey, and in accordance with Ernst and Young's survey (1995) (see last chapter) that the future trend in Europe, is for more employment opportunities in biotechnology. This survey shows that demand for staff in biochemistry, microbiology and fermentation technology is estimated to rise (see figure 7.13). Nearly 65 per cent of firms indicated that they would require skilled labour in immunology and engineering area (approximately 80 firms and 90 firms respectively), areas that were already cited as problem recruitment areas (for instance, see figure 7.9). From the findings, it is clear that biotech firms are beginning to feel more confident about the commercialisation of research by estimating more recruitment in marketing and public relations (see figure 7.14). However, there is likely to be a slow down in the recruitment of management in comparison to actual recruitment during the time of the survey (cf. figure 7.8).

4.5 Supply-Side Problems? Taking A Broader Assessment Of Firms' Needs

In response the question raised at the beginning of this enquiry - to what extent is there a skills deficit in the biotechnology labour market, this investigation shows that skills shortages in the biotechnology industry are more accurately defined as *selective* rather than *wide-spread.* The implications for policy-making of this finding are discussed in more detail in the following chapter. However, this discussion continues the theme of examining the dynamics of the biotechnology market *which move beyond the concerns of supply and demand* conceptual approaches to understanding labour market functions in this sector. The following section then, examines trends in the *quantity and quality* of applications for biotech positions according to the firms; explores the perceptions of firms about the labour market more generally, and how firms go about recruitment in this sector. As the survey findings show, the quantity of available labour figures less of an immediate problem than the quality of labour which is considered to be generally below the level required by the firm. Recruitment is concentrated on national labour markets and *ad hoc* measures such as 'knowledge of knowledge' through personal networks and contacts.

Across the firms, there is a general trend for the *supply* of applications for biotechnology positions to have increased. However, in relation to meeting specific recruitment needs, firms replied that *other factors* were effecting firms. Generally, these factors included the problems of small firms attracting highly qualified scientists and technologists, along with a general perception that there is a decline in the quality of applications received. Overall, there were specific *national* differences in terms of needs and perceptions - however, the overall theme in relation to the quantity and quality of available labour is generally unvaried. For example, in relation to the available supply of labour, one firm in Portugal responded that the relatively small scale of the biotechnology sector meant that the supply of scientific labour in Portugal was not a problem for their company stating:

> 'Due to the restricted number of biotechnology companies and to the appreciable offer of manpower there are at present no problems in relation to the manpower supply' (firm in Portugal).

A firm in Italy claimed:

> 'In my opinion, manpower and training are well dimensioned in certain countries and under dimensioned in others. Italy has sufficient manpower but not well trained' (firm in Italy).

Another firm in The Netherlands added; '..worried about the quality of scientific supply, worried about the quality of technical supply'. And in Finland the theme continued, '...the quantity is OK - its the quality that needs to be improved..'

Another problem is that many biotechnology companies are under severe pressure to recruit and to set up business quickly in their early stages (for example, see chapter six section 6.4). In this investigation, a large number of companies referred to the amount of time that was required to find suitably trained personnel, for example, a firm based in Italy commented '....it is extremely time consuming trying to find the right skilled workers and, in Switzerland one firm continued this theme of 'time' in the small firm , ...'the time loss due to the training of new staff is enormous - inevitably this effects the motivation of all staff in R&D..' Training and biotechnology firms is treated below.

4.6 Biotechnology Firms and Training

The UK Interest Group reported that there was rising demand for training activities among biotechnology firms, that training systems needed to be adaptive and responsive to the needs of industry; that there was a major movement of scientists from the southern European countries to the north to benefit from the more developed national systems of innovation there, and that disparity across the European countries training and education systems acts as a major obstacle to labour mobility. This survey revealed that overall training was available to firms, but less so in southern European countries. More of an obstacle, according to firms, is related to their size and the problems related to releasing personnel and financing training in an environment where workers are expected to perform a wide-range of tasks. This correlates to the earlier discussion on flat, non-hierarchical organisation in the flexible specialisation debate in chapter two.

One of the primary aims of the BEMET investigation then, has been to identify training needs in biotechnology firms. The dependency of these firms on the generation of new 'knowledge', 'know-how' and new techniques means that there is a high level of demand for training within the companies. This was illustrated in the survey, with over 80 per cent indicating that training was very important. One of the theoretical themes of this thesis is the intractable relationship between politics and economics. This was discussed at a theoretical level in chapter two and three, and specifically in relation to understanding the economic development of the biotechnology industry in chapters five and six. To repeat my theoretical argument follows in the tradition of radical political economists who have challenged the methodological individualism of neo-classical rational behaviour. In chapter five, I demonstrated how 'culture' and the social relations within society have had a direct bearing on the *pace* of economic development in the biotechnology sector. And, in chapter six, I argued that given the close relationship between small biotech firms and the public sector, knowledge creation activities in the biotechnology sector are highly *politicised*, where the national system of innovation is shaped by the political choices of the ruling elite. In so far that many small, biotech firms are particularly vulnerable to the political decisions of the state, the availability of training to the firms in many cases is dependent on the system of innovation in the host country, and the scientific and educational infrastructure already in place.

Overall, firms responded that training was easily available in their country (60 per cent) (see table 7.10). Taking the accessibility and levels of training for specific scientific and technological areas, most of the training needs appeared to be satisfied, however nearly 30 per cent of the firms seeking training in the area of molecular genetics responded that training was generally poor in this area. Looking more closely at training and breaking down the responses by country, national differences do emerge. For example, closer analysis reveals disparity across the regions for firms accessing training. Firms based in Greece, Spain, Italy and Portugal indicated severe problems accessing training compared to companies based in the north. This is shown in table 7.11 and in table 7.12. For instance, 40 per cent of firms from Greece, Spain and Portugal (South) responded that training was inadequate there for R&D activities, with a further 30 per cent indicating that training was poor (see table 7.13). In production activities, training needs appeared more acute not only for the southern countries, equally, in Germany and the Britain, 40 per cent and 30 per centre respectively, responded that training was poor for this area (see table 7.14).

The problems challenging scientists to also act as *managers* which is particularly the case for small biotech firms was a general theme underpinning the UK Interest Group Meetings. For example, one of their recommendations was that more training was required in the management areas for training in commercial areas such as finance, marketing and public relations and for increasing the awareness of scientists of business. Overall, the survey shows that very few firms (around 50 per cent of the total number of companies per country) are seeking training in management and marketing. Of those, around 35 per cent of firms indicated that training was only adequate for these areas (see table 7.15 and 7.16). In Britain and the Netherlands, where biotechnology is more advanced and therefore at closer stages of commercialisation, 20 per cent of firms indicated that training for management was poor or unavailable and in Germany and the southern European countries 30 per cent. More firms in Britain and the Netherlands indicated that training provision in marketing and PR activities was either good or excellent, with more firms in Germany, the southern European countries and Belgium stating that training for this area was either only adequate, or poor, or not available (see table 7.15). When invited to comment on scientists as 'managers', many stated that 'scientists' lacked sufficient training and awareness of the commercial environment. For instance, on firm in the Netherlands commented; '..research managers often have a scientific background and lack training in management..'., with another adding, '..there is a need for management training in R&D project management and strategic R&D management.' One Belgian company summed up the general tone of comments made by a large number of firms in the survey:

> '...experience in management is lacking. It could endanger the future of the company. The Scientists are "afraid of doing business" they don't know the vocabulary of the business man and they think businessmen are existing in order to crook scientists. The best thing to do is put them into business schools for two years there they can learn business is only a question of common sense ..' (firm in Belgium).

Types and Areas of Training

The types of training used by firms appears to vary, however the most popularly used media are workshops, courses, conferences and in-house learning. Interestingly, despite efforts by the European Commission Framework Programmes for developing multi-media training; exchanges of scientific staff and distance learning throughout the European Union, these are hardly used by biotech firms (see figure 7.14). One of the reasons for this could be linked to the fragmented sources of information concerning biotechnology courses and training. For example, this was revealed in the *Positive Actions* exercise (see Walshe et al, 1993), an evaluation of the biotechnology COMETT programmes for COMETT and in the BEMET research investigation of training provision available across Europe (Griffin et al, 1993). Many other companies stated in the survey that attending conferences and advanced courses in biotechnology was desirable and a major media for remaining ahead of technological advancements. However, this was not always a feasible strategy for the small firm and as some firms clearly pointed out this method of training was not only costly financially but, equally, a time-consuming exercise.

In terms of the *areas* of training used, the survey revealed that the most important area of training for firms is in *updating* and *remaining abreast with key scientific developments,* for example, over 35 per cent of all company training is in this area see figure 7.16. In terms of identifying specific training needs for biotechnology firms, according to companies advanced level training were not presently satisfied. For instance, respondents indicated that 'the levels of training were too low' (Netherlands) and that 'this should be the main type of training improved ' (Portugal). The need to correspond to the multidisciplinary character of biotechnology was also recognised with one firm stating that '..practical courses are limited to a single technique or discipline' (Italy). Furthermore, there was a general negativity towards 'up-dating' training provision on offer to firms. For example, many British based companies commented on the differentiation of training provision across the disciplines. One Portuguese firm commented that their training strategy was '...accomplished somewhat through the reading of scientific journals.'

Although firms responded that training for management was generally inadequate or poor in their country, it is interesting to note that a small percentage (15 per cent) of all training activity is dedicated to improving business skills of scientific staff, although this was anticipated to increase in the future to over 20 per cent of all training. Even less is used on making scientific staff aware of business skills or increasing the awareness of non-scientific staff of science. The future emphasis of training then appears to move from being heavily for keeping staff up-to-date to more evenly spread training across the categories. This is seen more clearly in France, the Netherlands and in Britain in Table 7.17. It is clear that differences in national and cultural value-systems occur. For example, the Netherlands and France are closer together in their anticipated future training strategies, with firms in both countries replying that that training would shift from the research end towards to training the scientific staff in business skills, and non-scientific staff awareness of the needs of scientists. In comparison, firms in Britain replied that they would be concentrating more training efforts into new areas of biotechnology research and up-dating present staff, with no increase in training science staff in an awareness of business, and unlike France and the Netherlands, for improving the awareness if science for non-scientific staff.

The financial structure for biotechnology and training

In chapters three and five, it was argued that the finance of biotechnology was a major factor challenging many small firms, with the real possibilities of firms running out of available investment for research and development. Given the extremely long lead times and stages to commercialisation the financial cost of supporting biotechnology had become a disincentive to many venture capitalists, particularly in Europe where the market for venture capital is already under-developed compared to the United States.

It is clear that the shortage of funding for biotechnology firms in Europe has had a major impact on firms' strategies towards training. Firms starved of funding to undertake research and development and production are unlikely to invest in the training side of its company. In this climate then, training is one area that small firms are facing problems funding adequately. It is not unsurprising then, that most firms indicated that government is the most important 'actor' for training in the sector.

According to firms, the vast proportion of training is supplied either at the expense of the firm, and to a lesser extent through the national government (see figure 7.17). However, *over 50 per cent of firms responded that it was the responsibility of the state* to provide the necessary infrastructure for training in biotechnology (table 7.18). Many of the multi-national firms taking part in this investigation however, clearly saw the provision of applied research and training to be the responsibility of the firm.

Equally, the findings show country by country differentiation reflecting the variations in culture and national systems of innovation across Europe. For example, in Italy, it was suggested that the state has an integral role for the provision of education and training. One firm commented on his thoughts in relation to training and the role of the state in Italy:

> 'SMEs will need the help of government mainly in training their staff. Otherwise manpower should be duly trained during school age. In any case the public authorities intervention is necessary' (firm in Italy).

On the other hand, a number of firms, particularly in Britain saw education and training to be delivered through a 'partnership' between industry and the public sector. Yet, in Britain, many firms commented on the problems challenging small firms in relation to training given their organisational structure, with personnel expected to be multi-disciplinary and perform a wide-range of tasks. For example, Massey's (1994) study of science park workers shows how scientific workers are expected to perform a wide range of tasks and Bryce et al (1989) argue that one of the real problems identifying skills needs in this sector is linked to the multi-disciplinary base of biotech workers. These inherent obstacles in the structure of firms combined with lack of finance for training were identified as structural problems challenging firms in relation to meeting their own training requirements, a complaint noted by participants at the BEMET 'workshop' sessions (*see methodology appendix).* For example, one firm pointed to the problem of loosing staff while on a course, '...the loss of individual skills either by leaving the office or 'out of the office' for training presents practical problems for us..' Another commented on the financial pressures experienced by biotech firms, ..'too many companies opt out of training staff. Economic pressures are exacerbating the situation..' and that training was often resourced in-house '..we had to resource our own adequate training functions to grow our own..' And one firm replied that strategic planning in small firms for training was too difficult because; ..'training and staff supply cannot be easily planned for the medium and long terms..'.

Companies were also asked to comment on *what steps should be taken to meet the training and education needs of companies?*[5] In response, the general theme was an increase in sponsoring of training in the firm; increasing the co-operation and dialogue between public agencies and industry and an *improvement in access to information* on available courses and workshops (see table 7.21). Furthermore, companies also commented on facilitating training by offering more incentives as inducements to small firms. For example, one firm in the Netherlands stated that government should create: '... more facilities, for example, tax reductions for people who follow courses on a private basis..' Similarly, one firm in Britain commented that:

> '.. schemes to allow very small companies to train staff without suffering too much income loss should be provided. Training ought to be seen as an investment both socially and commercially to attract fiscal concessions..' (firm in Britain).

One firm based in Ireland commented on the unevenness of government policy towards the allocation of grants for training there which disqualified state research agencies from state assistance, stating ...

> 'training is restricted across the board due to lack of funding for example, government grants of up to 50 per cent are paid to commercial companies by the training authority but are not available to state R&D bodies' (firm in Ireland)

In relation to the education and training institutes offering education and training, firms felt that there could be more dialogue and co-operation between industry and training providers. Furthermore, that the training providers offered a wider range of types of

---

5 This was in the form of an 'open question' on the survey questionnaire.

courses to accommodate small firms. As one firm in Britain put it, there is a need for '...greater flexibility in training methods, more opportunities for evening only study, allowing individuals easier access to courses..' Equally, firms also suggested that more could be done to help themselves. The general theme throughout the comments was that firms needed to take training more seriously. For instance, one firm in the Netherlands stated ; '...increasingly companies have to realise that monies spent on training are well spent..'

This section has provided some empirical evidence in response to the frequently cited argument as regards biotechnology development that there is a rising demand for training activities among biotech firms, that training systems need to be more flexible, that scientific labour was moving from southern Europe to the north in order to gain access the more developed science infrastructure thus better opportunities there, and finally, that the disparity across the European countries training and education systems prevented labour mobility.

First, the survey revealed that training was highly in demand by firms. However, it is clear from these findings that overall training was considered to be available to firms, however, in specific scientific niches, training was generally either unavailable or poor. It is also clear that country by country variation exists. One of the assumptions underpinning this survey was that biotech firms now required managers and that suitable skilled scientist managers were hard to recruit. However, the survey showed that only half of the sample were seeking training in this area, although on management, training was generally inadequate. One of the reasons for this low number of firms seeking training in the commercial areas could be directly linked to the low number of firms reaching the market stage for their products (as indicated in chapter five on the discussion of the sector). Working on the assumption that biotechnology will in the future, develop at a more rapid pace, it could be argued that there is a policy justification for addressing this area of training for the industry.

It is also clear that despite framework programmes initiated by the European Commission, to support multi media training and exchanges of personnel is still undertaken through traditional methods as conference attendance and in-house learning. There are perhaps, two reasons for this. The first relates to Russell's (1990) argument that the EC framework initiatives have generally been taken up by the large, multinational corporations, despite attempts at the European level to directly involve small firms. The second reason is explained by the findings of this research - the transaction costs involved in being part of large scale funded initiatives are often too high for the newly started firm. Alternatively, the proliferation of information sources in relation to available schemes at the European level is also another obstacle from small firms from participating in these programmes.

This section also empirically supported the argument advanced at a conceptual level in chapter three concerning labour market analysis and the role of institutions and the broader macroeconomy, and in chapter five, which argued that finance (and demand) have been major factors determining the pace of biotechnology development in Europe.

Here it has been shown that the shortage of funding facing biotech firms has had a major impact on firms' attitudes towards training, normally the first area in the firm to be abandoned in the face of investment problems.

The discussion also reveals the relationship of the sector with the public realm and the variegated responses from firms in different member states in the European Union on the responsibility of training. This reveals important cultural attitudes towards the role of the state and the firm within, and it is evident that these values are by no means homogenous across the member states. At a political level then, this compounds the problems of the European project and the further, more 'deeper' integration of the European economic systems.

4.7 Brain Drains

In chapter six, it was shown that another characteristic of biotechnology labour markets is the idea that scientists are leaving Europe to go to the United States - commonly referred to as the brain drain. In addition, it is frequently cited in policy circles that young or experienced scientists are leaving Europe to go to the United States. However, as Bevan et al (1987) argue (see previous chapter), the slow down in growth and the maturing of biotechnology in North America has also been reducing the demand for migrants. In this investigation, the firms reflected a mixture of perceptions concerning the 'brain drain' phenomenon. Some firms suggested that the brain drain was a characteristic of the European labour market. The reasons for this were linked to the greater opportunities and higher salaries that could be earned outside Europe. For example, a firm in Italy commented '..other countries mainly the USA offer more interesting scientific positions in a dynamic and stimulating environment..' However, following the concern of the UK Interest Group, the survey also found that there are concerns within Europe about a gravitation of skilled labour from the south to northern Europe, for instance on firm in Belgium stated,'...we have a supply to the UK. Keeping staff in the company more than five years is usually a problem' and another in Ireland commented on the '...worrying tendency for skills to gravitate to better developed industrialised regions, i.e. Germany, Netherlands, Britain and US and Australia'. This was also identified as a concern for southern European countries at the Second BEMET Conference held in Orense, Galicia, Spain in 1993 (Griffin et al 1993).

On the other hand, a large proportion of firms believed that the concept of the brain drain was misleading and that international mobility around the scientific community was welcome and necessary. In addition, some firms commented on how international mobility of labour diffused knowledge, skills and know-how around the scientific community and this was, on the whole, a positive phenomenon. Firms in Britain suggested that the free movement of people around a scientific network actively contributed to the diffusion of ideas. As a firm in Britain commented, '...international mobility is essential for creating a well trained force with creative ideas..' and that 'mobility is good in the area for the flow of information and techniques between labs' and another commented on the practical obstacles of the diffusion of knowledge and know-how around an industry that is characterised by secrecy, '..for students it would be a great opportunity to learn from of the situations/new insights. Staff mobility is a problem because of the secretness of the processes..' (Netherlands). One firm in Italy observed '..scientists go abroad more than in the past but also come back more than in the past. The brain drain is slowing down;' and '...in Portugal, the problem of the brain drain is not yet an acute one. The international mobility of staff and students is desirable and beneficial..' In Germany this view was echoed by one firm,'...we don't see a problem with this - students should move and travel more..' And another commented on the changing perceptions and a reversal of the brain drain to the United States:

> 'Italy is now bringing back its scientists from the US and Europe some of the people that emigrated - still there is a lot to do in order to ensure the appropriate conditions (equipment, salaries and so forth.)' (firm based in Germany).

This was supported by another firm in Britain stating, 'less of an issue to US now but can in fact reverse this trend and have recruited experts from the US..'

5. SKILLS SHORTAGES AND ECONOMIC DEVELOPMENT: AN EVALUATION OF THE SURVEY RESULTS

In the earlier chapters, I argued that despite the current interest in skills and training and its relationship with economic competitiveness, the labour market constitutes one strategic component of the overall production system. In chapter three, it was suggested that understanding the labour market as one characterised by the laws of supply and demand offer little insight into the behaviour of biotech labour markets. The general conclusion is that skills shortages are highly selective and not wide-spread across the European biotechnology industry and that overall it is not shortfalls *per se* of scientific labour that characterise these labour markets. Moreover, the European labour market is highly *imperfect and variegated* across Europe reflecting *differentiated national systems of innovation*, and *the inherent problems confronting small high technology firms* heavily reliant on their *national* environment for the science and technology infrastructure and financial system, but operating at a global level. As it was discussed in chapter five, the absence of know-how and knowledge for biotech firms can lead to a spiral of under-investment and for the small firm to seek strategic alliances with larger firms, rather than become fully integrated biotechnology firms.

Thus drawing from the theoretical arguments developed hitherto, along with the general conclusions reached in the previous chapter on other labour market studies and the empirical research here, it is clear that a deeper approach to understanding the relationship between the skills needs of firms and the economic development of the biotechnology industry is required. In this sense, it is necessary, to go beyond the concerns (and I would argue limited analysis) offered by skills shortage investigations of scientific labour markets for understanding the economic development of a knowledge-based sector which biotechnology represents. A broader evaluation of the survey results is now discussed using the theoretical tools developed hitherto in the previous chapters.

5.1 Beyond Skills Shortages: The Labour Market And The Production System

5.1.1 National Systems Of Innovation

One of the recommendations made at the UK Interest Group meeting in Delft (see earlier section in this chapter), was that the heterogeneous scientific and educational infrastructure of the European Union was a major impediment to labour mobility in Europe. This was a major disadvantage to European firms in terms of accessing the right 'know-how' and skilled labour. And, that co-operation in the area of developing skills and qualifications was necessary to facilitate the mobility of scientific labour across Europe.

As it was discussed in chapter six, despite the globalisation of knowledge (discussed in chapter two), the labour market is one area where the still nation-state exerts control. In many ways, education and training is still considered to be an important preserve of national sovereignty reflecting *a national culture* and a national value-system. The survey revealed that international and pan-European exchanges of personnel are relatively under utilised within the biotechnology sector despite the scientific labour market's *global* appearance. Indeed biotechnology firms commented on the disparity across Europe that *prevented* free labour mobility and access to knowledge and skills. These findings correlate with Teague's (1994) argument on national control of the labour market (cf. chapter two) and Thompson and Grahame (1995) have recently made a similar argument in their questioning of the reality of globalisation. One firm in the

Netherlands pointed to the incoherent social legislation facing European biotech small firms in the scientific labour market:

> 'More exchange of staff and students within Europe is required. National governments and the European Commission should encourage this by a simpler social legislation (easier housing, tax facilities, no pension cuts, easier to return to job at home etc.) and by financing the exchange (fellowships, sabbaticals etc.). On the other hand a high educational level of trainee is required to be an interesting candidate for the institution abroad (exchange education has to pay off in additional research capacity)' (firm in the Netherlands);

another stated:

> 'in comparison to the United States, Europe is too nationalistic. Very little recruitment of highly skilled personnel from one country to another. Differences in taxes and social security are bottlenecks.' (firm in the Netherlands).

The issue of access to information of market for skills and knowledge was also cited by one company in France, commenting that the EC should:

> '. ..compile frequently updated records of companies and research labs with contact addresses, names, telephone numbers and telefax numbers in member states divided into different subject areas and distribute to different labs..'(firm in France).

Another company based in Ireland commented on the disparity of policies across the member states suggesting '.. the sooner we have an agreed pan-European policy the better co-ordination to avoid duplication..' On the issue of labour mobility, another (large) firm in Britain commented that '...we would welcome more co-operation in this area - we regularly take foreign students for up to one year' whilst a small biotech company in Britain cited the opposite, claiming that '..this has a limited impact on our company.'

National and cultural differences and the role of social forces in relation to the economic development of biotechnology were discussed in chapter five. Here it was argued that these factors have an important bearing on labour market outcomes. For example the role of ethical lobby groups concerned with the longer term implications of some aspects of biotechnology techniques and processes. As it was discussed this was particularly pertinent in the case of biotech development. Furthermore, these national and cultural differences have implications for the development of a co-ordinated labour market in Europe with one firm in Germany commenting '..this is incredibly problematic in Germany due to the regulations and biocracy.'

Overall, the survey revealed that the public perception of biotechnology tended to be negative, with the onus being on domestic groups and the media for information about biotechnology. In Italy, firms reported severe constraints in relation to the public perception of biotechnology there. For example, One firm in Italy stated that '...it is getting better - but we are still about ten years behind the USA and Japan in terms of industrial development;' and that:

> '..in spite of growing interest for biotoechnologies in many working fields part of the public, media and political classes fear that biotechnology represents a future danger' (firm in Italy).

Another firm in Italy commented:

> 'Bad or missing information has generated big expectations and consequently disappointment. Biotechnology is often regarded as dangerous and uncontrollable. Confusion exists between biotechnologies and bio-ethical issues'

and that public perception had been '..an Italian disaster - we import near all products for blood diagnostics..'

In other countries, firms reported similar themes. In Portugal, '...the public is still very afraid of it. Mainly caused by publications in journals and TV programmes' and in the Netherlands, one firm stated that '...biotechnology is to a great extent considered as suspicious..'. The Ministry for Agriculture in the Netherlands summarised the general feeling there:

> 'Biotechnology is often considered as synonymous for dangerous gene manipulation and excessive power of multinationals in agriculture. Action groups take repeatedly the lead in the news and workers in the field are pushed into defence. A platform for public discussions on the pros and contras is missing, but [is] of utmost importance' (Ministry for Agriculture, The Netherlands).

Firms in the Netherlands commented that public perception '..could be better and should be improved at high school level..' and that the '..public lacks basic knowledge to understand the fast developments, the public is not predictable..' and that it was '..sometimes negative because of unknown and not clear threats of biotechnology for some people ... but that's a minority group..' One Norwegian firm commented on the 'urgent need for objective information..' and in Austria firms commented on the strength of the domestic forces there, '...the green organisation believes in new dangers coming out of biotechnology for mankind..' and that in Austria there is a 'strong ecological/green movement thus quite weak acceptance of high technology but a high acceptance of ecological sound actions..' In Britain the feeling was very similar; with comments from firms ranging from how the public are 'wary of the implications of DNA manipulations..'

and that 'perception is nil..' and that biotechnology is 'viewed with a lot of suspicion and a lot of misunderstanding..' with a 'concern at the lack of appreciation of benefits of science and technology and possible over emphasis of negative effect of progress..' A company in France commented on the lack of information to the public stating '..the public are not well informed : they have misinformed ideas about what biotechnology means. People in agriculture have a better perception of biotechnology.' One firm in Belgium summed up the dangers of this prevailing mood, '.. biotechnology could be an opportunity for the future but no-one is really aware of that!'

Furthermore, in chapter five, the differences between the United States and European development of biotechnology was also discussed. As it was argued, one of the reasons for the dynamic industrial structure of biotechnology firms in the United States was attributed to government funding and a dynamic venture capital market for high-risk technologies. In addition, it was argued that European biotechnology has generally been characterised by developments within academe, and as Sharp comments there has been a lack of entrepreneurial activity in European biotechnology more widely. One of the problems can be linked to the overall financial structure for the industry and the lack of available capital for developing European biotechnology from the private sector. Equally however, the organisation of academe and their linkages with industry has been recognised as one vital link in the value chain of biotechnology start-up development (Sharp, 1987). Major differences exist across Europe in the organisation of science and the commercialisation of science and technology. On the whole, the role of the university in Europe has been far more polemical (Strange, 1987). One firm in Belgian comments on this stating:

> 'In Europe science is very advanced. But there is no proper link between the $ and science! This is at the origin of the quasi-failure of biotechnology in Europe. In the United States there are start ups in Europe there are not. We first need co-ordination of research and second training of business people' (firm in Belgium).

and:

> '..there are very few start ups because there is no sense of initiative and scientists are afraid of doing business.'

Thus while on the whole the majority of firms seem to indicate that international mobility of labour was highly desirable in reality the structural obstacles to the free movement of people dominated the industry.

5.1.2 The Labour Market And A Broader Structure Of Power

The imperfect market for biotechnology labour is also conditioned by the 'knowledge of knowledge' of firms. As I showed earlier, the survey illustrated that many of the biotech firms relied on personal contacts (and national press) for recruitment purposes. This demonstrates that despite the global characteristics of the biotechnology sector, the firms themselves are not recruiting from a global labour market which in turn leads to the direct questioning of Reich's overall thesis.

Recruitment on global labour markets is not only conditioned by access and control of information to labour market knowledge. Similarly, small firms are frequently unable to compete on an elite market for 'symbolic analysts.' This is compounded by the overall structural problems that were discussed in detail in chapter five in relation to the economic development of the sector, which are particularly challenging to small firms. For example, the firms commented on the problems of accessing human capital and the problems confronting small firms on an elite labour market. One firm in the Netherlands put it ; ' ..if there is enough capital there's no problem but for small companies that's a major problem - how to gather capital for manpower.' and '... the price of labour is the bottleneck. Contracting out is not attractive, because of very high upfront payments and the very limited technology transfer..' A company in Austria explained ; '...SMEs will get into more difficulties in the supply of manpower in connection with high salaries and difference of regulations towards SMEs..' An Italian firm suggested that '...the problem facing SMEs needs to be advertised properly and for SMEs to be appealing to the manpower available..' However, other firms commented on the barriers confronting small firms '... small companies cannot guarantee life time employment making the barriers a more severe problem..' (firm in Netherlands) and one firm in France explained:

> '..the main problems for such companies if offering security and career structure to staff without which it is difficult to attract the right candidates. Scientists on contractual work must be able to produce high quality publishable results : companies must provide the infrastructure for this' (firm based in France).

This was also felt by and firm in Ireland, commenting '..SMEs are unable to provide the salaries or career structures that the larger companies can provide to attract the best people..'

6. CONCLUSIONS

The aim of this chapter has been to demonstrate through an empirical examination of the biotechnology industry how knowledge inputs into the economy in the form of skills and training are but one part of an advanced production system which is itself articulated through the nation state societal system and the global industrial system. At a broad conceptual level, this argument is based on the analysis of the global system set out in chapter two which argues that contemporary industrial policy requires recognition of a new world order characterised by the interplay of firms and government as *strategic actors* in the industrial field. In this scenario, competition is both systemic and global and focused on quality more than costs. However, implicit in this argument (and contrary to conventional thinking about markets) is that governments, markets and hierarchies have a complementary and interactive role to play in the upgrading of human and physical assets and the restructuring of economic activity in the global economy. The argument is that skills and training are a necessary factor of production in the new world order, but, equally, the role of institutions and the socio-political environment are crucial to the restructuring of economic activity and competitiveness in the global economy.

The case study therefore, has served to support my overall thesis which questions the popular mantra of the relationship between investments in the workforce and firms competitiveness. This chapter has shown that European biotech firms have a number of concerns which may not necessarily be resolved through an increase in the supply of labour available to enter the sector, or by raising skills levels. As I argued in chapter six, there are several reasons other than a shortage of suitably qualified labour for why firms experience recruitment difficulties, and these were reflected in the study reported here. For example, the imperfect, fragmented (and, more often than not, national) labour market and the problems facing small firms accessing information about the labour market. This chapter provides a challenge to the conventional wisdom that in the knowledge economy, investments in skills and training are a panacea for economic growth.

Thus in terms of public policy, the study casts a number of doubts on the assumption that investments in education and training are the *prime determinant* of a nations' prosperity in the global economy (cf. chapter one). Drawing on the empirical discussion of European biotechnology in chapter five, it is clear that skills and training are one important dimension of an advanced production system, however, these are locked into a broader structure of capital, power and institutions. The investigation of firms' skills and training requirements presented here reveal that firms' concerns are far wider than those of the perceived skill deficit problem facing the industry.

This gives rise to two important issues. The first concerns the wider implications for public policy and for understanding state intervention and national competitiveness in the knowledge based economy. This is considered further in the concluding chapter. The second concern relates to the analysis of skills shortages and their overall relationship with the economy. The findings presented here indicate that the 'skills deficit' proposition as the critical factor impeding economic development (as advanced through the perspective of Reich, and increasingly, the European policy elites), is one part of a broader process and cannot be debated in one corner, with science policy and macroeconomic conditions debated in another (see Curran and Lovering, 1994). For example, contrary to popular perceptions of the skills deficit in biotechnology, the empirical research reported in this chapter shows that skill shortages are not as wide-spread as originally thought at the onset of this investigation. If this is the case, we must ask why, have skill shortages been directly related to the overall economic development and performance in the biotech sector? Thus, more generally, why have skills and training been taken as a panacea for growth?

In chapter one, I argued that the reasons for these assumptions are directly linked to the analyses of the contemporary period. A key point at issue in the debate is whether or not the international competitive position of an economy is actually important in practise. Reich (and Thurrow) believe it is but have been heavily criticised by economists such as Krugman for their willingness to promise policies that by their recipe for promoting high-value industries, they could not only improve the economy, but solve its problems (Krugman, 1994). As already indicated, their analysis has become the 'conventional wisdom' on the economy, particularly among the well meaning liberal left: the world economy has become globalised, and productivity growth must be increased in order to compete effectively in this new, harsh world. High-value industries (biotechnology) must be supported and the human capital of the nation upgraded through education and training. Only in this way can the living standards be secured and unemployment reduced. The European political classes, bemused by the scale of economic and social problems which confront them and bereft of any real solutions, regularly chant this mantra.

This perspective has rapidly become the new orthodoxy, especially in Britain where the wide spread view is that a big part of the poor economic performance of the UK is attributable to the poor skill levels of a large portion of the UK workforce making this an important issue, (not least, perhaps, because of the media attention that it regularly attracts). However, despite this perennial concern, there is a general reluctance to go beyond the headlines and clarify the debate and where possible sketch the nature of recruitment difficulties and contextualise these problems in the broader political economy of high technology development.

Research by Robinson exposes this myth. He argues that skill shortages themselves have very little economic impact on an economy, unless the whole economy is experiencing considerable growth (Robinson, 1996). In his assessment of skill shortages in the British economy, Robinson considers data from three surveys reporting on the incidence of skill shortages, the CBI Quarterly Industrial Trends Survey, the

British Chamber of Commerce Quarterly Economic Survey, and the annual Skill Needs Survey carried out on behalf of the Department of Employment. In his analysis of these surveys, Robinson argues that up until 1980s, firms tended to rate skill shortages as a more important constraint than shortages of physical capacity. Since 1980 capacity constraints have been reported as more important and indeed by April, 1995, while one in ten manufacturing firms were reporting skill shortages as a constraint, one in four were reporting capacity constraints. The late 1980s peak in the proportion of firms reporting skill shortages as a constraint (28 per cent in October 1988 according to CBI) caused much renewed concern over the nature and consequences of possible skill deficiencies for Britain's economic performance. However, as the peak was almost identical to the peaks in the 1970s (27 per cent in October 1978, CBI data) and well below the peaks in the 1960s. Robinson suggests that reported skill shortages only increased sharply in the late 1980s when the economy was going through a period of very rapid output growth and sharply falling unemployment. This leaves open the possibility that a more sedate pace of output growth and a more gradual reduction in unemployment might not have caused serious skill shortage problems. Additionally, during the Lawson boom in 1987-8 the pace of the expansion was such that manufacturing employment was actually increasing in contrast to the quite rapid fall in manufacturing employment over the rest of the period since 1979.

The point here is that only when manufacturing output was rising so rapidly and manufacturing employment was also rising did skill shortages in manufacturing increase sharply. Robinson (1996) argues that this research points to the pace of expansion as being a crucial variable in determining whether or not skill shortages became a significant problem. A similar finding is made by Sentance and Williams. They argue that another reason why skill shortages has been seen as major impediment to economic growth, (and an argument vigorously supported by the business interest groups such as the CBI) is that skill shortages increase the rate of manufacturing wage inflation over the period 1983-9 (Sentance and Williams, 1989). However, their research for the CBI shows that skill shortages and other demand led variables had not been the major cause of manufacturing wage inflation during the period 1983-9. Moreover, the skill shortages variable was acting as a proxy for all the demand-led variables, and especially growing profit levels, which would have been pushing up wage inflation.

Another myth is that investments in skills and training will automatically increase productivity and economic growth (Hutton, 1996). Sentance and Williams show that there is only a very weak relationship at an industry level between output and employment growth on one hand, and skill shortages on the other. In other words those industries which were growing rapidly did not tend to experience above average increases in reported skill shortages. It is only when the manufacturing sector (and the economy) as a whole was growing strongly that skill shortages began to emerge. Sentance and Williams also noted that this suggested that the skills which were in high demand must be quite mobile across industries. This research has been supported by Haskell and Martin (1993) who found that variations in skill shortages had little effect on wages across industries, but the aggregate skill shortages across the whole economy has an effect on aggregate inflation. So just as Sentance and Williams found no link between output and employment growth in particular industries and skill shortages in those industries, so Haskel and Martins found no link between skill shortages in particular industries and wages in those industries.

The main point here is that specific sectors may suffer more acute shortages but the evidence is strong that such sector-specific shortages do not put significant upward pressure on pay, in part because the skills in demand do seem quite highly mobile across sectors. In the case of biotechnology then, it could be argued that the initial growth of the sector during the 1980s with the proliferation of biotechnology firms that have followed this development, inevitably led to a skill shortage problem in specific areas because of the time lag involved between producing skilled individuals and their entry into the labour market. In addition, as an infant industry at primarily R&D stages, the relevant skills, 'learning-by-doing' experience along with commercial skills is generally under developed, (areas where research by Faulkner and Senker into science and technology inputs in the biotechnology sector found to be the most important 'knowledge' contributions to the firm (Faulkner and Senker, 1992), which would explain why many firms in this survey have commented on the lack of experienced staff and managers available within the sector.

In terms of specific policy response for supporting education and training for knowledge-based industries, once it has been proved possible to sketch in this way the nature of recruitment difficulties facing biotechnology firms, it becomes feasible to think about the appropriate response in terms of public policy. For example, it is clear that in some specific discipline areas and management training, the empirical research found a problem with regard to the *quality* of state training schemes in some European countries. However, there appeared to be no real obvious problem with the supply of courses. There is a general question here then concerning the type of training required. Despite the general euphoria around the 'biotechnology revolution', the present size of the biotechnology sector (in terms of employment creation and wealth creation) does not necessarily justify large-scale training programmes which have in the European case tended to benefit the larger (and less needy) firms. Additionally, drawing on my theoretical argument advanced earlier and supported by this study of biotechnology, a public policy geared towards large scale investments in education and training at the opportunity cost of other policies based on the recognition that in some sectors increasing returns will apply. Moreover, small-scale, well targeted, well co-ordinated, high-quality programmes organised at the national level might have modest significantly positive effects, and the scale of the problems in European countries might argue for just such a small high-quality scheme.

What about labour market schemes at the European level? As I have argued previously, co-ordination of the labour market at a European Union level is particularly problematic because of the role of institutions and the social organisation of individual member states. The creation of a pan-European labour market whereby workers move round freely is still, in many cases, for the majority a myth. However, as this research has revealed there is scope for European co-operation in the area of information on labour market activity - particularly within a sector such as biotechnology where the labour market is still relatively small scale and highly specialised. The heterogeneous nature of the labour market for biotech workers and the dependence of small biotech firms on national recruitment, infers that collaborative programmes at the European level or co-ordinated within and across member states, designed to enhance the effectiveness of job search or to improve job placement or matching derives can have modestly significant positive effects on participants' job and earnings prospects (for example, see OECD, 1993; Robinson, 1995).

Based on the case of biotechnology, I have argued that an industrial policy based on investments in skills may be ineffectual by itself as means of developing competitiveness. In addition, the role of the nation-state as a facilitator within the global economy, pursing supply-side policies, rather than as a pro-active *strategic* actor can also be called into question. Having shown both theoretically and empirically, that such strategies may only offer half-way measures for raising overall living standards, the next chapter discusses the overall ramifications of these findings, not only for academic debate on the global political economy and the role of skills and training in it; but equally, at a policy level, especially Britain, where the current trend in the thinking of the New Left has been to adopt the conventional wisdom which has been aptly referred to as 'supply-side socialism' (Thompson, 1996).

Figure 7.1 Organisation and Structure of the Project

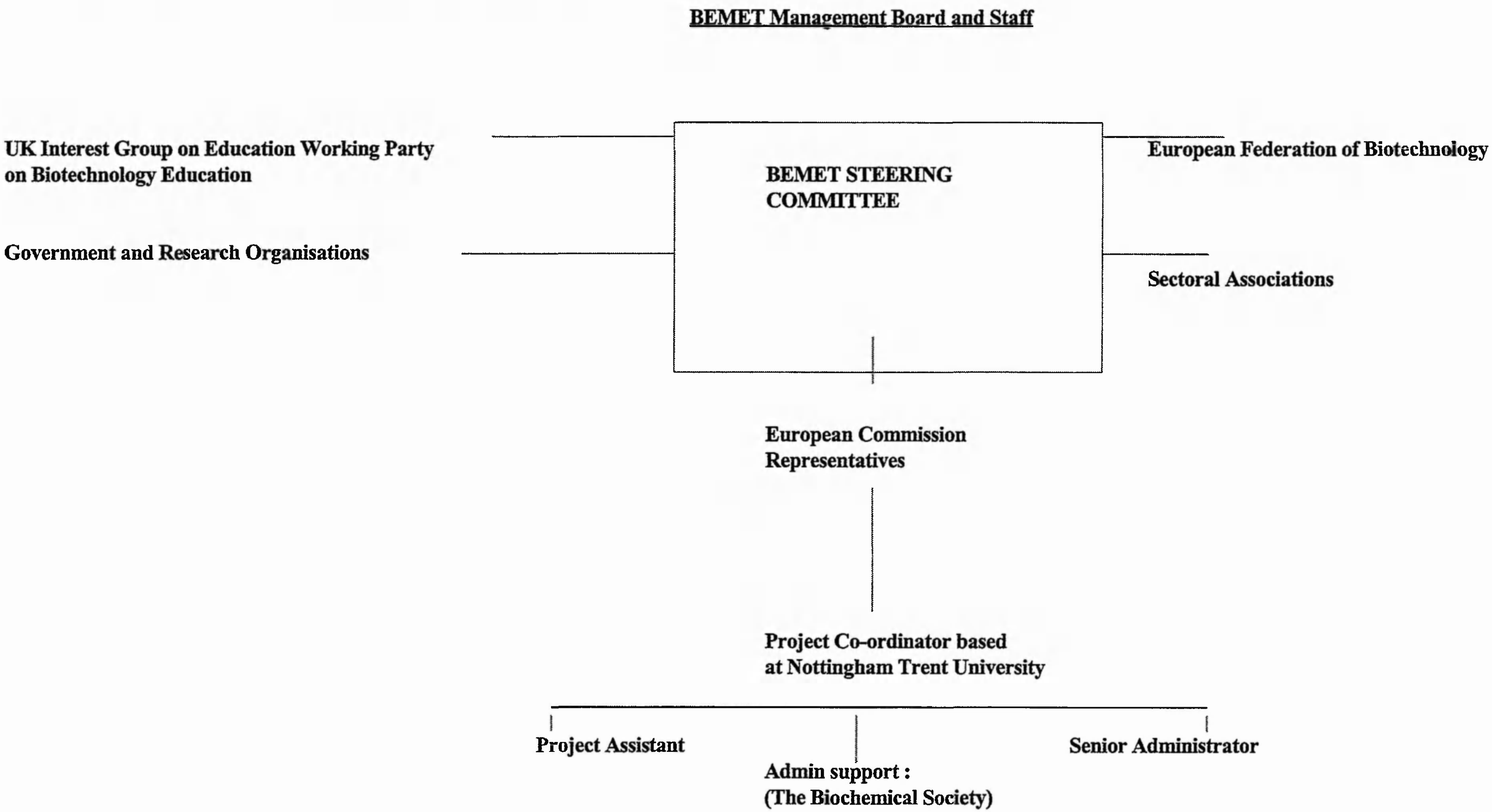


Table 7.1 Aims and Objectives of BEMET

Primary objectives
1. to identify biotechnology skill shortages in specific areas and disciplines across EC and EFTA Member States;
2. to investigate existing training provision by creating an up to date inventory of biotechnology courses across EC and EFTA member states;
In addition to these objectives BEMET also has six trans-European aims;
3. to facilitate the development of training programmes in biotechnology, including scientific and professional updating and open and distance learning, by its members, other COMETT projects and other organisations;
4. to facilitate the development and dissemination of a range of complementary materials related to the wider aspects of education and training in biotechnology for the general public and schools;
5. to aid in the harmonisation of qualifications in biotechnology throughout Europe to facilitate transnational mobility of students and staff;
6. to facilitate arrangements for transnational and academia/industry exchanges of students and staff;
7. to establish an effective network for the exchange of resource materials in biotechnology education and training ;
8. to promote the improvement of general public understanding of biotechnology and its applications as part of the activities of 1-7 above.

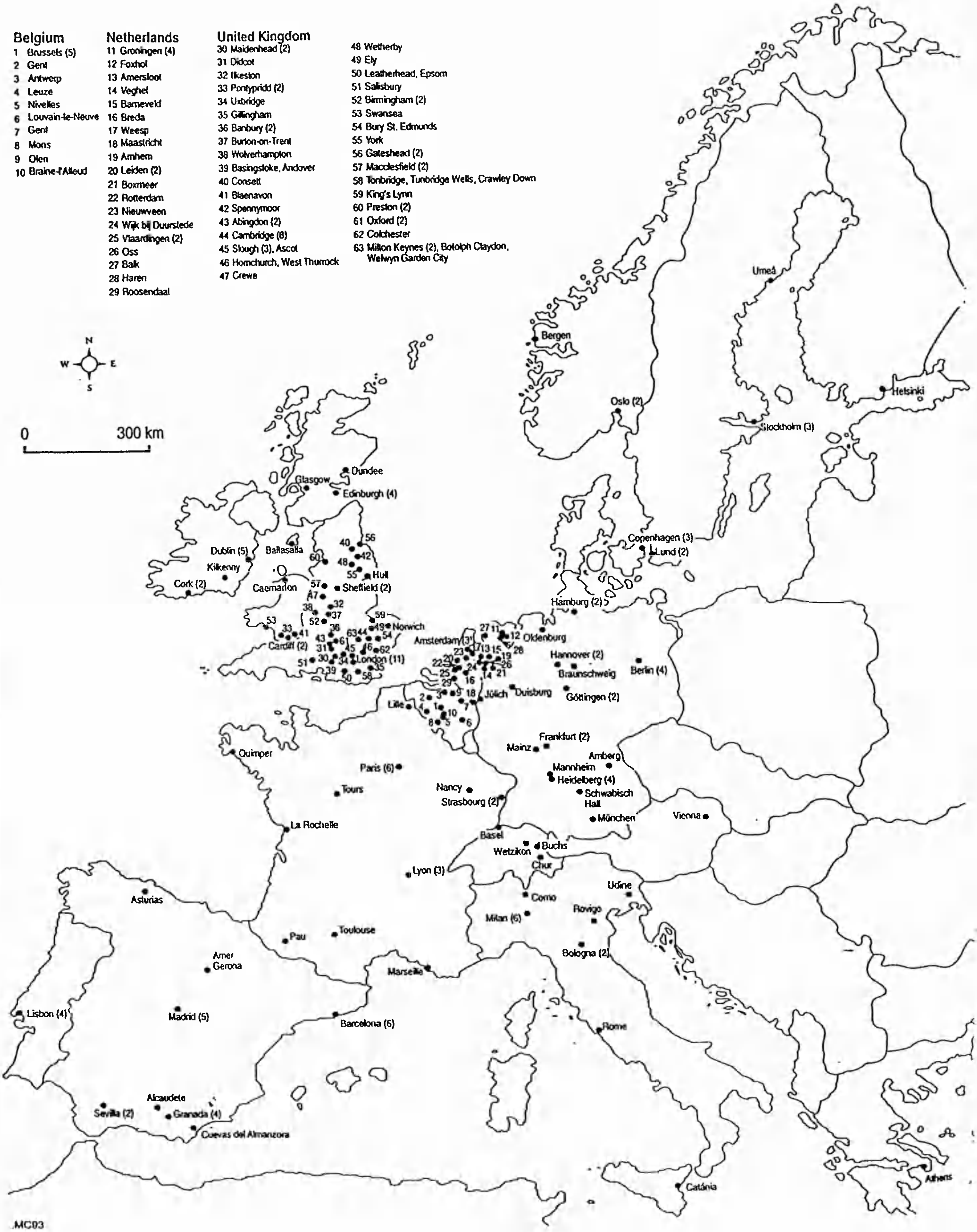
Table 7.2

Geographical Distribution of Firms in Sample

British Isles	
Scotland	
Dundee	1
Glasgow	1
Edinburgh	4
Wales	
Cardiff	2
Caernarfon	1
Pontypridd	2
Blaenavon	1
Swansea	1
England (North)	
Consett	1
Homchurch	1
West Thurrock	1
York	1
Gateshead	2
Wetherby	1
Spennymoor	2
Macclesfield	2
Sheffield	2
Crewe	1
Preston	2
England (Midlands)	
Birmingham	2
Wolverhampton	1
Ilkeston	1
Burton-on-Trent	1
England (South and South East)	
Norwich	1
London	11
Maidenhead	2
Didcot	1
Uxbridge	1
Gillingham	1
Banbury	2
Basingstoke	1
Andover	1
Abingdon	2
Cambridge	8
Slough	2
Ascott	1
Ely	1
Leatherhead	1
Salisbury	1
Bury St Edmunds	1
Tunbridge	1
Tunbridge Wells	1
Crawley Down	1
King's Lynn	1
Oxford	2
Colchester	1
Milton Keynes	2
Botolph Clayton	1
Welwyn Garden City	1
Belgium	
Brussels	5
Gent	1
Antwerp	1
Leuze	1
Nivelles	1
Louvain-La- Neuve	1
Gent	1
Mons	1
Olen	1
Braine L'Allend	1
Denmark	
Copenhagen	3
Sweden	
Lund	2
Stockholm	3
Umea	1
Finland	
Helsinki	1
Norway	

Bergen	1
Oslo	2
The Netherlands	
Amsterdam	3
Groningen	3
Foxhol	1
Amersfoot	1
Veghel	1
Barneveld	1
Breda	1
Weesp	1
Mastricht	1
Arnhem	1
Leiden	2
Boxmeer	1
Rotterdam	1
Nieuwveen	1
Wijk bij Duurstede	1
Vlaardingen	2
Oss	1
Balk	1
Haren	1
Rosendaal	1
Germany (North)	
Hamburg	2
Oldenburg	1
Hannover	2
Julick	1
Duisburg	1
Braunschweig	1
Gottingen	1
Berlin	4
Germany (South)	
Frankfurt	2
Mainz	1
Amberg	1
Hiedelberg	4
Schwasbisch Hall	1
Munchen	1
Austria	
Vienna	1
Switzerland	
Basel	1
Wietsikon	1
Buchs	1
Chur	1
Ireland	
Dublin	5
Cork	2
Kilkenny	1
Italy (north)	
Milan	6
Como	1
Udine	1
Rovigo	1
Bologna	2
Italy (south)	
Rome	1
France (north)	
Lille	1
Paris	6
Quimper	1
Tours	1
La Rochelle	1
Nancy	1
Strasbourg	2
France (south)	
Lyon	3
Toulouse	1
Pau	1
Marseille	1
Spain (north)	
Aturias	1
Amer	1
Gerona	1
Madrid	5
Barcelona	6
Spain (south)	
Seville	2
Alcaudete	1
Granada	4
Cuevas del Almanzora	1
Portugal	
Lisbon	4
Greece	
Athens	1

Figure 7.2 Map to show distribution of firms by country



1-63 represents names of towns as indicated on map

Source : Hayward and Griffin, 1993

Table 7. 3

Breakdown of no. of respondents in self-selected sample group	
Country	*no of companies*
United Kingdom	65
Germany	24
France	29
Ireland	13
Italy	16
Netherlands	29
Greece	1
Spain	23
Portugal	4
Finland	5
Sweden	9
Norway	4
Denmark	6
Belgium	7
Austria	2
Switzerland	2
Total	239

Table 7.4

Market Sectors of sample firms		
Market Sectors*	no. of companies	(%)
Healthcare	127	(32)
Food and Beverages	80	(20)
Agriculture	65	(16)
Environmental	64	(16)
Fine Chemicals	50	(12.5)
Energy	7	(2)
Mining	1	(0.25)
Veterinary	2	(1)
Cosmetics	1	(0.25)

* all companies - some companies are involved in more than one commercial sector

Figure 7.3 Commercial Sectors by Country in Sample Group

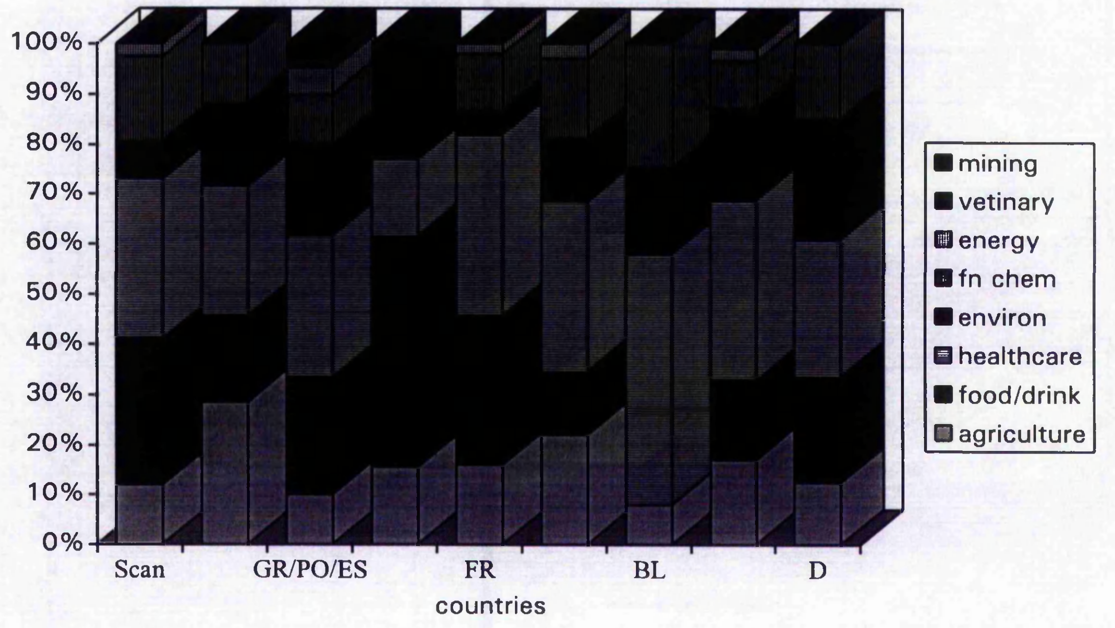


Figure 7.4 Distribution of firms by number employed in the sample

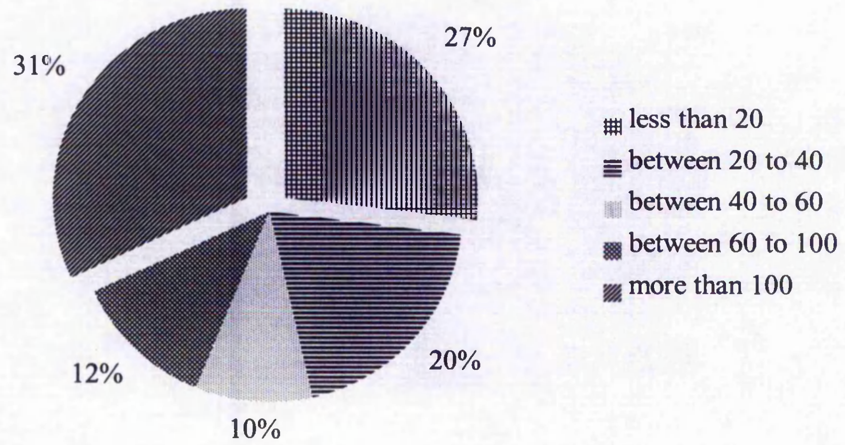


Figure 7.5 Allocation of workers by activity within the biotech firm

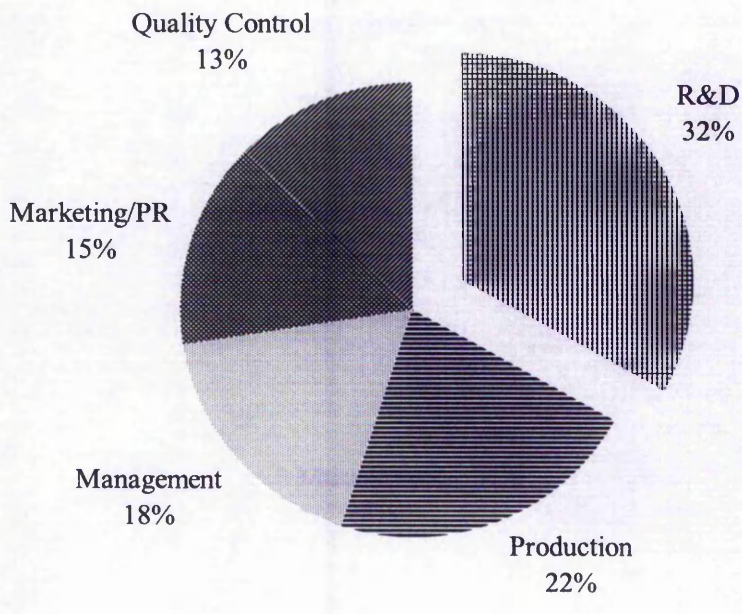


Figure 7.6 Comparison of distribution of firms according to numbers employed by country

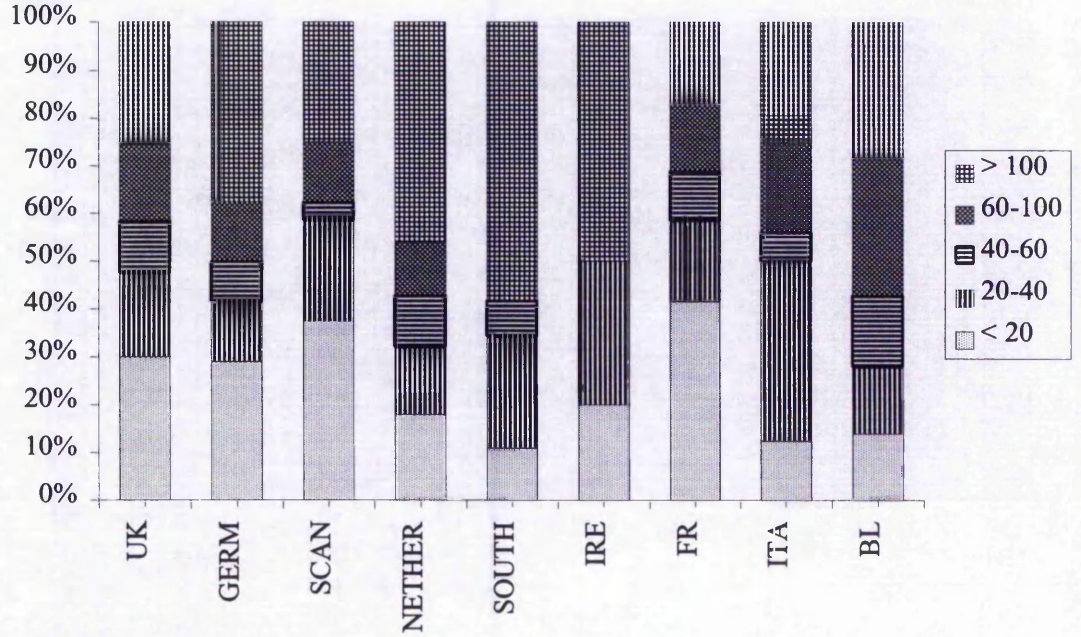


Figure 7.7 Number of companies employing staff qualified to Ph.D, Masters, Graduate, Diploma and Technical grades.

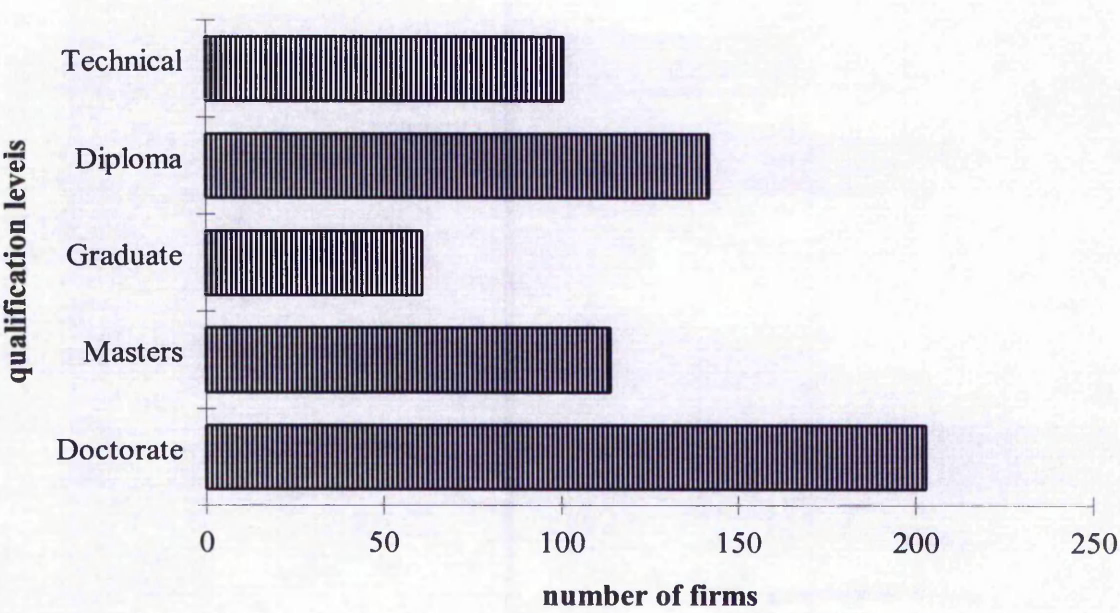


Table 7.5 Qualification profile of biotech staff in sample firms according to area of work

	R&D	Prod	Mang	Market /PR	QCon	biochem	micro	ferment	molec gen	animal science	pharm.	immun.	plant science	engin	information technology
Doctoral	79	29	47	31	17	80	59	29	42	13	29	31	20	18	24
Masters	34	23	24	20	13	34	30	27	21	10	19	11	16	20	11
Graduate	15	17	10	7	12	19	16	9	8	4	10	9	8	14	7
Diploma	43	34	23	21	21	58	47	24	16	13	16	17	15	16	79
Technical	35	32	5	12	17	41	40	25	17	9	6	13	13	16	10

Figure 7.8 Most popularly recruited scientific labour by firms (1991-93)

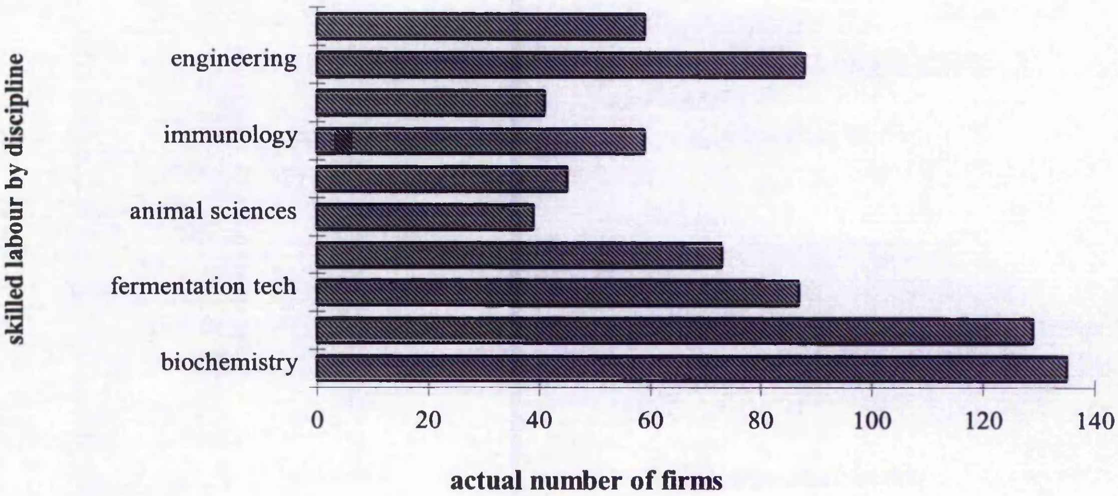


Figure 7.9 Most popular recruited occupational area (1991-93)

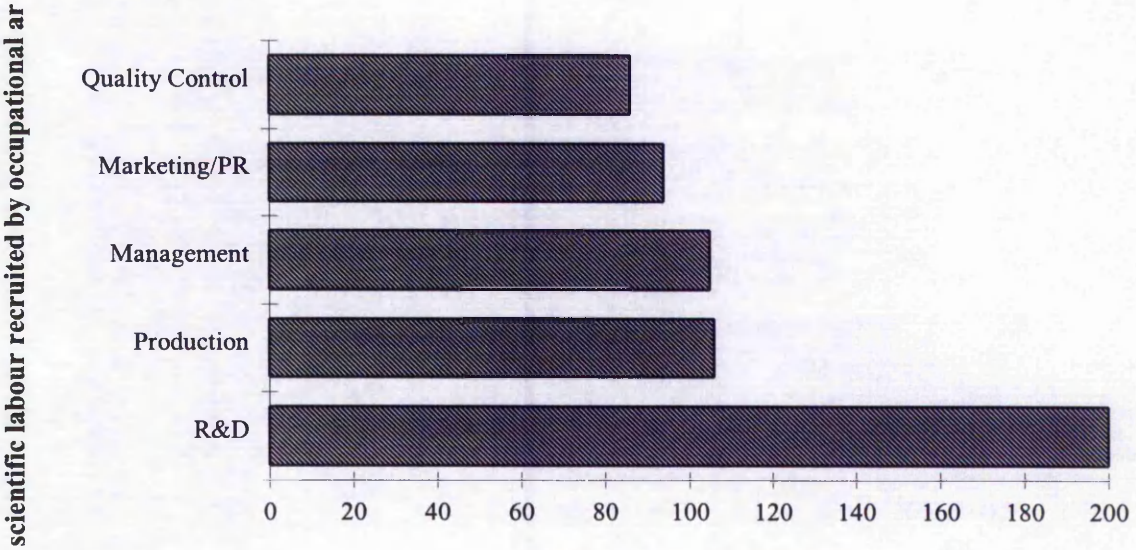


Figure 7.10 Recruitment of scientific labour by biotechnology firms (1991-93)

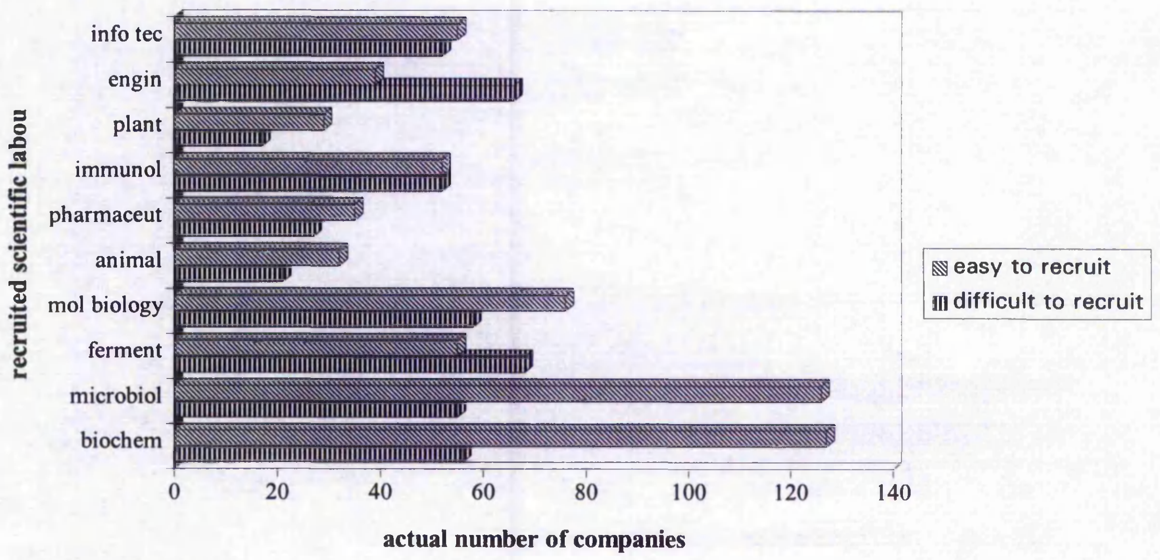


Figure 7.11 Recruitment of biotechnology firms categorised by occupational areas in the firm

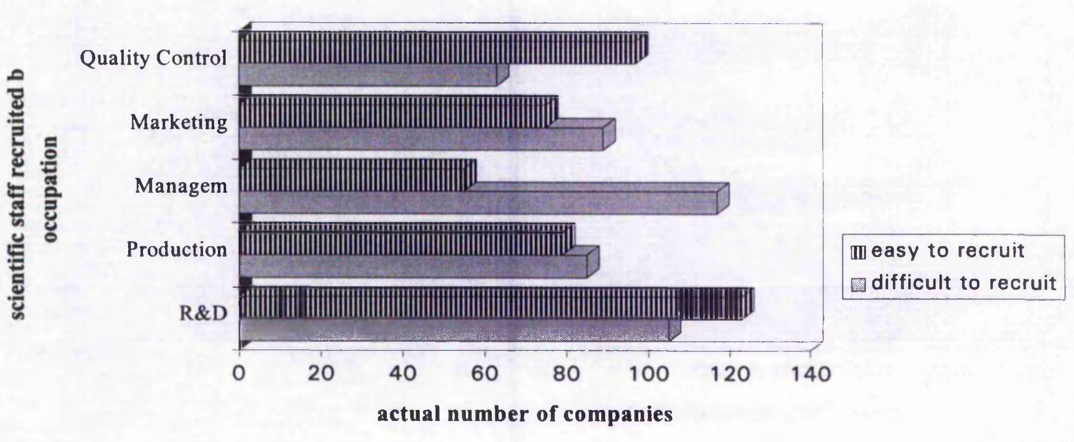


Table 7.6 Facility of recruitment in the health care, agriculture, food and energy sectors

	health		agriculture		food		energy	
	difficult	*easy*	*difficult*	*easy*	*difficult*	*easy*	*difficult*	*easy*
R&D	38	47	21	21	16	27	0	1
Production	35	25	15	14	12	23	0	1
Management	39	16	28	8	25	12	0	1
Marketing	25	25	20	11	23	17	0	1
Quality Control	27	30	14	16	9	26	1	1

Table 7.7 Facility of recruitment in the environment, fine chemicals, mining and vetinary sectors

	environment		fine chemicals		mining		vetinary	
	difficult	*easy*	*difficult*	*easy*	*difficult*	*easy*	*difficult*	*easy*
R&D	19	17	8	9	1	1	1	0
Production	10	10	11	6	0	0	1	0
Management	15	4	10	2	0	0	0	1
Marketing and PR	11	13	9	7	1	0	0	0
Quality Control	7	14	5	10	0	0	0	0

Table 7.8 Percentage change in size of workforce in 1993 compared to 1992 for all companies

Percentage change in size of workforce	
	%
decrease	4
static	20.5
up by 25 %	24
up by 50 %	1
up by 70 %	6.5
100 %	27
more than 100 %	17
total number of firms	215

Figure 7.12 Methods of Recruitment

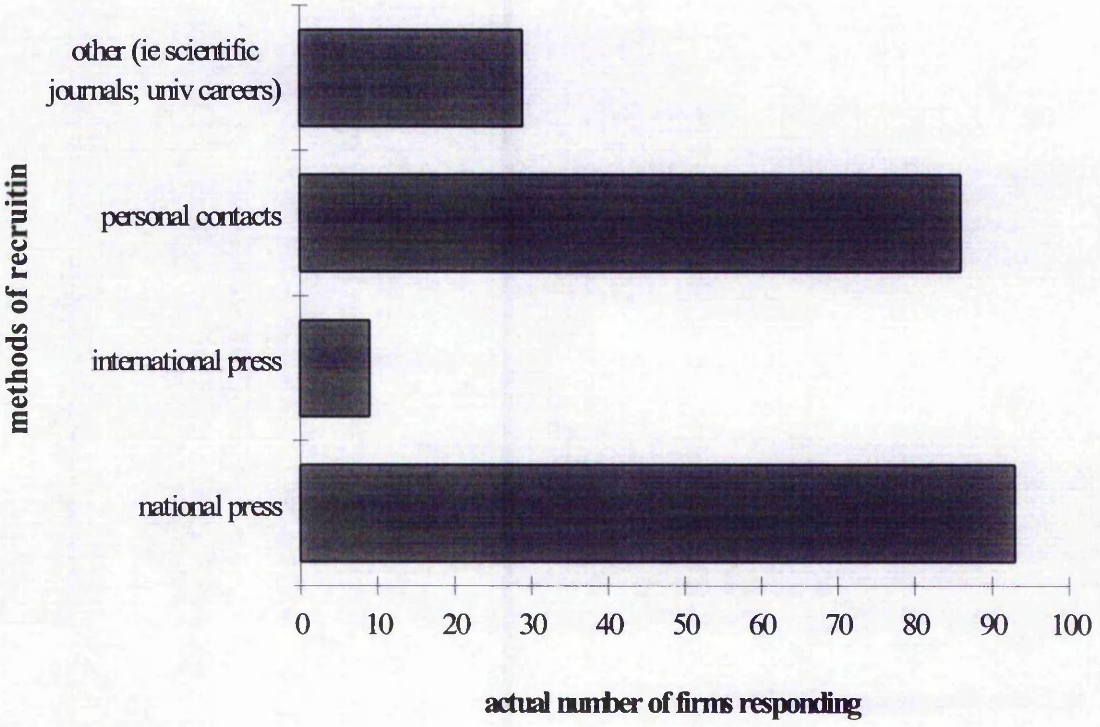


Table 7.9 Comparison of change in the size of the workforce by countries in 1993 compared to 1992

	DECREASE	STATIC	INCREASE	total no of firms
Europe*	5	20	75	215
Netherlands	0	36	64	26
Greece, Portugal, Spain	4	27	69	24
Ireland	30	0	70	12
Germany	9	18	73	22
France	0	16.5	83.5	24
Italy	6	19	75	16
Britain	2	21	77	61
Belgium	0	17	83	6
Scandinavia	0	8.5	91.5	24

Notes * includes repondents from Austria and Switzerland

Figure 7.13 Forecasted demand according to firms for staff over the next 5 years by academic discipline

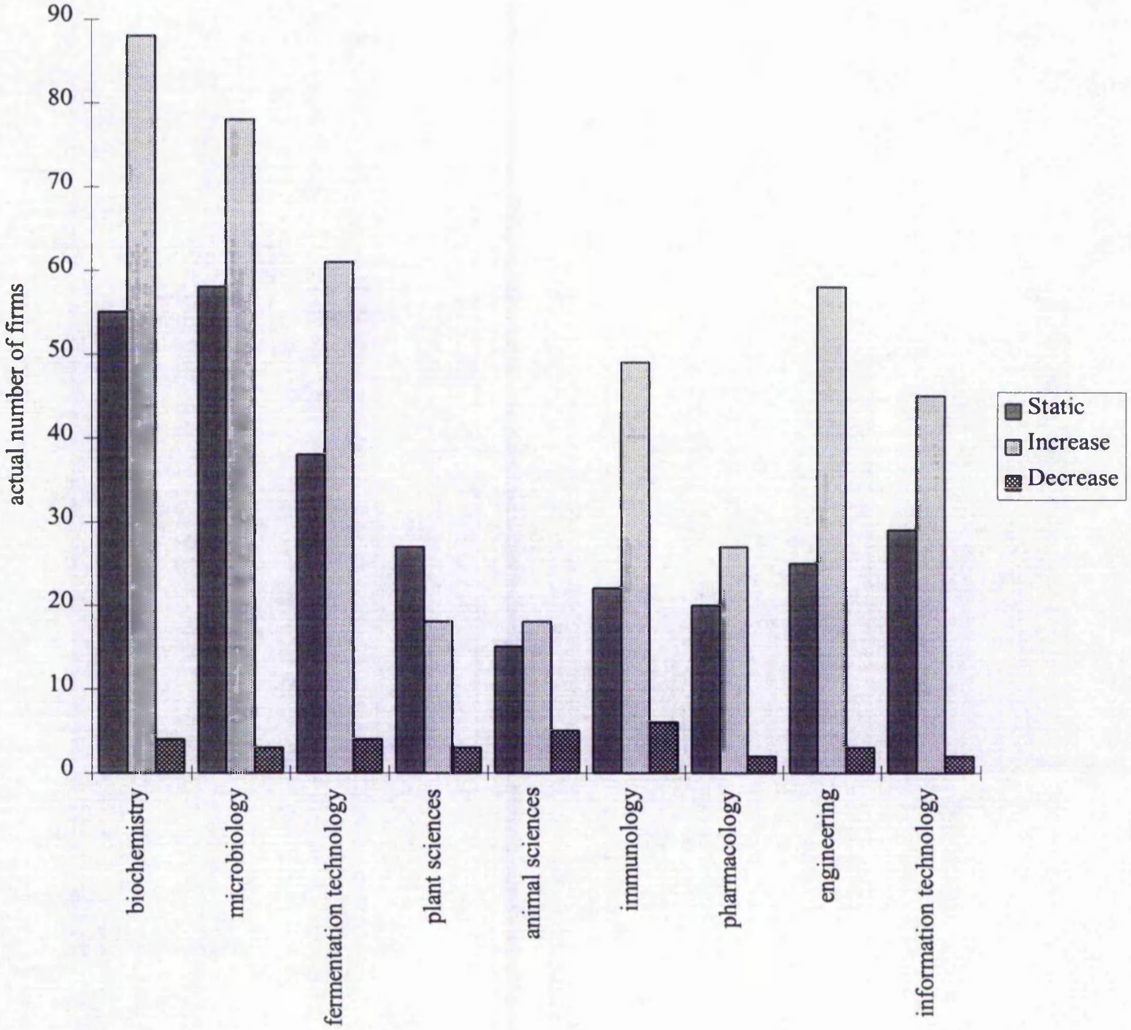


Figure 7.14 Forecasted demand for staff over the next 5 years by occupational category

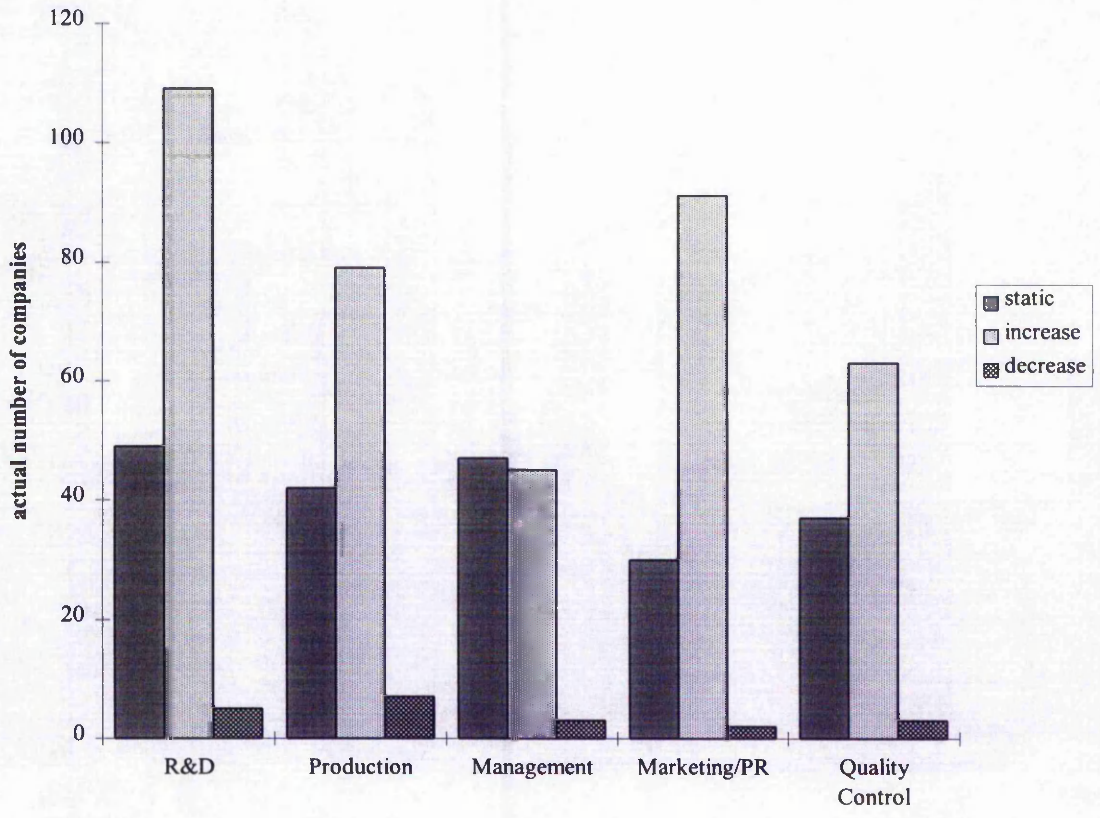


Table 7.10 Training Available in Countries according to Firms

Levels of Availability	UK	Germany	Scan	Gr/Es/Po	Netherl	Ireland	France	Italy	Belgium
Very easy	73.5 (%)	64 (%)	57 (%)	19.5 (%)	86 (%)	67 (%)	65.5 (%	29.5 (%)	71.5 (%)
Not Easy	20 (%)	27 (%)	33 (%)	69 (%)	14 (%)	33 (%)	34.5 (%)	59 (%)	28.5 (%)
Not Available	3.5 (%)	4.5 (%)	5 (%)	7.5 (%)	0	0	0	5.5 (%)	0
Don't know	3 (%)	4.5 (%)	5 (%)	4 (%)	0	0	0	6	0

Table 7.11 Number of companies who specified levels of scientific and technological training available (excellent /good/adequate/poor/unavailable) in their country categorised by discipline area

	biochemistry	microbiology	fermentation technology	molecular genetics	animal sciences	pharmceutical sciences	immunology	plant sciences	engineering	information technology
excellent	37	25	19	29	11	10	19	12	21	19
good	65	60	35	37	27	29	28	18	33	31
adequate	33	38	30	19	12	15	16	21	34	18
poor	13	14	25	18	19	10	14	6	8	10
unavailable	1	1	4	2	2	2	1	3	1	1

Table 7.12 Number of companies who specified levels of scientific and technological training available (excellent/good/adequate/poor/ unavailable) in their country categorised by ocupational group

	R&D	Production	Management	Marketing/PR	Quality Control
excellent	30	14	16	16	12
good	63	22	36	30	34
adequate	38	37	32	34	28
poor	16	27	14	12	12
unavailable	1	5	5	8	4

Table 7.13 Comparison by country of levels of training for R&D according to firms

	Britain	Germany	Netherlands	Italy	Ireland	South	France	Belgium
excellent	10	3	7	1	2	0	4	0
good	15	6	7	5	5	7	11	0
adequate	10	4	4	4	1	9	1	1
poor	3	4	2	3	1	6	0	2
unavailable	1	0	2	0	0	0	0	0
responses	39	17	22	13	9	22	15	3

Table 7.14 Comparison by country of levels of training for Production activities according to firms

	Britian	Germany	Netherlands	South	Ireland	France	Italy	Belgium
excellent	2	3	3	0	2	2	2	0
good	6	2	4	2	2	2	2	0
adequate	7	1	2	8	3	6	5	2
poor	7	4	3	4	1	1	4	0
unavailable	2	0	3	0	0	0	2	1
responses	24	10	15	14	8	11	15	3

Table 7.15 Comparison by country of levels of training for marketing and PR according to firms

	Britain	Germany	Netherlands	South	Ireland	France	Italy	Belgium
excellent	6	1	4	0	1	1	1	1
good	10	2	5	3	1	4	3	0
adequate	9	4	4	5	2	4	3	2
poor	2	4	1	2	2	1	0	0
unavailable	1	2	1	2	0	0	1	1
responses	28	13	15	12	6	10	8	4

Table 7.16 Comparison by country of levels of training for management according to firms

	Britain	Germany	Netherlands	South	Ireland	France	Italy	Belgium
excellent	7	1	5	0	1	0	2	0
good	9	2	7	6	4	3	2	0
adequate	10	5	5	3	1	3	2	2
poor	4	3	3	2	1	0	1	0
unavailable	0	0	3	2	0	0	1	1
responses	30	11	23	13	7	6	8	3

Figure 7.15 Types of Training Used by firms

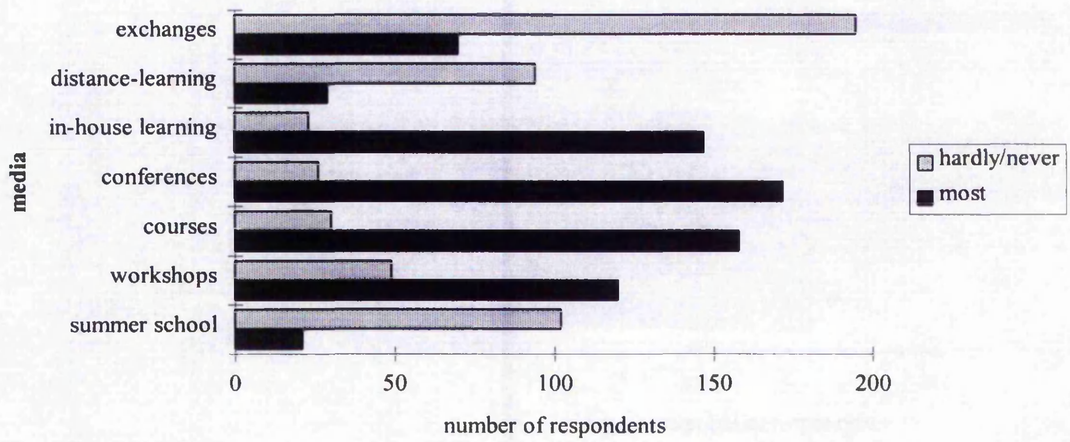


Figure 7.16 Areas of Training currently and anticipated to be used in the future

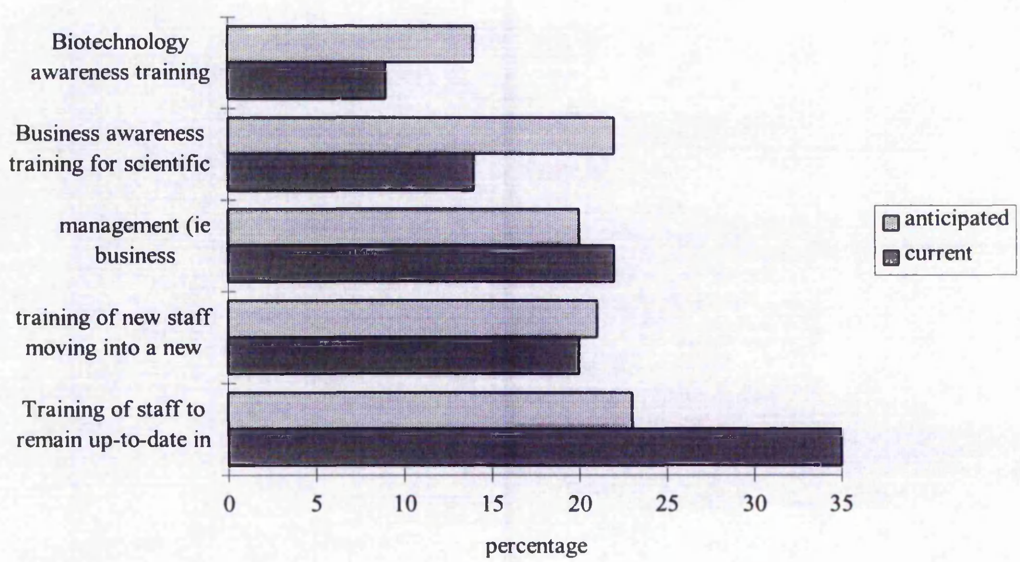


Table 7.17 Comparison of current and anticipated future training in the Netherlands, Britain and France

	Netherlands		Britain		France	
	current	*anticipated*	*current*	*anticipated*	*current*	*anticipated*
Training to remain up to date in their present area of biotech	40.5	23	28.5	28	34	22
Training of new staff into a new area of biotech	12.5	17	18	22	28	15
Management i.e. business administration marketing	25	17	25	28	18	30
Business awareness training for scientific staff	9.5	23	25	22	10	15
Scientific awareness training for non-scientific staff	12.5	20	3.5	-	10	18

Figure 7.17 Financing of biotechnology training

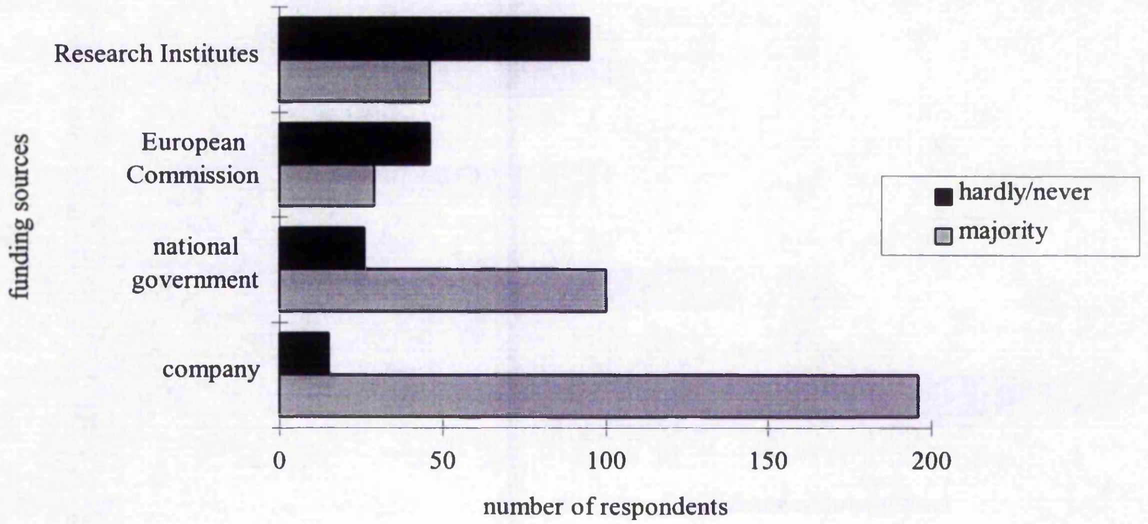


Table 7.18 Responsibility for training according to biotech firms

providers	number of firms
Company	9
Both Public Sector and the Company	11
Public Sector	23
total	43

CHAPTER EIGHT

CONCLUSION

1. INTRODUCTION

This concluding chapter begins with an assessment of the significance of the case study material and the implications that these findings have for debates on skills and training and economic development. The subsequent sections take up the themes outlined in chapters two and three in the light of the conceptual arguments about the rationale of the politics and economics of education and training (the 'new orthodoxy') and the role state intervention and national competitiveness. At a conceptual level, this study of biotechnology shows that the nature of markets and the global economy is more complex than the conventional wisdom of globalisation implies and that consequently the policy recommendations based on this analysis are generally misguided. Three broad conclusions are emphasised. First, the value of analysing the present structural transformation in terms of a decline of the nation-state in economic affairs is questioned, especially in relation to the emergence of globalisation. Instead, drawing on the theoretical argument advanced in this thesis, a modified form of the nation state is considered and the potential for alternative state intervention based on an alternative analysis of markets and the knowledge economy is stressed. Second, the emergence of the 'new orthodoxy' (the overall economic benefits to be gained from investments made in skills and training for improving national competitiveness in the global economy) is examined, both in the light of the biotechnology case, and at a broader conceptual level

2. EVIDENCE FROM THE CASE STUDY

The biotechnology industry emerged during the late 1970s. However, contrary to earlier prophesies, the industry has not been the catalyst for the emergence of a new techno-paradigm and has been characterised by uncertainty and investor (and consumer) scepticism. Whilst this has been less so in the United States than in Europe, nonetheless, the number of US dedicated biotechnology companies that have become fully integrated and profit-earning corporations remain few.

However, the economic development of biotechnology has primarily been a western phenomenon. Opportunities to be gained from third generation biotechnology, (for example the production of bio-pharmaceuticals), requires an affluent society prepared to pay relatively high sums of money for health care treatment, antibiotics and for improved standards in medical diagnosis and treatment. Biotechnology, therefore, is fundamentally no different from other high technology sectors such as electronics and chemical industries, relying on an affluent society for its economic development. It was argued earlier while biotechnology, as with any other knowledge based industry, not only requires very high amounts of capital for research and development stage, additionally the extraordinarily high costs of evaluating the efficacy of a new product and its accompanying long-term safety has become a major deterrent factor for investors and for new developers. This has led to the 'globalisation' of the sector which is the outcome of the recent trend towards the mergers and acquisitions of dedicated biotechnology firms.

Despite this trend, this study has shown that although biotechnology is an enabling technology with global markets, it is also firmly embedded within the national environment. Most of the innovative and dynamic activity in biotechnology has taken place in the dedicated biotechnology firm as a direct result of scientific research in public funded laboratories. Thus in terms of development, biotechnology is highly dependent on national institutions and infrastructure for access to new scientific knowledge, skilled labour and finance. The argument advanced therefore, was that the dynamics of the biotechnology sector were such that despite its global orientations, the industrial structure of the sector is firmly locked into the territorial structure of production.

European biotechnology clearly illustrates that national systems still have an enduring role in terms of shaping consumer demand. Indeed, to some extent, state actions have been constrained by the knowledge on the part of the state's agents of what is possible and what it precludes. As Cox (1982) describes, this has nothing to do with specific manipulation of state policies or the actions of particular 'actors' but with general understanding about the tasks and limits of the state given powerful social preferences. This was illustrated in the social democratic countries of Denmark and Germany, where strong lobbies by domestic pressure groups have prevented these countries from adopting certain regulations as regards the release of genetically manipulated organisms into the environment. Contrary to the more extreme version of globalisation which suggest that there has been an erosion of national identities and 'national economy,' the influence of domestic social forces and the national societal system in shaping policy responses, albeit altered by globalising tendencies and the movement towards supra-regional arrangements, still have an enduring role in shaping *national* policy responses.

The biotechnology case study also revealed the enduring significance of the nation state in providing the necessary environment for firms to compete - thus for analysing why some nations do better than others. It is the 'institutional thickness' (Amin and Thrift, 1994) that can provide a stable and secure domestic base to those industries which are already competing successfully on a world scale. Understanding competitiveness in biotechnology, I argued, was more than a question of assessing the shortage of skills and knowledge inputs into the sector, but required an analysis that extended to an assessment of national-societal factors. These factors include business systems and social and political institutions and the interpenetration of the dynamics of the global economy, such as TNC activity, all of which are essential for understanding the development trajectory of biotechnology and why some nations and regions have done better than others. For example, as this study has stressed, firms are now harnessing the power of new technology to create systems of activity linked across national borders so they are increasingly concentrating on those territories offering the greater potential for recovering their investments. Biotechnology shows just how the basis of competition is shifting to emphasise product quality and not just costs. In industries such as biotechnology, competitive advantage appears to be determined by the knowledge generated by firms through R&D and labour market experience. Thus, locations that can offer not only knowledge resources but, equally, favourable macroeconomic conditions such as finance and demand, are likely to benefit.

Indeed, the effect of these new forms of negotiation between non-state actors and nation-states is a changing balance of competition in the global system. It is clear that these new demands from firms are affecting government strategies as regards the allocation of resources to attract foreign investment. At a macro economic level, the internationalisation of R&D activities by large firms and the global scientific labour market has broadened the bargaining structure for some actors at the expense of limiting it for others. For the global firm there is much to be gained from this enlarged arena - they have more choices than the parameters of the nation-state and have greater leverage over government agencies. For instance, this was illustrated in chapter five in relation to how states are compelled to respond to powerful macroeconomic forces, as with the case of the state of Massachusetts in the United States which fears losing its status as the biotechnology Mecca, and, equally so, as in the case of Germany in the face of losing TNC capital as a result of its national regulations for biotechnology research and development. Thus, biotechnology shows how states no longer negotiate among themselves, but, equally with global firms. The relationship between the firm and the state therefore, is characterised by a complex process of bargaining where, in terms of economic development, governments are compelled to keep strategic industries by accommodating them because the cost of loosing them in terms of employment and wealth generation are too high.

At the European level, it was argued that biotechnology continues to be cited as a key generic technology which will underpin future economic growth and raise overall living standards of the member states. Based on this assumption, European projects have been targeted towards the development of a pan-European technology community, of which the scientific labour market figures a major part. Overall, the development of biotechnology in Europe has been targeted through policies to support the supply base, centred around the assumption that knowledge and skills are fundamental to national wealth and firms' competitiveness and that governments need to create policies aimed at improving the scientific and educational infrastructure. This has been exemplified in the case of biotech through an evaluation of the general assumptions that led to the skill deficit perception in high-technology sectors and the damaging effects that these could have on its overall long term competitiveness. This was more closely examined through the case-study of the COMETT funded BEMET project in chapter seven.

However, the real problem with this particular industrial strategy, as this analysis has shown, is that by privileging education and training issues above others, salient business concerns related to the sectors' development, especially in relation to tackling low demand for biotechnology-derived products and underdeveloped financial institutions for the promotion of high-technology industries in Europe, risk exclusion. Consequently, despite European scientific strength in the field, European biotechnology has failed to deliver at the pace originally forecasted. In addition, European governments have left the development of biotechnology to the vagaries of the market, which as it was theoretically argued in sectors with the possibility of increasing returns, there is reason (and contrary to orthodox economic theory) to argue that markets are imperfect and that state interventionism is appropriate.

It was also argued that enhancing competitiveness in European biotechnology, the role of demand has a major, if not central role, to its overall success. To date, for commercialisation to be successful in Europe, much of the drive to create the necessary institutions and environment to develop biotechnology, has had to come from professionals who have consistently lobbied governments and the European Commission, for example, as in the case of the Senior Advisory Group on Biotechnology (SAGB) and the European Federation of Biotechnology (EFB) and the European BioIndustry Association (EBA). Following this, it was argued therefore, that the future economic impact of biotechnology depends not only on the expansion of demand but also on the existence of the appropriate institutions within which demand can be articulated and met. Consumers buy products, but, their expectations are shaped and their choice limited - in some cases decisively determined - by intermediaries who exercise their professional judgements, and by the effects of a series of government regulations. This raises a number of questions in relation to the overall EU policy as regards the development of the supply base and the need for more highly skilled labour to enter into the new biotechnologies. This is discussed in more detail in the final section to this chapter.

Indeed, the case study focused on one aspect of supply side policy: developing the skills and training of the labour supply - because skills shortages were *perceived* to be a critical factor preventing the development of a European biotechnology sector. Following the study of biotechnology, it was suggested that the problem with this policy conclusion was that it privileged the economics of education and training as an issue-area at the expense of addressing other dimensions of the production system which have had a major impact on biotechnology's economic development. As it was empirically demonstrated, it is certainly not clear that skill-shortages are as wide-spread as conventional wisdom on scientific labour implies. For example, the argument advanced through this thesis has been that despite the current interest in skills and training and its relationship with economic competitiveness, the labour market constitutes one *strategic* component of the overall production system. In chapter three, it was suggested that understanding the labour market as one characterised by the laws of supply and demand offer little insight into the behaviour of biotech labour markets. Taking a specific case-study of European firms, it was shown that the labour market for this sector is more complex than the labour market economics 'orthodoxy' implies. The empirical evidence suggested that a range of institutional factors underpin the functioning of this labour market, in conjunction with broader production and knowledge structures that underpin the global political economy. For example, the general conclusion from the case study in chapter seven was that skills shortages are highly selective and not wide-spread across the European biotechnology industry and that overall it is not shortfalls *per se* of scientific labour that characterise these labour markets. Moreover, the European labour market is highly *imperfect and variegated* across Europe reflecting different national systems of innovation, and the inherent problems confronting small high technology firms heavily reliant on their national environment for the science and technology infrastructure and financial system, but operating at a global level. As it was discussed in chapter five, the absence of know-how and knowledge for biotech firms can lead to a spiral of under-investment and for the small firm to seek strategic alliances with larger firms, rather than become fully integrated biotechnology firms. Thus, drawing from the theoretical arguments developed in the thesis, along with the general conclusions reached in the review of other labour market studies in chapter six and the empirical research in chapter seven, it was concluded that that a deeper approach to understanding the relationship between the skills needs of firms and the economic development of the biotechnology industry is required.

Re thinking conventional wisdom

In terms of understanding public policy, these research findings have major ramifications for the way in which we understand markets in the global economy, state intervention and national competitiveness. For example, on this subject, the study supported the thesis advanced which questioned the mantra concerning the relationship between investments in the workforce, firms'competitiveness and overall economic wealth. Indeed, the study showed that European biotech firms have a number of concerns which may not necessarily be resolved through an increase in the supply of labour available to enter the sector, or by raising skills levels. Furthermore, in terms of the functioning of the biotechnology labour market, the study revealed that unlike Reich's analysis of advanced skilled workers, the labour market in biotechnology is far from operating as a free market where labour is mobile and moves around global webs of enterprise. As demonstrated in chapter three which reviewed the theoretical debate and embellished through a review of previous biotechnology labour markets studies in chapter six and the research findings in chapter seven, there are several reasons other than a shortage of suitably qualified labour for why firms experience recruitment difficulties for example, the imperfect (and, typically national) labour market and the problems facing small firms accessing information about the labour market. In addition, recruitment problems formed only one aspect (and not necessarily the most important) of the concerns facing biotechnology firms in terms of developing the sector. The main point from this study therefore, is the implications that these findings have for conventional wisdom that in the knowledge economy, investments in skills and training are a panacea for economic growth.

In terms of public policy, the study casts a number of aspersions on the assumption that investments in education and training are the prime determinant of a nations' prosperity in the global economy. Drawing on the empirical discussion of European biotechnology in chapter five, it is clear that skills and training are one important dimension of an advanced production system, however, the system is locked into a broader structure of capital, power and institutions. The investigation of firms skills and training requirements presented here, for example, reveal that firms' concerns are far wider than those of the perceived skill deficit problem facing the industry. The findings presented in this study indicated that the 'skills deficit' proposition as a integral factor impeding economic development is only one part of a broader process and cannot be debated in one corner, with science policy and macroeconomic conditions debated in another.

The study, therefore, raises wider implications for public policy and for understanding state intervention and national competitiveness in the knowledge based economy. Indeed, the biotechnology sector neatly fits the assumption that governments can only provide services and focus on the supply base of their economies and thus build the *external competitiveness* of an economy in the global system. This study empirically has shown that such an analysis and policy recommendation is based on a misunderstanding of the nature of the global economy and the transformation of international production. Insofar as structural transformation has taken place, this study of biotechnology suggests that it is not external competitiveness that will have a major impact on the pace of economic development of the sector, but, that *social and political institutions* are an essential dimension, as argued in this study.

In a world where trade as a direct consequence of knowledge inputs and 'added value' at various points in the international division of labour is more complex than is suggested by the tenets of comparative advantage, it is clear that social and political institutions - the state among them - help to shape international specialisation. This global division of labour presents itself as an opportunity for *agency*, not just an exogenous constraint. For example, the study shows that 'strategic' targeting of industries characterised by increasing returns will have an impact on the pace of economic development. As the thesis argues the US has benefited from being a 'first mover' in biotechnology, and this has been an outcome of explicit US industrial policies. Following the new trade theory, which stresses the likelihood of increasing returns to scale and imperfect markets, such proactive actions reward those industries first successfully penetrating foreign markets while resisting penetration at home. In this sense then, the new trade theories are based on the assumption that trade now seems to arise because of advantages of large-scale production, the advantages of cumulative experience (thus access to knowledge and skills) and transitory advantages resulting from innovation.

This thesis then goes some way to explaining why some nations have gained more than others in biotechnology. To recap, the analysis of the sector has shown that these new developments in economic thinking recognise the centrality of knowledge because inherent in the theory is the notion that the generation of knowledge is particularly likely to generate valuable spillovers, creating external economies. This reassessment of trade gives technological innovation an enlarged role, rather than a subsidiary one. It is argued that important trading sectors are also sectors in which rent may not be easily competed away. Because of the importance given to economies of scale, advantages of experience and innovation as explanations of trading patterns, it seems more likely to the 'new trade theorists' school that rent will not be fully competed away - that is some types of labour and capital will sometimes earn significantly higher returns than others. In addition, given the importance of technology, it is argued that certain sectors will yield important external economies, so producers are not paid the full social value of their production. Once it is believed that substantial rent can be gained, it becomes possible for trade policy to be used as a way to secure more rent for a country. External economies, therefore present a justification for activist trade policies.

The importance of this theoretical position is in how the theory sets down a few guidelines for the conduct of interventionist industrial strategy, albeit of a different kind to the traditional ones. This is particularly pertinent, because as I have argued throughout this thesis, in terms of policy direction and economic development, the policy debate at the European level is developing a supply-side orientation, rather than recognition of the role of the socio-political environment. In the first place, support for companies to obtain new technologies and/or new products to market as rapidly as possible seems to be a sensible strategy in those industries where increasing returns apply. In an increasing returns world, there are potentially great advantages of this approach. As Omerod puts it, of course it is a necessary, not sufficient condition for industrial success, but the traditional British Treasury attitude of opposing such support as a matter of principle is simply wrong (Omerod, 1996).

Thus in relation to the politics and economics of education and training and the wider benefits to the economy of investments in skills and training, the study of the dynamics of the biotechnology industry alongside the theoretical position of this thesis, has shown that large investments in training employees to solve problems or make suggestions cannot compensate for an inferior product, an onerous regulatory system an under-developed structure of demand, lack of supportive institutions and insufficient investment funds. In this sense then, supply-side policies such as investments in producing more skilled people will have very little effect on a sector which is characterised by under-investment, has very little demand for its products and lengthy research and development times.

At a broader level, the study raises important concerns about the way in which the global economy is understood and how we make sense of the changes taking place in the global industrial system. For example, what is the role of the national environment in shaping 'development' in a global system? And, to what extent are positions in the international division of labour *structurally* determined or is their room for *agency* for creating that position? Or, put more simply, can actors deliberately change the position they fill in the international division of labour? In short, what are the implications for state intervention of this thesis.

3. GLOBALISATION: STATE INTERVENTION AND NATIONAL COMPETITIVENESS

There is little doubt that economic internationalisation has increased economic uncertainty and greatly qualified the ability of nation states to conduct economic and social policy efficiently. The theoretical argument advanced throughout has been that the stronger version of the globalisation thesis - that the globalisation of markets is 'hollowing out' the nation-state - underestimates the extent to which the nation state remains important in policy making, governance and as a social organisation. As I have suggested, this assumption is based on a conservative view of the role of markets and the inexorable logic of global competition whereby the only forces that matter are the those of transnational corporations and financial flows. An alternative conceptual base for understanding the global economy is sketched below. Based on this approach, a number of alternative concerns relating to development in the global economy are raised. These are discussed here.

Conceptualising the Global Economy

One of the underpinning themes of this thesis has been related to suitable methodological tools for understanding changes taking place in the global economy. In chapter two, it was argued that a new stage in the development of the world economic and political system had commenced, a new kind of world order, which is characterised by both unprecedented unity an unprecedented fragmentation. Understanding this new world system requires new models of analysis than developed hitherto free from, on the one hand, the limitations of methodological individualism in economics (markets) and political realism (the public sphere), and on the other, the separation of the international from the domestic. The methodological starting point for this study on skills and knowledge in the global economy was a rejection of theories that reified the state as a rational conscious agent in favour of theories that explained the state as shaped from other social structures such as the economy and the political structure of the international system, taking into account the material interest of political economic agents and of key social groups at the domestic and international level. Indeed, the findings from this study of the biotechnology industry have shown that traditional distinctions and ways of thinking that separate politics from economics and the national economy from the structural transformation in the world system no longer provide adequate analytical tools given that, as this empirical case demonstrates, the intimate relationship between politics and economics and the international and domestic spheres.

The first point concerns the role of the state in academic analysis. The argument advanced in this thesis is that whilst some form of convergence of economic systems has taken place in the world system and that national development is enmeshed in a global economy in which some positions are more dynamic and more rewarding than others, the role of the nation state and the national environment still requires analysis because of the salience of social and political institutions in shaping economic outcomes.

In theoretical terms then, this global division of labour presents itself as an opportunity for *agency*, not just an exogenous constraint. In this sense, methodologies that capture the inter-relationship between both structure and agency are required. As I argued, developments in new IPE address this particular methodological problem concerning the changing role of the state in a more complex and interdependent world. The significance of these theories for understanding an industry such as biotechnology which, I have argued, is simultaneously highly globalised through its markets and networks, yet at the same time, dependent on its national socio-political environment, is that structures define the limits and possibilities of agency and are continually reproduced through the actions of agents, including states. In this sense, the strategic calculations of states is only one level of analysis for understanding the concerns of global political economy, albeit a necessary one. As Gamble and Payne (1995) note, if it is made the only level of analysis then it becomes one sided; but equally one sided is an analysis which conceived of globalisation as though it were a process occurring outside and beyond the system of states.

These contributions, it was argued, suggest an organising framework to make sense of the state in the global industrial system, thereby the levels of analysis problem, and in addition, implicit in this conceptual approach is the relationship between politics and markets. The overall relevance of new IPE theories for this thesis is that they have helped to make some sense of what is a myriad of relationships in the biotechnology sector between social groups, small firms, transnational business classes, political agendas and

TNCs. Moreover, these theories offer some way of understanding the new stage of development of the world economic and political system. For example, in chapter five it was argued that new demands from firms will have an effect on how governments allocate resources. The case of biotechnology shows how states are compelled not only to negotiate with each other, as in the case of supra-regional arrangements, but increasingly enter into bargains with foreign firms. In addition, firms are becoming more 'statesmanlike' as they seek corporate alliances to enhance their combined capacity to compete with others for world market shares and to access finance. This stage in development is referred to as the 'new diplomacy':

> 'The growth of global competition can be seen as moving the world towards a position where events are conditioned more by an emerging technocracy than by traditional notions of state power. In this new technocracy, firms feature prominently but are only one component of a wider network that links them to the educational and skills infrastructure and the financial system. Competition is increasingly among different production and institutional systems and contrasting social organisations. Further challenges to the nation-state are provided by the Europe of 1992 and the North American debates about free trade area to run from Canada to Mexico. Supra-national bodies could emerge to offset the growing power of the world market. ..... new triangular relationships will continue to evolve' (Stopford and Strange, 1992 p.22).

It is clear that this situation has created a number of challenges for states in terms of how to manage the volatility of change presented by this new economic diplomacy. In the case of the biotechnology sector, how states both resolve increasingly intractable dilemmas and implement policy becomes a critical factor of success. But the real point here, and the argument advanced in this thesis against the stronger version of the globalisation argument, is that rather than diminish the role of the nation-state as a critical agent of power, the nation-state has merely been modified and has become the focus for this change. As Underhill comments:

> '..the tensions and conflicts of adjustment in advanced capitalism appear to centre on the state as the principal point of convergence of struggles for influence within advanced capitalist society. The state emerges as the political focus for the process of adjustment and change' (Underhill, 1994, p.34).

The state in this sense, is the mediator of all these processes: between the political and the economic; between the international and the domestic. New IPE offers some analytical tools for understanding what is taking place at a macro level.

Making sense of what is taking place at a structural level then, has been one necessary concern of this thesis for understanding the skills and knowledge in the economic development process of a globalised high-technology sector. This analysis of global political economy changes the direction of academic questioning away from the demise of the nation state debate in favour of a more useful question: what pattern of policy-making and institutions will be capable of harnessing the forces of change for economic social objectives and to ameliorate their negative effects? As argued, reaching any answer to these questions necessitate drawing from academic enquiries in other discipline areas. For example, debates in and around economics and industrial sociology are re-visiting this whole question and the implications that this has for understanding the role of institutions in shaping industrial policies.

Earlier in chapter two, it was argued that there are at least three areas where national policy seems to remain crucial as far as economic development is concerned and where pressures towards regionalisation or globalisation seem, in varying degrees, 'neither actual, practicable or desirable' (Amin and Tomaney, 1995a). The first of these is the area of corporate governance. Challenging Reich's thesis, Lazonick argues that the national environment is an issue in the global economy and that the governance of corporate investment strategies remains fundamentally a national phenomena (Lazonick, 1993). Additionally, as I argued in chapter five countries differ radically in the extent to which the national financial system supports long-term lending to industry. Second, there is growing evidence that national systems of innovation have an enduring importance challenging the idea of a globalisation of technology and knowledge. While it is clear that strategic alliances are dominating the biotechnology sector, it is still clear that the production of scientific knowledge is firmly located in the national environment and dependent on the national system of innovation. Linked to this, is the third point that nation-states still retain the dominant role in policies concerned with the labour market and the industrial relations system. Social security systems, much labour market legislation and pay determination remain at a national level, and seem unlikely to be transferred to supranational bodies (Teague, 1995).

In terms of the emergence of a globalised labour market, Taylor (1995) argues that the evidence is far less convincing when it is suggested that employment is heading in the same direction as the advanced telecommunications industries. This study of biotechnology labour markets revealed that labour is not always as mobile as conventional labour market theory implies. Furthermore, insofar as transnational networks or epistemic communities (Haas, 1988) of scientists are being formed, these movements of labour are for a very small, elite section of the global labour force, and in many circumstances for cultural and financial reasons. Furthermore, the general trend in most countries is for governments to strengthen, not weaken, restrictions on the movement of labour across frontiers. For example, the North American Free Trade Agreement has tightened not relaxed cross border employment movements, while the GATT negotiations mostly excluded free trade in services that involved labour migration. In so far as there exists an argument in support of a global labour market, Cable (1995) argues that migration has put a brake on powerful globalising tendencies. For example, the national differences in employment markets remain strong even inside the European Union, with the annual report for small and medium sized enterprises highlighting the wide diversity of workforces across western Europe, for example, in relation to temporary employment, age distribution and hours worked (EIMI, 1995). In total, this casts considerable doubt concerning the reality of a globalised labour market.

The notion of a global labour market also raised important questions concerning the distribution of wealth and resources in global political economy. As Cable argues, most of the restrictions used by governments apply overwhelmingly to the unskilled and unqualified workers. While it is clear from this study that people looking for a job across national borders who have professional qualifications that employers require (for instance, symbolic analysts) are actively sought. Indeed, this new 'global elite community' of workers identified by Reich - is exceptional because of the obvious ability of these highly skilled workers to succeed in finding employment in a genuinely high skilled and international labour market. In this sense then, it could be argued that globalisation is taking place but at a differential pace - and, in the longer term, reinforces social inequalities. Indeed, this raises a number of questions in relation to an industrial policy premised on the increase of this particular category of workers, which is examined in the next section.

In summary, in this section the idea that the nation-state is no longer important as a locus of economic policy-making has been challenged without rejecting the pressures posed by globalisation. As Halimi et al put it:

> 'Certainly there are constraints on governments today because of globalisation, as well as the Single Market, but a massive role for economic policy nevertheless remains at the national level. Indeed, greater international economic integration means that the successful national intervention is paradoxically greater than before. Conversely, a resigned abdication from active macroeconomic and industrial policy which allows the loss of competitive advantage, whether by one European country or by Europe as a whole, will have disastrous effects, magnified by global markets into far faster loss world and domestic markets, production and employment' (1994, p.115).

The lessons from the theoretical argument and empirical study of biotechnology point to the idea that it is possible to interfere with market mechanisms in a positive way. And, as Krugman noted, there is scope for the misuse of this theory - as in the case of the 'strategic traders' argument which has led to the implicit faith in investments in education and training as a panacea to resolving malign structural problems such as rising unemployment. Indeed, one of the aims of this thesis has been to 'unpack' the assumptions that are generated from this argument because of the policy judgements that it implies.

3. THE POLITICS OF THE ECONOMICS OF EDUCATION AND TRAINING

One dimension that has not been directly treated in this thesis concerns the role of education in the pursuit of attaining the goals of human fulfilment. One question that is rapidly dismissed amongst the 'hype' surrounding the poltics of education and training is, what if the education or skilling necessary for competitiveness is not that required to produce a more efficient and competitive workforce? How will such a tension be resolved? Granted, in many instances, there may be no conflict. Where fulfilment is seen by individuals essentially in terms of greater access to the high wage employment which education provides, there may be no perceived antagonism between it and efficiency or competitiveness. However, education of the people may have very little to do with the nation's competitive edge. Another argument of course, is whether the drive for competitiveness may prove inimical to human fulfilment. When education is conceived of solely as investment in human capital, the danger is that labour will remain just that - a factor input. Additionally, training may not serve those who most require it in society. This particular study has been concerned with the argument that governments should be in the business of creating more 'symbolic analysts'. But, critics of this position such as Krugman (1996) and Lazonick (1993) argue that by promising solutions to contemporary industrial problems through education and training creates an excuse for ignoring the problem of corporate governance because by focusing on the highly skilled worker as the prime source of global competition and future prosperity, the 'routine worker' are no longer relevant to factor creation because they are considered to be far less important. Lazonick (1993) agrees that some enterprises are pursing global strategies, however the real question is what determines which enterprises are successful in the globalisation process and is the national environment really becoming so irrelevant as a determinator of competitive advantage of enterprises in global markets? Indeed, the question about the loss of global competition to some states needs to be asked explicitly because of the large proportion of employment dependent on the activities of domestic firms.

It is these 'routine workers' and the unemployed that, overall, are much less likely to receive training than their more skilled counterparts; employees in good jobs (large, unionised employers) are more likely to receive training. All this suggests that, whilst training is a potential tool for redressing certain inequalities in the labour market, at the moment it merely reinforces existing inequalities. In sum, the real task is how to address these real inequalities pervading advanced societies. The politics and economics of education and training have, to date, offered one possibility to political parties of resolving what appears on the surface, to be directly related to the adequacy of skills provision and the amount of workers who receive training. However, the institutional analysis discussed here suggests that training may not go to those who need it most - within unequal job and training structures the allocation of workers is by institutions (i.e. customs and rules) and although workers can influence their access to training, through their own effort, their options are more often than not, constrained through institutions. Further, investments in human capital do not necessarily result in increased worker's productivity, because this is directly linked to the overall command over resources by the firm and as the study has shown, in biotechnology at least, financing the development of the sector is not without obstacles. Moreover, rather than on training per se and investments in human capital the productivity of workers is more dependent on a set of conditions which include the technology being used, the levels of motivation towards scientific discovery, perceived autonomy at work, the location of their workplace, and in the case of biotechnology the satisfaction derived from working on 'leading-edge' technology, which can be more important than salary expectations. In the case of biotechnology and its overall economic development then, the role of education and training is one aspect of a complicated advanced production system. In it, decisions related to this reflect the overall investment decisions of the firm which reflect global demand conditions for products which reflect the nation-state societal system (local preferences and culture) which reflect overall macro economic conditions that shape the investment decisions of high-technology firms (government investment, global venture capital markets, and global joint-venture agreements). It is the performance of these transnational and national institutions that ultimately will have a major impact on competitiveness, not skills and training alone.

APPENDIX ONE

METHOD

1. INTRODUCTION

> '.....my answer to the questions, 'How do you know? What is the source of the basis of your assertion ? What observations have led you to it?' would be: 'I do not know: my assertion was merely a guess. Never mind the source, or the sources, from which they may spring - there are many possible sources, and I may not be aware of half of them; and the origins or pedigrees have in any case little bearing on truth. But if you are interested in the problem which I tried to solve by my tentative assertion, you may help me by criticizing it as severely as you can; and if you can design some experimental test which you think might refute my assertion, I shall gladly, and to the best of my powers, help you refute it.'
>
> (Karl Popper, Conjectures and Refutations, 1969, p. 3.).

The aim of this appendix is to outline the process by which the research reported in this thesis was conducted and to describe some of the problems encountered. The discussion commences by outlining the BEMET survey of biotechnology firms and how this survey was constructed. It describes the choice of sample group as a 'self-selected sample group' from a relatively unknown total population of European biotechnology companies. It is concluded that the sample used for this study is a useful distribution of biotechnology companies both spatially and by commercial activity. The research undertaken combined both quantitative and qualititative research methods. The second section then moves on to consider my own experience as a social scientist working as a Research Assistant in a Life Science Department and pursuing doctoral training across a natural science Faculty and a social science Faculty. I attempt to show that the character of this thesis and the research on which it is based were affected significantly by this formal institutional arrangement which led to my own critical analysis in why the questions underpinning the BEMET project were asked as much as the answers to it. In particular, I became interested in creating a framework for understanding this material generated from the survey.

2. RESEARCH IN EUROPEAN BIOTECHNOLOGY LABOUR MARKETS

The doctoral research on which this thesis is based was funded for three years on the basis of a Research Assistant post in the Commission of the European Communities University Enterprise Training Partnership (UETP BEMET) 1990-1994. The function of the UETP and project BEMET has been described in more detail in chapter seven. In addition, previous national studies of biotechnology labour markets, particularly within Britain, along with more general reports on the biotechnology skills needs were discussed in chapter six. As it was shown, to date there has been very little comparative empirical labour market analysis of the European biotechnology sector. The aim of this section, then, is to describe in detail how the research presented in this thesis was undertaken and my specific role in this process.

One of the purposes of the BEMET research was to identify future training requirements within the sector. This was not a simple task. First, very little information existed on the biotechnology industry and its current industrial structure. Second, very few directories identified firms that were engaged directly with research and development activities. The first year of the research, therefore, was engaged in specifically identifying firms directly engaged in biotechnological research, or defined, using the Spinks Report's definition as firms that utilised 'biological organisms and processes for the manufacture of goods and services' (Spinks, 1980).

The Steering Committee[1] decided on a postal survey as the most appropriate method for the basis of the BEMET research. There are a variety of methods that can be utilised for surveys. A census is a study of a whole population, however this can be expensive and requires a long period of time to undertake. A sample survey may provide the required information with the desired precision and requires a far simpler and shorter approach. A random sample from the known population was the chosen method for this survey. For the purposes of this survey, the *known* population is used interchangeably with the *total* population, given that the total population was uncertain at the time of this survey.

The research is underpinned by research design in industrial geography on industry restructuring and the methodological aspects as indicated by Sayer and Morgan (1985) concerning intensive and extensive research methods. In intensive research enquiry the primary questions concern how some causal processes works out in a particular case. This method uses less formal, less standardised and more interactive interviews and focus groups were set up during the international conferences of BEMET to specifically address causal processes in a limited number of cases regarding biotechnology economic development in Europe and its relationship with skills and training. In addition, the

[1] The members of the BEMET Steering Committee are listed in Appendix 2.3.

research investigation employed large-scale extensive research methods, through large-scale questionnaires, descriptive and inferential statistics and numerical analysis (i.e. cross tabulations). The research investigation is described in more specific detail below.

2.1 Extensive research methods: determining the sample

One particular problem facing the BEMET research survey was how to identify the total population. In order to determine the sample group for the investigation the following questions were asked. What information is required? Can the population be identified and listed? How will the sample members be selected? How will information be obtained from sample members? How should sample information be used to make inferences about the population? What conclusions can be drawn about the population ? (Newbold, 1991, p728). Using this method, an outline of the creation of the sample and the survey questions are discussed below.

The Steering Committee of Project BEMET agreed that the target group for this study would be all firms engaged directly with research and development (R&D) activities (BEMET Management Board Meeting, 1991). The following definition was used 'any company requiring a highly skilled workforce for the application of scientific and engineering principles to the processing of materials by biological agents for goods and services'. In the first instance, as a consequence of the lack of *exact* information on biotechnology firms in Europe, it was necessary to compile a BEMET data base of firms. This is described below.

Survey Methodology: Creating a data-base

1. Field research was undertaken by BEMET Steering Committee members with a pilot questionnaire in selected regions of Europe.

2. An international directory of biotechnology companies (Coombes and Coombes, 1991) was used for the purpose of compiling a mailing list. From this source, in 1991 over 3,000 companies covering all sectors were identified and postal questionnaires distributed.

3. A very small number (96 responses) returned completed questionnaires (3.2 % of total). However, this survey revealed that a large proportion of the population were unsuitable for the purposes of this survey. The initial mailing revealed that many of the 3,000 firms included equipment suppliers, pharmaceutical companies and consultancies. From the basis of these findings, a new data-base was constructed that consisted of a far smaller list of firms that could be considered to be 'dedicated biotechnology firms' according to the definition adopted for the purposes of this survey (approximately 500 firms).

4. Additionally, in order to maximise the sample group, member associations of the BEMET UETP were utilised to create a European list of dedicated biotechnology firms in each member state. Combined with the initial mailing response, a unique pan-

European data base was created and utilised for the purposes of BEMET research. The list of contacts by member state are shown in table A1.1.

Table A1.1

European Contacts for the Construction of a data-base of European biotechnology firms
• Louis Da Gama, Executive Secretary, The BioIndustry Association, UK. • Dr Meike Beer, UETP NETWORC-FORBIEC, Univ. of Nijmegen, The Netherlands. • Prof. Enrica Galli, Universita degli Studi di Milano, Italy. • Dr Marie-Claude Dauchel, Universite Paris XII, France. • Snr Antonio Monterro Carro, Zeltia, Spain. • Dr Aidan Mcloughlin, University College Dublin, Eire. • Dr Eric Hornsten, University of Linkoping and European Federation of Biotechnology Working Party on Biotechnology Education. • Dr Rheinhart Berner, University of Vienna, Austria (and European Federation of Biotechnology Working Party on Biotechnology Education). • Prof. Humberto Rosa, University of Lisbon, Portugal.

On the basis of these investigations by country-wide contacts, a data base was constructed with contact names of approximately 450 biotechnology firms, both small size and larger firms. It was decided that all firms on this database would be targeted.

The aims of the BEMET project were shown in chapter seven, (table 7.1). To briefly recap, the primary objective of the project has been to examine the training and skills requirements of biotechnology firms across Europe. The aim of the survey was to undertake a European investigation of biotechnology labour markets according to the perceptions of European firms. To date, there has been no such investigation. The biotechnology sector is still relatively small in comparison to other industrial sectors and therefore it was appropriate to address the total population.

Following the construction of the data-base, a postal questionnaire was disseminated to all firms. Whilst there are limitations with this method, it was considered appropriate to use this method for cost reasons. The main categories of questions of this strategic appraisal of firms is set out in table A1.2 below.[2]

The main limitation is that it is impossible to clarify the question being asked in the questionnaire. An associated problem was related to the language differences across the member states. To overcome some of these limitations, the questionnaire was highly structured with some available space for semi-structured responses. In addition, the questionnaire was distributed in Spanish, French and English and a contact person in the firm's host country was provided. A stamped addressed envelope was included to facilitate the return of the questionnaire.

---

[2] The BEMET questionnaires are included at the end of this chapter.

Table A1.2 Main Categories of Questionnaire

Strategic Appraisal of Labour and Training Needs in European Biotechnology
Company profile - size and business sector
Recruitment during the last year according to qualification level, discipline, area of biotechnology and occupational category;
Recruitment difficulties and their effects
Expected demand for staff during the next ten years according to main area, discipline, and category of biotechnological activity;
Trends in number and quality of applications during the last five years;
Staff employed in each main area, discipline and category of activity;
Sex, full/part-time and age profile of staff
Areas of unsatisfied training
Steps required by various agencies to meet company training needs
Views on contextual questions
Types and availability of higher education courses in biotechnology

The postal questionnaire was supported by two international conferences which enabled focused groups to address further more in-depth questioning of firms and policy-making in biotechnology. These conferences created the opportunity to verify the results obtained from the postal survey. The following conferences and seminars were organised. These are shown in table A1.3.

Table A1.3

BEMET Conferences and Seminars 1991-1993
Manpower and Training Needs for Biotechnology in Central and Eastern Europe, Louvain-La-Neuve, Belgium December 1991
Positive Actions in Biotechnology: Results of Sectoral Survey of COMETT Training Projects, Bio Industry Association, September 1992, UK
Manpower and Training Needs for Biotechnology in Southern Europe; Orense, Spain, September 1993
Round Table Final Results, Pharmacia, Belgium, 1993

The sample is sufficiently proportionate to the total population to make inferences in relation to the total population. For example, see chapter four and chapter five for a discussion of the sector and the industrial reach of biotechnology and compare with the sample (cf. chapter Seven, table 7.3 *Breakdown of no. of respondents in self-selected sample group* and table 7.4 *Market Sectors of sample firms*). The sample group consisted of 239 replies out of 450 (over 50 % response rate of known biotechnology firms from data-base). This group primarily consisted of small firms (employing less than 40 persons) however, subsidiaries of larger corporations were also included in the sample group. This constitutes a useful sample of the known population of European biotechnology companies currently in operation. Although a structured postal questionnaire was sent to the target group, the questionnaires did not rigorously adhere to yes-no type answers and often required more than one response. Some companies did not reply to all questions. In most cases, the Managing Director of the company or where applicable those responsible for recruitment and training completed the questionnaire.

3. BEMET RESEARCH WITHIN A BROADER RESEARCH AGENDA

The earlier sections have described in detail how the BEMET research into the skills and training requirements of biotechnology firms were undertaken. In this sense then, the origins of this thesis are based in this survey and its findings. The survey findings were published in 1993.[3] My own interest in the BEMET research findings was more concerned with creating a framework for understanding this research, particularly given the importance of the debates taking place in European policy circles as regards the politics and economics of education and training in the 'global', knowledge economy. This is described in more detail below.

The empirical investigation does not attempt to provide an exhaustive account of specific training requirements in each particular region across Europe. Rather, the ethos and spirit of the UETP and the studies, has been to provide a first point of enquiry into an essentially under researched area. Additionally, the UETP created a unique forum in which these issues could be discussed. For example, one of the specific tasks of my research post was to disseminate the research findings of the BEMET project through meetings and the distribution of a regular newsletter[4] with information on labour market issues to members and interested parties.

---

[3]The BEMET findings were published in Hayward, S and Griffin, M (1993) *Europe at Work: Labour and Training for the European Biotechnology Small Firm Sector*. Photocopy of report front page attached at the end of this chapter.

[4] Photocopies of the front covers of these newsletters disseminated to members are attached at the end of this chapter.

Thus while a research project of this scope did not identify precise skills and training requirements, (this would require a great deal more resources), its strength for this thesis lies in how it offers a useful picture into an area that has currently received very little attention, despite the centrality of labour markets to contemporary debates on economic prosperity. As a Research Assistant with a primary background in the social sciences, and working in a Life Sciences department with natural scientists, it became evident to me that this was a useful platform from which to empirically explore doctoral research in the area of knowledge inputs into the production system and the ramifications that changing skills requirements had for public policy. As a consequence of my previous studies, I was already interested in broader research questions related to a number of contemporary debates in relation to the changes taking place in industrialised societies and the implications that these transformations now had for public policy and for overall economic development. Working in the UETP then, gave me direct access to a number of key people involved in the shaping of policy in the biotechnology sector, and in addition, exposed me to an alternative perspective as regards the economic development of this sector from the natural scientists point of view.

For instance, the Steering Committee for BEMET consisted of natural scientists working both in academia and industry and to a large extent, as I argued in chapter seven, there was already in place a number of assumptions regarding the overall needs of the biotechnology sector in relation to skills and training. However, whilst working on the EU project, I became conscious of a number of limitations concerning the overall structure of the research questions. Indeed, as I continued working on the investigation I became dissatisfied with the survey and more interested in why these questions had been asked as much as the answers that they were likely to generate.

From this perspective, and given that I was particularly interested in why these research questions had been asked, my own research enquiry became broader than that of the BEMET research agenda. In so doing, I used the survey to arrive at a number of broader research questions relating to academic discussions already taking place in the social sciences concerning the salience of education and training as an industrial policy in the global, knowledge-intensive society. Interestingly, the BEMET research agenda (described in chapter seven) was primarily set and driven by British interest groups, and it became apparent that these assumptions about the overall economic development of a future strategic industry such as biotechnology, reflected similar policy debates taking place in Britain, as signalled in chapter one and examined in more detail in chapter eight.

At the same time, I was interested in the number of academic debates taking place across the social sciences concerned with the phenomenon of *globalisation,* which although diverse in origin, all suggested that some form of increased interdependence was transforming the traditional Westphalian nation-state system. Within this system, knowledge and technology were binding together traditionally heterogeneous communities and, in addition, production systems had become far more knowledge-intensive as a result of knowledge inputs hence the belief that skills and training needs of societies were increasing dramatically (discussed in chapter two). At a policy level then, globalisation and skills and training in the knowledge economy were beginning to dominate discussions on what governments should now do in this contemporary period. For example, to what extent are skills and training becoming the bedrock of advanced industrialised societies for their own prosperity? Consequently, to what extent have the powers of the nation-state within the *trans*-national system, generally declined in its ability to guide and conduct its economic affairs?

My interest in these debates, alongside thepractical involvement in a university-industry led project on skills and training in the European biotechnology sector offered a unique opportunity to explore these questions further. More importantly however, this thesis provided an opportunity to place these empirical findings on labour markets, to date, a much discussed but under-researched area, within a wider context and to create a framework for understanding the relationship between education and training and firms' competitiveness in a global economy. Moreover, the data has been used to challenge the very assumptions around which the survey was constructed and to offer a critique of current preoccupations.

MET NEWS

ECHNOLOGY IN EUROPE
MANPOWER, EDUCATION AND TRAINING

BEMET

etariat: The Biochemical Society, 59 Portland Place, London W1N 3AJ, U.K. Tel.: (+44) 71 5805530; Fax: (+44) 71 3231136

EDITORIAL

This first issue of the BEMET Newsletter aims to introduce you to our major Europe-wide project entitled Biotechnology in Europe, Manpower, Education and Training (BEMET).

The UK Spinks report in 1980, recognised the importance of having an adequate supply of suitably trained people for biotechnology. Various surveys have identified shortages in specific areas and discipline, but there has been no concerted effort to identify these gaps and work towards filling them.

These issues were addressed by two conferences entitled Manpower and Training Needs for UK Biotechnology', April 1989, London, Great Britain and 'Manpower and Training Needs for Biotechnology in Europe of the 1990's' December 1989, Delft, The Netherlands. The recommendations from these Conferences lead to a proposal by the U.K. Interest Group on Education in Biotechnology to the European Commission under the COMETT II programme. A grant of 339.000 ecus for three years was awarded to fund a major Europe-wide project (BEMET) in order to identify recruitment difficulties and training needs.

AIMS AND OBJECTIVES

BEMET has two major objectives:

a) To identify skill shortages in Biotechnology in specific disciplines and areas in EC and EFTA countries.

b) To investigate training provision by creating an up to date inventory of biotechnology courses in EC and EFTA countries.

In more simple terms, we need to find out which specific areas of biotechnology are currently facing shortages of suitably qualified staff and find out why those shortages are occurring.

BEMET is coordinated by the U.K. Interest Group and managed by a Board consisting of representatives of the U.K. Interest Group, EFB Working Party on Education and the European biotechnology industry. The project has its secretariat at The Biochemical Society in London. The diagram below illustrates various aspects of BEMET

OTHER AIMS AND OBJECTIVES OF BEMET

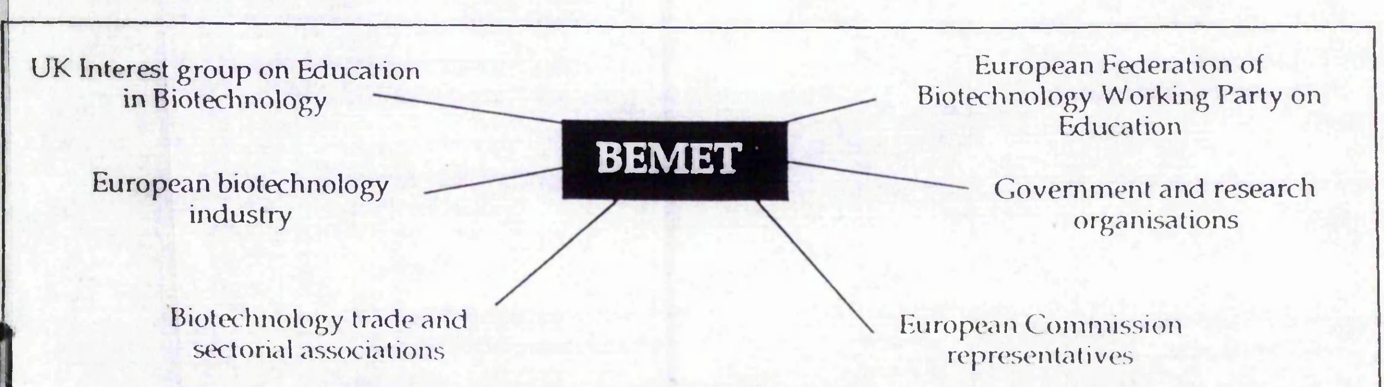
In additon, BEMET has six other trans-european aims and objectives in which it will play an active role:

i) facilitating the development and provision of training programmes in Biotechnology
ii) facilitating the development and dissemination of materials for the general public and schools.
iii) aiding in the harmonisation of qualifications to facilitate transnational mobility of students and staff
iv) facilitating arrangements for transnational and academic/industry exchanges for students and staff
v) establishing a network for the exchange of resource materials in biotechnology education and training
vi) promoting the improvement of general public understanding of biotechnology and its applications.

In order for the project to be a success, BEMET is inviting industrialists in biotechnology to complete a questionnaire. This will be sent to you in the forthcoming week. Furthermore, we are pleased to announce BEMET's first Annual Conference, to be held at Louvain La Neuve, in Belgium, between 29 November and 1 December, 1991. Full details are included in this newsletter.

M. Griffin
(Treasurer and Co-ordinator)
S. A. Hayward
(Senior Administrator)
BEMET

THE ANATOMY OF BEMET



COMETT II

BEMET NEWS

Issue Number 2

BIOTECHNOLOGY IN EUROPE
MANPOWER, EDUCATION AND TRAINING

BEMET

Secretariat: The Biochemical Society, 59 Portland Place, London W1N 3AJ, U.K. Tel.: (+44) 71 5805530; Fax: (+44) 71 3231136

Editorial

This second edition of BEMETNEWS aims to inform industry and academic institutions, concerned with biotechnology training and research of the current progress of the COMETT II funded UETP BEMET (Biotechnology in Europe, Manpower, Education and Training). The theme of this BEMETNEWS is in line with our recent Conference in Louvain-la-Neuve, Belgium which addressed the **East-West biotechnology concerns in Manpower, Education and Training.** A detailed report of this Conference is included in this newsletter. BEMET is an original UETP, established to carry out a number of surveys relating to manpower, education and training issues in European Biotechnology. The over-arching aim of the UETP is to diffuse information to the European Biotechnology Industry. This task has been termed **Project BEMET** and the two primary objectives are:

(i) **To identify current and to forecast future recruitment, education and training needs for biotechnology companies in Western Europe**, and in this respect, facilitate the meeting of these identified needs through the second aim.

(ii) **To investigate current undergraduate and postgraduate training provision throughout Western Europe by creating a compendium of courses in biotechnology.** This compendium will allow gaps in training to be identified and will facilitate the diffusion of training information for the benefit of all Europeans to spend a period of study in another European country.

Project BEMET is of considerable interest to the Biotechnology Industry: in the short term, networks of information on European education and training possibilities will increase in importance as the need for a highly skilled and dynamic workforce increases in line with the pace of technological development. In the future, European cooperation in the field of education and training for a dynamic technology such as biotechnology will become increasingly commonplace as cross-national exchanges of research, training and labour continue to develop in line with the European Community Single Market. Ultimately, the information gathered from this Project will benefit all UETP's and institutions arranging training courses in biotechnology. In addition, it will also facilitate student and staff exchanges in Europe by providing immediate information both in electronic and book form on courses available. Finally, the report on the European Biotechnology labour market will be of interest to all European companies and institutions when planning suitable future manpower and training strategies.

Developments in BEMET

• Since the last BEMETNEWS, the preliminary results of the BEMET strategic appraisal into manpower, education and training requirements of European Biotechnology companies have been analyzed (a report of this is given on page 8).

• In January of this year BEMET distributed a second, modified questionnaire designed for time effectiveness and including an extra section aiming *to assess attitudes towards greater European integration in the biotechnology industry*. This was considered to be necessary in order to compile a comprehensive appraisal of the labour market in the European biotechnology industry. The results from this second round of surveys will be presented at the **Second BEMET Annual Conference in Orense, near Santiago de Compostela, Galicia Spain between 18 - 20 September 1992.**

• BEMET has now published a U.K. Inventory listing all courses and exchange possibilities in biotechnology for undergraduates, postgraduates and staff and student exchanges, which has now been distributed to institutions around Europe.

• BEMET has gone "on-line" with the Microbial Strain Data Network (MSDN) which gives details of the UK course inventories.

• Course inventories for the Netherlands, Italy and Ireland will be published at the end of 1992. **All relevant departments receiving the UK inventory are requested to complete the short form at the back of the booklet in order for a similar inventory to be compiled for each EC and EFTA country.**

• The First BEMET Annual Conference held in Louvain-la-Neuve on 29 November - 2 December 1991 was a great success. In line with current EC policy developments in Eastern Europe, the Conference addressed the issue of *Central / Eastern Europe: Manpower, Education and Training in Biotechnology*. The Meeting included representatives of the **EFB Working Party on Education** from Latvia, Yugoslavia, Czechoslovakia and Hungary.

• BEMET is pleased to announce that we will be working closely with the fellow sectoral UETP Networc-Forbitec (Netherlands and Portugal) who organise student exchanges and short courses. BEMET will provide information on courses for students and will liaise closely when planning short training courses.

Continued Over..................

BEMET NEWS
Issue Number 3
BIOTECHNOLOGY IN EUROPE
MANPOWER, EDUCATION AND TRAINING
COMETT II
BEMET

Secretariat: Life Sciences Dept, Nottingham Trent University, Clifton Lane, Nottingham NG11 8NS Tel & Fax: +44 602 486628

From Right to Left: Sally Hayward, Joanne Curtis and Martin Griffin

Who is BEMET?

The BEMET Secretariat is based in Nottingham and is run by the Coordinator Professor Martin Griffin, Senior Administrator Sally Hayward and Project Assistant Joanne Curtis.

In addition to his role as Coordinator Professor Griffin heads a research group in the Department of Life Sciences at the Nottingham Trent University which is investigating the molecular biology of programmed cell death and its importance in tumour growth. His other research interests include the development of immuno-diagnostics for the food industry. Professor Griffin is also a member of the UK Interest Group on Biotechnology Education and the European Federation of Biotechnology (EFB) Working Party on Education.

Sally Hayward is in the second year of her PhD on work relating to the BEMET training needs analysis and helps coordinate the running of BEMET as well as taking responsibility for the Training Needs Analysis.

Joanne Curtis joined BEMET only 3 months ago, replacing Annie Walshe who left last summer. Joanne is responsible for the inventories of courses in biotechnology across Western Europe.

Editorial

This short update of BEMET NEWS aims to inform industry and academic institutions concerned with biotechnology training and research of the current progress of the COMETT II funded UETP BEMET (Biotechnology in Europe, Manpower, Education and Training). Since the last BEMETNEWS much progress has been made and the purpose of this brief update is to keep our partners and interested parties informed of these developments.

Project BEMET is proposing to extend its activities for another year through an application for funding by COMETT II under the call for Strand D proposals.

The over-arching aim of BEMET will remain the same ie: to facilitate information flow between academia and the European Biotechnology Industry. The two primary objectives of project BEMET are:

(i) To identify skill shortages in Biotechnology in specific disciplines and areas in EC

THE EUROPEAN COMMISSION IN ACTION

A STRATEGIC APPRAISAL OF MANPOWER AND TRAINING NEEDS FOR BIOTECHNOLOGY THROUGHOUT EUROPE

August 1991

Dear Sir/Madam

You are invited, with the help of members of your staff, to participate in project BEMET (Biotechnology in Europe, Manpower Education and Training).

The purpose of this project is to identify any specific areas of shortfall and relate them to, and thereby subsequently influence, training provision across Europe.

If you have been recruiting personnel in the biotechnology area, or have expectation to do so in the future, we would be greatly helped if you, and members of your staff would complete the enclosed questionnaire. Your response will enable us to progress this important Community project. You will of course receive copies of both the interim and final reports resulting from this survey.

If any areas of the questionnaire are confusing in your context, then please either contact the BEMET Office or annotate the questionnaire accordingly. We would be grateful if you could return the questionnaire as soon as possible.

Yours sincerely

Professor Charles F A Bryce
Co-ordinator

BIOTECHNOLOGY IN EUROPE MANPOWER, EDUCATION AND TRAINING

BEMET

SECRETARIAT: THE BIOCHEMICAL SOCIETY
59 PORTLAND PLACE
LONDON W1N 3AJ
UNITED KINGDOM

TEL: +44 71 580 5530

BIOTECHNOLOGY IN EUROPE
MANPOWER, EDUCATION AND TRAINING

COMETT II

Secretariat: THE BIOCHEMICAL SOCIETY, 59 PORTLAND PLACE, LONDON W1N 3AJ, U K. Telephone: +44 71 580 5530 Fax: +44 71 323 1136

MANPOWER AND TRAINING NEEDS QUESTIONNAIRE

Reference No:________ (for office use)

Date received:________________ (for office use)

A RECRUITMENT DURING THE LAST YEAR

1 Number of staff at each <u>qualification level</u> according to your national scheme, for example	1.1 Post-doctoral	
	1.2 Masters degree or equivalent	
	1.3 Graduate or equivalent	
	1.4 Non-graduate diploma	
	1.5 Technical support	
2 Number of staff in each <u>discipline</u>	2.1 Biochemistry	
	2.2 Microbiology	
	2.3 Fermentation	
	2.4 Molecular genetics	
	2.5 Animal sciences	
	2.6 Pharmaceutical sciences	
	2.7 Immunology	
	2.8 Plant sciences	
	2.9 Engineering	
	2.10 Computer sciences	
3 Number of staff in each <u>area</u>	3.1 Agriculture	
	3.2 Food	
	3.3 Health care	
	3.4 Environment	
	3.5 Fine chemicals	
	3.6 Energy	

4 Number of staff in each <u>occupational category</u>

4.1 Research & development	
4.2 Production	
4.3 Management	
4.4 Public relations/marketing	

5 Have you <u>succeeded</u> in meeting recruitment targets? Yes ______ No ______

<u>If "YES", go to Question 9</u>

6 In which occupational categories/levels/disciplines have you experienced continuing difficulties in recruiting?

____

____

____

____

____

____

7 Which of these is/are the <u>main</u> area(s) of greatest recruitment difficulty?

____

____

____

____

____

____

8 How have these recruitment difficulties affected your business (eg R&D/ production/investment/motivation)?

____

____

____

____

____

9 What do you expect your demand for staff will be during the next ten years? (eg static(0), increasing(+), decreasing(-), etc)

	Main area, discipline or category of activity	Involving recombinant DNA, hybridoma and related	Other biotechnology activities	Other non-biotechnology activities
Area:	Agriculture			
	Food			
	Health care			
	Environment			
	Fine chemicals			
	Energy			
Discipline:	Biochemistry			
	Microbiology			
	Fermentation			
	Molecular genetics			
	Animal sciences			
	Pharmaceutical science			
	Immunology			
	Plant sciences			
	Engineering			
	Computer sciences			
Category:	Research & development			
	Production			
	Management			
	Public relations/ marketing			

10 What trends have you noticed in the number and quality of applications in different disciplines during the last five years?

____

____

____

____

B STAFF EMPLOYED NOW

11 Total numbers of staff employed now in each main area, discipline and category of activity

	Main area, discipline or category of activity	Involving rDNA hybridoma and related	Other biotechnology activities	Other non-biotechnology activities
Area:	Agriculture			
	Food			
	Health care			
	Environment			
	Fine chemicals			
	Energy			
Discipline:	Biochemistry			
	Microbiology			
	Fermentation			
	Molecular genetics			
	Animal sciences			
	Pharmaceutical science			
	Immunology			
	Plant sciences			
	Engineering			
	Computer sciences			
Category:	Research & development			
	Production			
	Management			
	Public relations/ marketing			

12 Number of staff at each qualification level according to your national scheme, for example

12.1 Post-doctoral	
12.2 Masters degree or equivalent	
12.3 Graduate or equivalent	
12.4 Non-graduate diploma	
12.5 Technical support	

13 Please provide the following information about your staff in whatever form is conveniently available:
Proportion male/female, proportion fulltime/part-time, age profile.

C TRAINING

14 Which of the following general types of training do you use now, and/or do you definitely anticipate using?

	Use now	Anticipate using
.1 Training of staff to remain up-to-date in their present area of biotechnology		
.2 Training of staff moving into a new area of biotechnology		
.3 Management or commercial (eg business administration, marketing, etc) training		
.4 Business awareness training for scientific staff		
.5 Biotechnology awareness training for non-scientific staff		

15 Which of the following methods of training do you use now, and/or do you definitely anticipate using in your own country or another?

	Own country		Another country	
	Use now	Will use	Use now	Will use
.1 Advanced short courses, workshops, summer schools, etc organised by:-				
.1 Universities and polytechnics				
.2 Technical/vocational college				
.3 Research centres				
.4 Material and equipment suppliers				
.2 Part time training courses				
.3 Conferences				
.4 Management/business courses				
.1 In-house				
.2 External				
.5 Exchanges or attachments				
.1 Within the organisation				
.2 In other commercial organisations				
.3 At universities, polytechnics or research centres				
.4 With government organisations				
.6 Distance learning courses				
.7 In-house technical training (eg videos equipment demonstrations, etc				

16 Please give details of the <u>major</u> training requirements of your company which are presently not satisfied.

.1 Advanced level training while in employment

.2 Training for membership of a professional body or scientific society

.3 Updating

.4 Management

.5 Commercial

.6 Awareness

.7 Other

17 What steps should be taken to meet the training and education needs of companies?

.1 By companies

.2 By national government

.3 By the European Commission and Parliament

.4 By education and research institutions

.5 By other organisations

.6 By other means

E GENERAL

18 What are your views on the following questions?

.1 The international dimensions of manpower supply and training issues for biotechnology in Europe

.2 The problems of SMEs (small and medium-sized companies) in relation to manpower supply and training

.3 "Brain drains" and the international mobility of staff and students

.4 The public perception of biotechnology in your country

.5 Where do the main responsibilities for ensuring skill supply and training lie?

19.1 Company at this site ______________________________

.2 Parent company (if applicable) ______________________________

20.1 Person(s) interviewed ______________________________

.2 Position(s) ______________________________

21 Business area(s) of company ______________________________

22 Can your company be named when the data are presented? Yes______ No______

Thank you for providing this information and for giving your time to do so. You will, of course, receive copies of the reports resulting from this programme.

BIOTECHNOLOGY IN EUROPE MANPOWER, EDUCATION AND TRAINING

BEMET

SECRETARIAT: THE BIOCHEMICAL SOCIETY
59 PORTLAND PLACE
LONDON W1N 3AJ
UNITED KINGDOM

January 1992

Monssieur/Madame

Nous vous invitons à participer au projet BEMET (Biotechnology in Europe, Manpower, Education and Training).
La Communaute Européenne a commandite une étude sur la main-d'oevre,l'énseignement et les besoins de formation pour l'industrie en biotechnologie dans les pays membres de la CEE et l'Aele.

BEMET poursuit deux objectifs principaux:
(i) identifier le manque de formation specialisée en analysant les problèmes du recrutement en biotechnologie dans la CEE et l'Aele.
(ii) étudier les possibilities de formation en vue de crée un inventaire de cours universitaires disponibles en biotechnologie dans toutes la CEE et l'Aele.

BEMET est en train de recueiller cette information au moyen d'un auprès des industries de la CEE et l'Aele. Nous vous prions de trouver ci-joint notre questionnaire et nous serions reconnaissants nous l'envoyer après l' avoir complété.

Les reseignements obtenus par cette étude inflenceront les prévisions de formation qui seront disponibles pour la biotechnologie de l'avenir. Un nombre d'organisations et d'institutions ont déjà repondu. Cependant, L'AIDE DE L'INDUSTRIE EST ESSENTIELLE POUR ACHEVER CETTE ETUDE. Votre réponse sera considérée comme strictement confidentielle. Les entrprises qui prennent part de cette étude se verront addresser un sommaire des résultats qui seront publiés en 1993.

Pour des reseignements complémentaires nous vous prions de vous addresser à:
S.A. Hayward ou Proffeseur M. Griffin

BEMET
Nottingham Polytechnic
Clifton Lane
Nottingham NG11 8NS
United Kingdom
Tel. & Fax. (+44) 602 486628

BEMET Office
The Biochemical Society
Portland Place
London W1N 3AJ
United Kingdom
Tel: (+44) 71 580 5530
Fax: (+44) 71 323 1136

Professor M. Griffin

TEL +44 71 580 5530
FAX +44 71 323 1136

Voir l'autre côté pour la version anglaise

BEMET QUESTIONNAIRE

Veuillez répondre à autant de questions que possible

Numéro de série: Numéro de référence:

SECTION A

Nous voudrions savoir:

1. Quelle est la personne responsable du recrutement? Veuillez entourer le code SVP.

Chef du personnel	1
Chef du recrutement	2
Directeur général	3
Autres. Veuillez préciser	4

2. Indiquez la domaine de la biotechnology que votre entreprise s'implique. Si çela consiste de plus qu'une domaine veuillez cocher la deuxième colonne fournie.

	Domaine I	Domaine II
Agriculture		
Alimentaire		
Santé		
Environnement		
Produits chimiques		
Enérgie		

3. Pour ces 2 choix (réf à Q2) - Est-il facile/difficile de recruter dans les disciplines suivantes? Cochez (✓) SVP.

DISCIPLINES	DIFFICILE		FACILE	
	A I	A II	A I	A II
Biochimie				
Microbiologie				
Fermentation				
Biologie végétale				
Produits chimiques				
Biologie animale				
Immunologie				
Phytopathologie				
Ingénierie				
Génie génétique				
Informatique				

4. Est-il facile/difficile de recruter dans les catégories suivantes? Cochez (✓) SVP.

CATÉGORIES	DIFFICILE		FACILE	
	A.I	A.II	A.I	A.II
Recherche et Développement (R & D)				
Production				
Direction				
Marketing				
Contrôle de qualité				

5. Quelles sont les raisons principales entraînant des problèmes de recrutement dans votre entreprise? **Entourez le code, vous pouvez en choisir plusieurs.**

A. L'image de la biotechnologie est faible/mauvaise dans votre pays.
B. Les cursus universitaires proposés ne correspondent pas aux besoins commerciaux.
C. La formation professionnelle est insuffisante.
D. Le financement de la formation professionelle est insuffisant.
E. Aucuns problèmes de recrutement.
F. Autre. Veuillez préciser.

6. Combien d'employés avez-vous recruté cette année pour les disciplines et les catégories ci-dessous? (Réf à Q2). Cochez (✓) SVP.

DISCIPLINES	NOMBRE DE PERSONNEL													
	0-2		3-5		6-8		9-11		12-15		15-20		20+	
	A.I	A.II	A.I	A.II	A.I	A.II	A.I	A.II	A.II	A.II	A.I	A.I	A.I	A.II
Biochimie														
Microbiologie														
Fermentation														
Biologie végétale														
Biologie animale														
Immunologie														
Phytopathologie														
Ingénierie														
Génie génétique														
Informatique														
Autre. Veuillez préciser.														
CATÉGORIES														
R & D														
Production														
Direction														
Marketing														
Contrôle de qualité														

7. Indiquez le niveau de qualification de votre personnel recruté cette année. (Voir la légende ci-dessous réf à Q2)
(0)-1 (1-3)-2 (4-5)-3 (6-8)-4 (8-10)-5 (11-15)-6 (16-20)-7 (21+)-8

DISCIPLINES	3ème cycle Doctorat		Masters		Licence BSc Laurea		DUT (Bac + 2)		Personnel technique	
	A.I	A.II	A.I	A.II	A.I	A.II	A.I	A.II	A.I	A.II
Biochimie										
Microbiologie										
Fermentation										
Biologie végétale										
Biologie animale										
Immunologie										
Phytopathologie										
Ingénierie										
Génie génétique										
Informatique										
Autre. Veuillez préciser.										
CATÉGORIES										
R & D										
Production										
Direction										
Marketing										
Contrôle de qualité										

8. Quel est l'âge approximatif du personnel recruté pendant les 2 dernières années? Cochez (✓) SVP

Age: 18-20 ..... 21-23 ..... 24-26 .... 27-30 .... 30+...

9. Classez par ordre d'importance les moyens de publicité utilisés pour les postes (1=le plus important, 5=le moins important)

RANK

Presse régionale
Presse nationale
Presse internationale
Communauté européenne
Contacts personels
Autres. Veuillez préciser.

10. Comment est-ce que vous prévoyez la demande pour personnel pendant les 5-10 années suivantes? (statique/croissante/décroissante)

DISCIPLINES	Statique		Croissante		Décroissante	
	A.I	A.II	A.I	A.II	A.I	A.II
Biochimie						
Microbiologie						
Fermentation						
Biologie végétale						
Biologie animale						
Immunologie						
Phytopathologie						
Ingénierie						
Génie génétique						
Informatique						
Autre. Veuillez préciser.						
CATÉGORIES						
R & D						
Production						
Direction						
Marketing						
Contrôle de qualité						

SECTION B.

En Section B nous voudrions savoir:

11. Combien de personnes employez-vous dans votre entreprise? Cochez (✓) SVP.

PERSONNES RECRUTÉES

moins de 20	20 - 40	40 - 60	60 - 100	100+

12. Combien d'employés (%) y a-t-il actuellement par rapport à l'année dernière? Cochez (✓) SVP.
%

125	100	75	50	25	0	-25	Autre. Veuillez préciser.

13. Combien de femmes employez-vous dans le domaine scientifique? Cochez (✓) SVP.

35+	25	15	10	5	2	1	0	-1 ....

14. Voici une liste de disciplines et catégories. Cochez le nombre de personnes dans les 2 domaines. (Réf à Q2)

NOMBRE DE PERSONNES EMPLOYÉES EN CE MOMENT

DISCIPLINES	0-2		3-5		6-8		9-12		13-15		16-20		20+	
	A I	A II	A I	A II	A I	A II	A I	A II	A I	A II	A I	A II	A I	A II
Biochimie														
Microbiologie														
Fermentation														
Biologie végétale														
Biologie animale														
Immunologie														
Phytopathologie														
Ingénierie														
Génie génétique														
Informatique														
CATÉGORIES														
R & D														
Production														
Direction														
Marketing														
Contrôle de qualité														

15. Quel est le niveau de qualification du personnel à présent? Réf à Q2.
Légende: (0) - 1 (1-3) - 2 (4-5) - 3 (6-8) - 4 (8-10) - 5 (11-15) - 6 (16-20) - 7 (21+) - 8

DISCIPLINES	NOMBRE D'EMPLOYÉES À CHAQUE NIVEAU									
	3eme cycle Doctoral		Masters		Licence BSc Laurea		DUT Bac + 2		Personnel technique	
	A.I	A.II	A.I	A.II	A.I	A.II	A.I	A.II	A.I	A.II
Biochimie										
Microbiologie										
Fermentation										
Biologie végétale										
Biologie animale										
Immunologie										
Phytopathologie										
Ingénierie										

Génie génétique										
Informatique										
Autre. Veuillez préciser.										
CATÉGORIES										
R & D										
Production										
Direction										
Marketing										
Contrôle de qualité										

SECTION C
En Section C nous voudrions savoir:

(I) LES MOYENS DE FORMATION DANS VOTRE ENTREPRISE

16. Engagez-vous à la formation?

Non - 1 Rapportez-vous à question 18
Oui - 2 Continuez

17. Qu'utilisez-vous et dans quelle proportion les moyens de formation ci-dessous?

TEMPS

TYPE	PLEIN TEMPS	PARTIES	MIS TEMPS	À PEINE	JAMAIS
Les écoles d'été					
Stages					
Cours					
Conférences					
À la maison					
Par correspondence					
Échanges internationaux (hors Europe)					
Échanges européens					
Autre. Veuillez préciser.					

18. Pourquoi est-il nécessaire de fournir une formation professionelle? Entourez le code. Vous pouvez choisir plusieurs réponses.

A. Pour la formation professionelle dans les applications/techniques nouvelles.
B. Pour la formation professionelle du personnel dans les nouveaux domaines.
C. Pour augmenter la connaissance commerciale du personnel scientifique.
D. Pour augmenter la connaissance scientifique du personnel commercial.
E. Pour les besoins administratifs.
F. Pour créer un échange dans l'entreprise.
G. Pour garder un esprit d'innovation dans l'entreprise.
H. Autre. Veuillez préciser.

19. Quelle importance la formation professionelle tient-elle dans votre entreprise? Entourez le code SVP.

Très important	: 1
Important	: 2
Pas très important	: 3
Pas du tout important	: 4
Sans opinion	: 5

II) LES MOYENS DE FORMATION DANS VOTRE PAYS

20. Quelle est l'accessibilité à la formation dans votre entreprise? Entourez le code SVP.

Accessible	: 1
Peu accessible	: 2
Pas du tout accessible	: 3
Sans opinion	: 4

21. Quel est le niveau moyen de formation dans votre pays? (Réf à Q2). Cochez (✓) SVP.

DISCIPLINE	EXCELLENT		BIEN		MOYEN		MAUVAIS		PAS DU TOUT	
	A.II	A.II	A.I	A.II	A.I	A.II	A.I	A.II	A.I	A.II
Biochimie										
Microbiologie										
Fermentation										
Biologie végétale										
Biologie animale										
Immunologie										
Phytopathologie										
Ingénierie										
Génie génétique										
Informatique										
Autre. Veuillez préciser.										
CATÉGORIES										
R & D										
Production										
Direction										
Marketing										
Contrôle de qualité										

22. Qui finance la formation dans votre pays? Cochez (✓) SVP.

	TOUT	PARTIE	À PEU PRÈS LA MOITIÉ	À PEINE	JAMAIS
Votre entreprise					
Gouvernement ou état					
CEE					
Organismes à l'échelle européens					
Organismes de recherche internationaux					
Autre. Veuillez préciser.					

SECTION D

En Section D nous voulons connaître les attitudes vis-à-vis de l'integration et l'homogénité en Europe.

23. Serait-il un problème pour votre entreprise si:

	OUI	NON	SANS OPINION
les cours de biotechnologie étaient harmonisés partout dans la CEE?			
les cours de biotechnologie étaient harmonisés partout dans la CEE et l'AELE?			
il y avait plus d'échanges entre la CEE et l'AELE au niveau de personnel?			
la recherche était commune à toute la CEE?			

24. Quelle importance le marché unique détient-il dans votre entreprise? Entourez le code SVP.

Très important : V
Important : W
Pas très important : X
Pas du tout important : Y
Sans opinion : Z

25. Quels sont les avantages du marché unique? Cochez (✓) SVP. Vous pouvez choisir plusieurs réponses.

A. L'industrie de la biotechnologie sera avantagée.
B. Le profit se développera.
C. La dissémination de la recherche sera plus répandue.
D. La dissémination de la recherche sera plus importante.
E. Grande colloboration entre la CEE et l'AELE.
F. Les subventions gouvernementales seront régulées.
G. Les normes techniques seront mises en commun.
H. Normes de securité des produits seront harmonisées.
I. Aucun avantage.
J. Sans opinion.

26. Quels sont les plus grands inconvénients du marché unique pour votre entreprise?

K. L'industrie de la biotechnologie n'en profitera pas.
L. La concurrence s'accrôitra.
M. La dissémination de la recherche ne sera pas importante.
N. Les rapports politiques en Europe ne se renforceront pas.
O. Trop de formalités (administratives).
P. Aucun inconvénient.
Q. Sans opinion.

27. Comment est-ce qu'une CEE et l'AELE qui serait plus uniforme pouvait améliorer les secteurs suivants en biotechnologie? Cochez (✓) SVP

	BEAUCOUP	PEU	TRÈS PEU	AUCUN
Le recrutement				
La formation professionelle				
Mobilité de la main-d'oeuvre				
La mise en commun de la recherche				

NOUS VOUS REMERCIONS POUR VOTRE COOPÉRATION. VEUILLEZ RETOURNER CE QUESTIONNAIRE À :

THE BIOCHEMICAL SOCIETY 59 PORTLAND PLACE LONDON W1N 3AJ UNITED KINGDOM

COMETT II

The Nottingham Trent University

Labour and Training for the European Biotechnology Small Firm Sector

EMICAL SOCIETY
DED 1911

BEMET

EUROPEAN FEDERATION OF BIOTECHNOLOGY

APPENDIX TWO

APPENDIX TO CHAPTER SEVEN

A 2.1

List of Participants at the Manpower and Training Needs In UK Biotechnology Conference, 4 April, 1989 at The Biochemical Society, London, UK.

Prof M Griffin
Nottingham Trent University

Dr D.J.Best
Stirling Organics
Newcastle upon Tyne, UK

Dr P Critchley
Unilever Research
Bedford, UK

Dr S.W.Elson
Beecham Pharmaceutical
Surrey, UK

Prof C Fewson
University of Glasgow

Prof. T. Godfrey
Biocatalysis Ltd
Mid Glamorgan, Wales

Prof. K .Goulding
Lancashire Polytechnic

Miss G Gilliam
PCFC
London

Mr G Street
North East Biotechnology Centre
Teeside Poly

Dr S Taylor
ICI plc
Cleveland

Prof H Dalton
Univ of Warwick

Dr M Hoare
Univ College London

Dr J A Birkett
Glaxochem ltd
Cumbria

Dr R Bishop
Univ of Ulster

Dr D Broad
Celltech Ltd
Berks

Dr J Corfield
Dista Products Ltd
Liverpool

Dr K Holdom
Pfizer Ltd
Kent

Prof L Pyle
Univ of Reading
Berks

Mr T A Savidge
Beecham Pharm
Worthing

Dr A Radford
Univ of Leeds

Mr T.W. Buckley
Amersham Int.Cardiff

Dr C Caten
Univ of Birmingham

Dr E Gingold
South Bank Poly

Dr P Harper
Microplants
Derby

Dr R.C. Imrie
Beecham Pharm
Epsom

Dr P Long
Univ of Leicester

Dr A Makoff
Wellcome Biotech
Kent

Dr K McFarthing
Amersham Int
Bucks

Ms J Smith
Celltech Ltd
Berks

Dr C Thomas
Univ of Birmingham

Prof G Morton
Lancashire Poly

Dr D Allsopp
CAB International Mycological Institute
Surrey

Mrs C Gaylarde
City of London Poly

Dr G Higton
South Bank Poly

Dr A Smith
Nottingham Trent Univ

(UK Interest Group on Education in Biotechnology Representatives)

Prof C.A. Bryce
Napier Poly

Dr D J Bennett
AABB
Cambridge

Mr A Gasson
Royal Society of Chemistry,London
Dr J M Grainger
Univ of Reading

Dr P E O Wymer
National Centre for School Biotechnology
Univ of Reading

Ms S Andrews
The Biochemical Society
London

(speakers)

Mr G H Fairtlough
Celltech Ltd
Berks

Dr A D W Jones
Director of the Wolfson Foundation
London

Prof O B Jorgensen
The Technical University of Denmark

Dr M Lex
SERC
London

Ms J Munday
Enterprise and Education Unit
DTI
London

Dr K Sargeant
CUBE
DG XII
Brussels

A2.2

Manpower and Training Needs for Biotechnology In Europe in the 90s, Meeting held on 2 December, 1989 at Delft University of Technology, Netherlands

(European Federation of Biotechnology Representatives)

Dr D Bennett
Cambridge Biomedicals Consultants
Cambridge

Prof H Blanchere
Inceltech
France

Dr M Bosnjak
PLIVA Research Institute
Zagreb

Prf C Bryce
Napier Poly

Prof E Galli
Univ of Milan

Dr M Godinho
Waterford RTC
Ireland

Prof G Goma
Institut National des Sciences Appliquees
Toulouse
France

Pof G Greco
Univ of Naples

Dr K Hult
Royal Institute of Technology
Stockholm

Porf J G Kuenen
Delft Univ of Technology

Dr U Leinhos
DECHEMA
Germany

Dr A McLoughlin
UCD
Ireland

Prof L Melo
Univ of Minho
Portugal

Prof Mohr
Norwegian Institute of Tech

Prof U Nissen
Engineering Academy of Denmark

Prof Novais
Instituto Superior Tecnico
Lisbon
Portugal

Prof L Nyeste
Univ of Technical Sciences
Budapest
Hungary

Prof P Peringer
Ecole Poly de Lausanne
Switzerland

(UK Interest Group on Biotechnology Representatives)

Prof C.A. Bryce
Napier Poly

Dr D J Bennett
Cambridge Biomedical Consultants
Cambridge

Mr A Gasson
PHLS
Porton Down
Salisbury

Dr J M Grainger
Univ of Reading

Ms S Andrews
The Biochemical Society
London

Prof M Griffin
Nottingham Trent Univ

(Biotechnology Industry Representatives)

M Bourat
Rhone-Poulenc Sante
France

Prof H Brunnhofer
HOESCHT AG
Germany

Mr T Buckley
Amersham Int
Cardiff

Sr Julio Calvo
Chamber of Commerce and Industry
Granada
Spain

Dr P Cardoso
Cipan
Portugal

Prof T Godfrey
Biocatalysis ltd
Mid Glamorgan

Prf E Meiher
DSM Chemicals BV
Netherlands

Dr J O'Shea
Interbio Labs
Dublin
Ireland

Dr A Owens
Arran Chemical Company Ltd
Dublin
Ireland

Dr M Soria
Farmitalia Carlo Erba apo
Milan
Italy

M C Vincent
Elsevier/ Biofutur
Paris
France

A2.3

BEMET Steering Committee

Prof M Griffin
Nottingham Trent University

Dr R N Barnes
Pharmacia Biosystems, Belgium

Dr Mieke Beer
NETWORC - FORBITEC
University of Nijmegen, Netherlands

Prof. Enrica Galli
Universita delgi Studi di Milano, Italy

Dr Marie-Claude Dauchel
Universite Paris XII, France

Mr Louis Da Gama
BIA, BioIndustry Association, UK

Mr Anthony G Gasson
PHLS Centre for Applied Microbiology &
Research, UK

Professor Tony Godfrey
Biocatalysts Ltd, UK

Dr Alan Radford
University of Leeds, Chair UK Interest
Group on Biotechnology Education

Snr. Antonio Montero Carro
ZELTIA, Spain

Adminstrative and research support

Joanne Curtis
BEMET Project Assistant

Annie Walshe
BEMET Project Assistant

Sally Hayward
BEMET Senior Adminstrator/researcher

BIBLIOGRAPHY

Abrahams, P (1994) 'Just out of the starting blocks' Finanical Times Survey: Biotechnology, *Financial Times*, May 9

Advisory Council for Science and Technology (ACOST) (1990), *Developments in Biotechnology*, ACOST, UK.

Amin, A (ed.) (1994a) *Post Fordism: A Reader*, Oxford: Blackwell

- (1994b) 'The difficult transition from informal economy to Marshallian industrial district' *Area*, 26, 1, pp.13-24

-, Gills, B, Palan, and Taylor, P (1994) 'Editorial: Forum for heterodox international political economy', *RIPE,* Vol.1No.1, pp 1-5, London: Routledge

-, and Robins (1990) 'The re-emergence of regional economies? The mythical geography of flexible accumulation' *Environment and Planning: Society and Space*, Vol 8, pp 7-34

-, and Tomaney, J (1995a) 'The Regional Dilemma in a Neo-Liberal Europe', *European Urban and Regional Studies*, 2 (2) : Longman Group Ltd.

-, (eds.) (1995b) *Behind The Myth of the European Union: Prospects for Cohesion*, London: Routledge.

-, (1995c) 'The Regional Development Potential of Inward Investment in the Less Favoured Regions of the European Community,' *ibid.*

-, and Thrift, N (1994) *Globalisation, Institutions and Regional Development in Europe*, Oxford University Press, Oxford

-, and Dietrich, M (1991) 'From Heirarchy to Heirarchy: the Dynamics of Contemproary Corporate Restructuring' in Amin, A and Dietrich, M (eds) *Towards a New Europe*, Edward Elgar, Aldershot

Aggarwal, R and Agmon, T (1990) 'The International Success of Developing Country Firm's Role of Government-Directed Comparative Advantage' *Management International Review*, Vol. 30, no.2, pp163-80

Albert, M (1993) *Capitalism against Capitalism*, London: Whurr Publishers Ltd.

Alvesson, M (1993) 'Organisations as Rhetoric: Knowledge-Intensive Firms and the Struggle with Ambiguity', *Journal of Management Studies*, special issue Knowledge Workers and Contemporary Organisations, 30:6 November, pp. 997-1015

Archibugi, D and Michie, J (1995) 'Technology and Innovation: An Introduction *Cambridge Journal of Economics* special issue Technology and Innovation, Vol. 19 Number 1, February, pp1-4

-, (1993) 'The globalisation of technology: myths and realities' Research Papers in Management Studies, Judge Institute of Management Studies, Cambridge.

Armstrong, P (1993) 'Professional Knowledge and Social Mobility: Post-war Changes in the Knowledge-Base of Management Accounting', *Work, Employment and Society*, Vol. 7, No.1, March pp.1-21.

Arthur, W.B., (1990) 'Positive Feedbacks in the Economy' *Scientific American*, February, pp. 9-10

Asheim, B (1992) 'Flexible Specialisation industrial districts and small firms: a critical appraisal'. In H. Ernste and V. Meier (eds.) *Regional Development and Contemporary Industrial Response* : Extending Flexible Specialisation, Belhaven, London.

Association for Manufacturing Excellence (1990) *Manufacturing 21 Report: The Future of Japanese Manufacturing*, translated from Japanese articles in *Communications of the Operations Research Society of Japan*, Vol 34. No 12.

Atkinson J and Meager, N (1994) 'Running to stand still: the small business in the labour market' in Atkinson, J and Storey, D.J. (eds) *Employment, The Small Firm and the Labour Market*, London : Routledge

Atkinson, R (1990) Supply fear 'Supply and Demand for Scientists and Engineers: A National Crises in the Making' *Science*, Vol 248, 27 April p. 425-432.

Averitt, R (1968) *The Dual Economy*: NY: W.W.Norton and Co.

Bailey, T (1991) 'Jobs of the Future and the Education that they will require: Evidence from occupational Forecasts' *Educational Research* pp11-20

Bangemann, M (1995) *The Information Society*, Commission of the European Communities, Brussels

Bartlett, C and Ghosal, S (1989) *Managing Across Borders: The Transnational Solution*, Century Business, London.

Barley, S, Freeman, J and Hybels, R 'Strategic Alliances in Commercial Biotechnology' in Nohria, N and Eccles, R (1992) (eds.) *Networks and Organisations: Structure Form and Action*, Harvard Businesss School Press, MA

Becker, G.S (1957) *The Economics of Discrimination*, Chicago: University of Chicago Press.

-, (1962) 'Investment in Human Capital' *Journal of Political Economy*, Vol.70, No 5. pt 2, pp 9-19

-, (1964) *Human Capital*, NY: Columbia University Press

-, (1975) *Human Capital : a theoretical and empricial analysis*, New York: National Bureau of Economic Research

-, (1993), 'The Economic Way of Looking at Behaviour', *Journal of Political Economy* , vol 101, no 31 , pp. 101-150

Bell, D (1973) *The Coming of Post-Industrial Society*, New York: Basic Books

BEMET Managment Board Meeting Minutes (1991), BEMET UETP, The Biochemical Society

Benfrey, P and Chua, C.H.(1986) 'Regulated Genes in Transgenic Plants,' *Science*, 244, pp.174-181

Ben-Porath (1967) 'The Production of Human Capital and Life-Time Earnings' *Journal of Political Economy*, Vol 75, No 2, pp. 352-65

Bergman, B (1986) *The Economic Emergence of Women*, Basic Books, New York

Bevan, S, Parsons, D and Pearson, R (1987) *Monitoring The Biotechnology Labour Market*, Institute of Manpower Studies/SERC, Sussex

Bio/technology, (1994) 'European Alliances should double by 2000', Vol. 12 April, p12.
-, (1989), 'Critical UK Manpower Shortage Discussed', Vol 7, August, p.761

Biotechnology Business News (1992) 'Biotech - to benefit the developing world or the mulitnationals?' 11 December, p.8

Blaug, M (1990) 'The Firm's Decision to Train' in Basia, LJ and Crawford, D.L. (eds) *Research in Labor Economics*, Vol 11 1990, pp. 53-75

Blanchere, H (1983) *Manpower and Training Implications of the Expansion of Biotechnology Based Industries* XII-341-83-EN Commission of the European Communities, Brussels

Boosveld, J and Van Der Kwaak, R (1992) 'The Art of Soical Bioengineering' *Bio/technology*, Vol 10, August, pp. 873-875

Bosworth, D.L (1990) 'Professional Skill Shortages' *International Journal of Manpower*, Vol 11, No 2/3 pp. 6-17

Borrus, M, D'Andrea Tyson, L and Zysman, J (1986) 'Creating advantage: how government policies shape international trade in the semi-conductor industry in *op.cit.* Krugman

Boyer, R (1986) *La Theorie de la Regulation: Une Analyse Critique*, La Decoverte : Paris

Braverman, H (1974) *Labor and Monopoly Capital* New York: Monthly Review Press

Brander, J. A. (1986) 'Rationales for Strategic Trade and Industrial Policy' in *op.cit.* Krugman

-, and Spencer, B (1985) 'Export Subsidies and International Market Share Rivalry. *Journal of International Economics*, 18(1), pp. 83-100

Broglie, (1991)'Transgenic Plants with Enhanced resistance to the Fungal Pathogen *Rhizoctonia solani', Science*, 254, p1194-1197.

Brown, C (1988) 'Income distribution in an Institutional World' in Magnum, G and Phillips, P (eds.), *Three Worlds of Labor Economics*, NY : Sharpe, M.E, Armonk

-, (1993) 'Training Productivity and Underemployment in Institutional Labour Markets', *International Journal of Manpower*, Vol 14, No 2/3, pp.

-, Reich, M and Stern, D (1991) *Skills and Security in Evolving Employment Systems*, California: University of California, Berkeley

Brown, G (1994) 'Fair is efficient: A Socialist Agenda for Fairness', *Fambian Pamphlet*, 563, London

Bryce,C and Bennett, D (eds) (1990) Report by the UK Interest Group on Biotechnology Education *Manpower and Training Needs for European Biotechnology*, UK Interest Group, London: The Biochemical Society.

-, Bennet, D and Griffin, M (1989) Report by UK Interest Group on Biotechnology Education *Manpower and Training Needs for UK Biotechnology*, UK Interest Group, London: The Biochemical Society.

Bull, H (1977) *The Anarchial Society*, Columbia University Press: New York

Burowoy, M (1979) *Manufacturing Consent*, University of Chicago Press: Chicago

Canning, D (1984) 'A theory of wages and employment' in *Internal, Local an Regional Labour Markets*, Cambridge : Dept of Applied Economics, University of Cambridge

Cantley, M (1983) Plan by Objective: Biotechnology, European Commission FAST Project XII/37/83/EN, Brussels, Commission of the European Communities

-, (1987) 'Democracy and Biotechnology: Popular attitudes, information, trust and the public interest' *Swiss Biotech* 5, pp5-15.

Carnoy, M, Castells, M and Cohen, S and Cardoso, F.H, (1993) *The New Global Economy in the Information Age*, Pennsylvania: The Pennsylvania State Press

Castells, M (1993) 'The Informational Economy and the New International Division of Labour' *op.cit* Castells and Hall, pp.15-45

-, and Hall, P (1994) *Technopoles of the World, The making of twentieth first century industrial complexes*, London, Routledge.

Cardiff, B and Claessens, M 'Education and Training: An Overview of some EC Initiatives', *Biofutur* - Hors series no.2 1994.

Caulkin, S (1996) 'Capitalists shun risk of investment', *The Observer*, 16 June

Cecchini, P (1988) *The European Challenge, 1992: The Benefits of a Single Market*, Wildwood House for the Commission of the European Communities, Aldershot

Cerny, P (1995) 'Globalisation and the changing logic of collective action' *International Organization*, 49, 4, Autumn, pp.595-625

Charles, D, Hayward, S and Thomas, D (1995) 'Science Parks and regional technology strategies: European experiences', *Industry and Higher Education*, Special Focus: The role of Science Parks in University-Industry Co-operation, Vol 9, No.6, December, pp. 332-339, Brighton: In Print

Chinitz, B (1961) Contrasts in agglomeration: New York and Pittsburgh, *Am. Econ.Ass.Pop. Proc.* 73rd Meeting, 51, pp.279-89

Clarke, L (1995a) 'Investors become more cautious' *Financial Times* Biotechnology Survey, Monday 27 November

-, (1995b) 'New drugs in the pipeline' *Financial Times* Biotechnology Survey, Monday 27 November.

COMETT and Biotechnology, Task Force for Human Resources, *Higher Education - Industry: getting to the point* COMETT Bulletin No15 December 1992, Brussels, CEC.

Commission of the European Communities White Paper (1993), *Growth Competitiveness and Ways Forward into the 21st Century*, Brussels, CEC.

-, (1991) *Promoting the Competitive Environment for the Industrial Activities Based on Biotechnology within the European Community* Commission Communication to Parliament and the Council, Working Paper III. A3.SEC (91) 629, final, 19 April, Brussels, CEC.

-, (1993b) Working Party *Guidelines for Community Action in the field of Education and Training* COM (93) 183 final Brussels May 1993

-, (1990) *Biorep, Permanent Inventory of Biotechnological Research Projects in the European Communities, Scientific and Technical Communication Unit*, DG Telecomunications, Information Industries and Innovation, CEC, Brussels

-, (1993) *Inventory of Biotechnology Information* Material, DGXII, CEC, Brussels

Concertation Unit for Biotechnology Education (CUBE) (1991) *Biotechnology for All*, CUBE, CEC, Brussels

Connor, H, Bevan, S (1993) *The Biotechnology Labour Market*, SERC/IMS, Sussex

Cooke, P (1995). 'Keeping to the high road: learning, reflexivity and associative governance in regional economic development'. In: P Cooke (ed). *The Rise of the Rustbelt*. London: UCL Press.

Coombes, J (1992) Biotechnology for Quality Management in Agro-Industrial Production. 1st Interview Report for The Monitor Programme, (SAST) CEC, Brussels

Coombes, J and Coombes,(1992) *The International Biotechnology Directory*, Macmillian, London

Costello, N., Michie, J and Milne, S (1989) *Beyond the Casino Economy: Planning for the 1990s*, Verso, London

Cox, K (1992) 'The politics of globalisation: a sceptic's view' *Political Geography*, 11 (5): 427-9

Cox, R. W (1987) *Production, Power and World Order: Social Forces in the Making of History*, New York : Columbia University Press,

-, (1982) 'Social Forces, States and World Orders ; Beyond International Relations Theory', *Millenium : Journal of International Studies* Vol 10, No. 2

Crowe, C (1990) 'Whose Mind Over Matter? Women, In Vitro Fertilisation and the Development of Scientific Knowledge' pp. 27-58 McNeil *op. cit.,*

Cunningham, E.P(1990) 'Animal Production' in Persely. G (ed) *Agricultural Opportunities for International Development*, CAB International, Oxford

Curran, L and Lovering, J (1994) 'As the State Contracts: Emerging Tensions in the Scientific Labour Market in Britain', mimeo EASST Conference, Budapest

Dale, R (1995) 'Developing World is not Stealing Jobs' *International Herald Tribune*, 14 July.

Daly, J and Willis, E (1988) 'Technology in the Healthcare' pp. 113-127 *op.cit.,* Willis

Dando, M.R (1993) 'Negotiating Verification of the Biological Weapons Convention: Successful Multilateralism in the New World Order?' Paper presented at British International Studies Association (BISA) Annual Conference, Univ. of Warwick, December.

Da Silva, E.J. Rateledge, C and Sasson A (1992) *Biotechnology Economic and Social aspects Issues for Developing Countries* Cambridge University Press, Cambridge.

Daniels, P (1993) 'Research and development, human capital and trade performance in technology intensive manufactures: a cross country analysis' *Research Policy*, 22, pp.207-241.

De Nettancourt, D and Magnien, E (1993) 'What drives European biotechnological research?' in Blakely, E.J. and Willoughby, K.W (eds.) *Biotechnology Review No.1: The Management and Economic Potential of Biotechnology*, pp.47-58

Dicken, P (1994) 'Global-local tensions: firms and states in the global-space economy. *Economic Geography*, 70 (2), pp.101-28

Dixon, B (1991) 'Respecting Irrationality' *Biotechnology*, Vol 9, November, pp.101
-, (1989) 'Silent Science' Biotechnology Vol 7 June, p.535

Doeringer, P.B and Piore, M.J (1971) *Internal Labor Markets and Manpower Analysis*, Massachussetts: Health Lexington Books.

Dosi, G, Freeman, C, Nelson, R, Silverberg, G and Soete, L (eds.) (1988) *Technical Change and Economic Theory*
Dosi, G (1988) 'The nature of the innovation process' in Dosi et al, *ibid.*
-, Tyson, L.D and Zysman, (1989) 'Trade, Technololgies and Development : A Framework for discussing Japan' in *op.cit.* Johnson et al

Doyle, J.J and Spradbrow, P.B (1990) Animal Health in Persely, *op.cit*

Drake, P and Brown, G (1994) 'Biotech Firms gain greater bargaining power' *Bio/technology*, Vol.12 April, pp. 222
-, (1995) CEOs must seek pharmaceutical partners now' *Bio/technology*, Vol 13 April, pp.313

Drucker, P (1983) 'Quality Education: The New Growth Era', *Wall Street Journal*, 19th July
- (1993) *Post-Capitalism,* Oxford: Butterworth Heinemann

Dunhill, P and Rudd,M (1984) *Biotechnology and British Industry*, Biotechnology Directorate, UK, Science and Engineering Research Council, London

Dunning J, H (1992a) *The Globalisation of Business*, Routledge, London
(1992b) 'The competitive advantage of countries and the activities of transnational corporations' *Transnational Corporations* 1 (1) (Feb.) pp.135-68.

Eaton. J. (1986) 'Credit Policy and International Competition' in *op.cit* Krugman.

Edwards, R.C., Reich, M and Gordon D.M., (eds.) (1973) Labour Market Segmentation, Lexington, Massachusetts, Lexington Books

Elam, M (1994) 'Puzzling out the Post-Fordist Debate' in Amin, 1994 *op.cit*

Erlick, B. J (1989) 'Biological and Toxin Agents' presented to Committee of Governmental Affairs of the US Senate February 9-10, US printing Office, Washington.

Ernst and Young (1995) *European Biotech 95' Gathering Momentum: The Industry Annual Report*, Ernst and Young, The Netherlands

Eurobarometer (1991) *Opinions of Europeans towards Biotechnology*, Brussels:CEC.
-, (1993) Opinions of Europeans towards Biotechnology, Brussels, CEC.

The European Citizen (1992) 'Overview' No.17 Special Issue, Euro Citizen Action Service (ECAS), CEC, Brussels

European Federation of Biotechnology (EFB) (1993) Newsletter, June, Macmillian Press, London.

Enzing, C.M., Bilderbeek R and Otto, S.R. (1991) *Biotechnology Companies In The Netherlands Human Resources in R&D and Production*, Summary of a Report to the Dutch Ministry of Economic Affairs, TNO Centre for Technology and Policy Studies, The Netherlands.

Fajnzylber, F (1988) 'Technical Change and Economic Development Issues for a Research Agenda' World Bank Seminar on Technology and Long term economic Prospects, Washington DC, November.

Fallon P. and Verry, D, (1988) *The Economics of Labour Markets*, Hemel Hempstead : Phillip Allan.

Faulkner, W (1989) 'The New Firm Phenomenon' in Rosa, P, Burly, S, Cannon, T and O'Neil, K (eds.) *The Role and Contribution of Small Business Research*, Gower, Aldershot

Featherstone, M (ed) (1990) *Global Culture* London, Sage

Ferguson, M (1992) 'The Mythology About Globalisation' *European Journal of Communication*, Sage, London, Vol 7 pp 69-93

Feitelson, J, Paynes, J and Kim, L (1992) 'Bacillus thuringiensis: Insects and Beyond', *Biotechnology*, 10, pp271-275

Financial Times, (1994) Financial Times Biotechnology Survey 'Location a High Priority', Monday 9 May
-, (1995), 'Stock markets open the door' Monday 27 November,
-, (1991), 'Sandoz follows Roche to the US', Friday 19 December.

Forging Ahead, (1995) The UK Government Second Competitiveness White Paper, London: HMSO

Frankel, B (1987) *The Post-Industrial Utopians*; Cambridge, Polity Press.

Frayley, F (1992) Sustaining the food supply, *Biotechnology*, 10, pp.939-943

Freeman, C (1995) 'The National System of Innovation in histrorical perspective', *Cambridge Journal of Economics*, Vol 19. No.1, February

-, Sharp, M and Walker, W (eds.)(1992) *Technology and the Future of Europe* Pinter Publishers, London and New York

-, and Perez, C (1988) Structural Crises of adjustment, business cycles and investment behaviour. in *op cit.* Dosi et al..

Freeman, R.B. (1986) 'Demand for Education' in Ashenfelter, O.C. and Layard, R. (eds.) Handbook of Labour Economics, Vol.1 Amsterdam, pp357-86.

Frost and Sullivan (F&S) (1992) *The European Market for Hormone Related Tests*, Frost and Sullivan, New York and London

Gamble, A (1996) 'The New Political Economy', *New Political Economy*, Vol.1, Oxford: Carfax Publishing,

-, and Payne, A (1996) (eds.) 'Introduction: The Political Economy of Regionalism and World Order' in Gamble, A and Payne, T, *Regionalism and World Order,* Macmillian Press, London.

Gasser, C and Fraley, R (1989) 'Genetically Engineering Plants for Crop Improvement' *Science*, 240, pp.1293-1299

Genetic Engineering News (1994) 'Biotech Firms Sign On to help Massachusetts defence workers' Jan 15 Vol 14 No2

-, (1993) 'Biostrategies in the Pacific Rim: Biotech Job Opps in Asia' December.

George, S (1991) *Politics and Policy in the Euoropean Community*, Oxford University Press, Oxford

Gewirtz, C (1995)'Multinationals are not Fleeing Developed World, OECD says' *International Herald Tribune,* 26 June

Giddens, A (1990), *The Consequences of Modernity*, Polity Press, Cambridge

-, (1991) *Modernity and Self Identity*, Polity Press, Cambridge

-, (1984) The Constitution of a Society, Polity Press, Cambridge

-, (1985) *The Nation-State and Violence*, Polity Press, Cambridge

Gill, S (1993) *Gramsci, Historical Materialism and International Relations*, Cambridge: Cambridge University Press

-, and Law, D (1988) *The Global Political Economy* Harvester Wheatsheaf, Hemel Hempstead.

Granovetter, M (1985) 'Economic action and social structure: the problem of embeddedness' *Am. Journal of Sociology*, 91, pp.481-510.

Grayson L, P (1983) *Japan's intellectual challenge* US National Institute of Education

Green, D (1994) 'Seeking a Backer' Financial Times Biotechnology Survey, *Financial Times*, May, 9.

-, (1995) 'Billions spent on global quest for wonder cures' Financial Times Biotechnology Survey, *Financial Times*, Monday 27 November

-, and Burt, T (1994) 'Improving the Survival Index' *Fianancial Times*, Tuesday, November, 1.

Greenwood, J and Ronit, K (1994) 'The ABCs of Biotechnology Lobbying Organisations in Europe', *Biotechnology*, Vol 12 April, pp. 371-374.

Gregory, R.A and Ho, V. (1986) 'Equal pay and comparable worth : what can the US learn from the Austrialian experience?' Australian National University Discussion Paper, 123

Grossman, G (1986) 'Strategic Export Promotion: A Critique' in *op.cit.* Krugman

Grindley, J and Bennett, D (1992) 'Public Perception and the Socio-Economic Integration of Biotechnology' in BioIndustry Association *The UK Biotechnology Handbook*, London.

Goldberg, R.B (1988) 'Plants - Novel Developmental Processes', *Science,* 240, pp. 1460-1467

Gordon, D.M (1972) *Theories of Poverty and underemployment*, Massachussetts :Health Lexington Books

Gorz, A (1982) *Farewell to the Working Class: An Essay on Post-industrial Socialism*, Pluto Press, London

-, (1991) *Capitalisme, Socialisme, Ecologie*, Editions Galilee, Paris

Gilpin, (1987) *The Political Economy of International Economic Relations*, Princeton University Press, New Jersey

Griffin, M, Hayward, S and Curtis, J (eds.) (1993a) *Manpower and Training Needs for Biotechnology in North and South Europe in the 90s*. Report of a Meeting held in Orense, Spain 18-19 September, BEMET, London

-., Curtis, J, Hayward, S and Walshe A (eds.) (1993b) *Directory of Higher Education Courses in European Biotechnology* , BEMET, UK Interest Group, London

Haas, P (1992) 'Epistemic communities and international policy coordination' *International Organisation* 46, 1 Winter

Hacking, A (1989) *The Economics of Biotechnology*, Cambridge Press

Halimi, S., Michie, J and Milne, S (1994) 'The Mitterand Experience' in Michie, J and Grieve-Smith (eds) *Unemployment in Europe*, Academic Press, London

Hansen, A, Hansen, N and Pedersen, J.L, (1990) *Forskning og udvikling i dansk bioteknologi*, Projekt Pegasus Tecnoloi Naevnet, Report to the Danish Ministry.

Harrison, B (1991) 'Industrial Districts: Old Wine in New Bottles?' *Regional Studies*, Vol 26 pp. 469-483.

-, (1994) *Lean and Mean: the Changing Landscape of Corporate Power in the Age of Flexibility*, Basic Books, New York.

Harvey, D (1990) *The Condition of Post Modernity*, Blackwell, Oxford

Haskell, J and Martin, C (1993) 'Skill Shortages, Productivity Growth and Wage Inflation in UK Manufacturing', Discussion Paper 859, Centre for Economic Policy Research.

Hayward, S (1997) 'The Neglected Case of Labour Markets in Global Political Economy' Talalay et al, *op.cit*

-, and Griffin, M (1994a) *Europe at Work: Labour and Training in the Biotechnology Small Firm Sector*, BEMET, The UK Interest Group, London.

-,(1994b) 'De la Formation a l'emploi,'*Biofutur, hors serie* no2, pp.72-76, Elsevier, Paris

-,(1994c) 'Europe at BioWork: Challenges and Prospects', *Bio/technology* Vol 12 July, pp. 667-670, MacMillian

-, and Tomaney, J (1996) 'Innovation Systems and Regional Development : The case of the North East of England', paper presented to the EUNIT seminar, Dortmund, 22-25th May

Helpman, E and Krugman, P (1989) *Trade Policy and Market Structure*, MIT Press, Cambridge

Herman, B (1990) 'Economic Development and Industrial Relations in a small firm economy: the experience of metal workers in Emilia-Romagna', Center fro Labour Management Policy Studies, Graduate Center of the City University of New York.

Hicks, D and Hirooka, M (1991) 'Science in Japanese Companies: a Preliminary Analysis' National Institute of Science and Technology Policy ; Tokyo.

Higgot, R (1994) 'International Political Economy' in A.J.Groom and M.Light (eds.) *Contemporary International Relations: A Guide to Theory*, Pinter Publishers, London

Hirst, P and Zeitlin, J. (1989) Flexible specialisation and the competitive failure of UK manufacturing, *Political Quarterly*, 60 (3), pp. 164-78

-, (1991) Flexible specialisation versus post-Fordism: theory, evidence and policy implications, *Economy and Society*, 20(1), pp. 1-156

-, and Thompson (1996) *Globalisation in Question: The International Economy and the Possibilities of Governance,* Polity Press, Cambridge

Hobbelink, H (1989) *Biotechnology and the Future of World Agriculture.* Zed Books, London

Hone, J (1994) 'The rise and pull of CRO partnerships' *Scripp* Magazine, March 1, pp.32-34.

Hodgson, J (1982) 'Agbiotech R&D rises 5 percent' *Biotechnology*, 10, August 1992, p.850

Hoover E. and Vernon R. (1959) *Anatomy of a Metropolis*, Harvard University Press, Cambridge, MA

Howells, J (1990) 'The Globalisation of Research and Development: A New era of Change?' *Science and Public Policy*, Vol 17 No 4, October, pp.273-285 Beech Tree Publishing, Surrey.

Howes, C and Markusen, A (1993) 'Trade, Industry and Ecomomic Development' in *op.cit* Markusen, et al

Humbert, M (1994) 'Strategic industrial policies in a global industrial system' *Review of International Political Economy*, 1:3, Autumn

-. (1993) (ed.) *The Impact of Globalisation on Europe's Firms and Industries*, Pinter, London.

Hughesman, M (1994) 'Distrust remains' Financial times survey Biotechnology, *Financial Times*, May 19.

Hutton, W (1995) *The State We're In*, London: Jonathan Cape

-, (1996) 'Educated Guesses are wide of mark' *The Guardian*, Monday, January 8

Industrial Development Agency (1995) *Ireland: Leading Location for Call Centres and Teleservicing*, IDA, Dublin, Ireland

Industrial Research and Development Advisory Committee of the Commission of the European Communities (IRDAC) (1992) *Skills Shortages in Europe* CEC, Brussels.

-, (1994) *Quality and Relevance*, CEC, Brussels.

Institute of Labour Studies (1993) *Lean Production and Beyond, Labour Aspects of a New Production Concept*, ILO, Geneva

Institute of Manpower Studies (IMS) (1983) *The Biotechnology Brain Drain*, SERC , UK

Jameson, F (1991), *Postmodernism or the Cultural Logic of Late Capitalism*, London, Verso Press.

Jessop, B (1992) 'Fordism and post-Fordism: critique and reformulation' in Storper, M and Scott, A.J (eds) *Pathways to Industrialisation and Regional Development*. London, Routledge.

JETRO, (Japanese External Trade Research Organisation) (1982) *Special Report on Research in Biotechnology* in Japan, JETRO, Tokoyo

Johnson, B (1992) 'Industrial Learning in Lundvall *op.cit*

Johnson, C, Tyson, L.D, Zysman, J (1989) (eds) *Politics and Productivity: How Japan's Development Strategy Works*, Harper Business, New York

Jones, S (1994) *The Biotechnologists*, Macmillian, London

Kaldor, N (1989) 'The role of Increasing Returns, Technical Progress and Cummulative Causation in the Theory of International Trade and Economic Growth', in Targetti, F and Thirwell, A.P.(eds) *The Essential Kaldor*, Duckworth, London.

Kenny, S (1995) 'Defining a National System of Innovation: Implications for Irish Industrial Development Policy', Policy review section, *Regional Studies* Vol 29, No 7, November, pp.692-697.

Keohane, R.(1984), *After Hegemony: Cooperation and Discord in the World Political Economy* , Princeton, Princeton University Press

Keynes, J.M (1936) *The General Theory of Employment, Interest and Money*, Macmillian, London

King, I and Murphy, P (1996) 'Biotech rights issue flops' *The Guardian,* August, 2

Kline, S.J (1989) *Innovation styles in Japan and the United States : cultural bases implications for competitiveness*, Report INN-3B, Thermosciences Division, Mechanical Engineering, Stanford University, December.

Krasner, S (ed) (1983) *International Regimes* Inthaca NY, Cornell University Press

Krugman, P (ed.)(1986), *Strategic Trade Policy and the New International Economics*, Cambridge: The MIT Press

-, (1994) *Peddling Prosperity: Economic Sense in the Age of Diminished Expectations*, New York : W.W. Norton Company.

-, (1991a) 'History and Industry Location : The Case of the Manufacturing Belt', *American Economic Review*, 81(2), 80-83.

-, (1991b) 'Increasing returns and economic geography' *Journal of Political Economy*, 99(3), 483-499.

Kuper, S (1996) 'Shareholders shun £143m rights issue at British Biotech' *Financial Times*, August 2.

Labour Party, (1993) *Winning for Britain : Labour's Strategy for Industrial Success*, The Labour Party, London

-, (1996) *Labour's Plans for a skills revolution: Learn as you Earn*, The Labour Party London

-, (1993) *Labour's Economic Approach*, The Labour Party, London

-, (1992) *Britain Working Again*, The Labour Party, London

Lazonick, W (1993) 'Industry Clusters versus Global Webs: organisational changes in the American Economy', *Industrial and Corporate Change* 2 (1) pp. 1-24

Leborgne, D and Lipietz, A (1992) 'Conceptual Fallacies and open questions on post-Fordism' in *op.cit.* Storper and Scott.

Levidow, L and Young, B (eds.) (1981) *Science, Technology and the Labour Process*, Marxist Studies Vol 1, Blackrose Press, London

Lipietz, A (1988) Accumulation, crises and theways out : some methodological reflections on the concept of 'regulation'. *International Journal of Political Economy*, 18(2), pp.10-83

-, (1987) 'La regulation: les mots et les choses' *Revue Economique* 3, p.1049-1060

Livingstone, J. M (1989) *The Internationalisation of Business* , Macmillian Press, London

Lundvall, B.A. (1992) *National Systems Innovation*, London: Pinter

Machin, S and Wilkinson, D (1995) Employee Training Unequal Access and Economic Performance, Institute for Public Policy Research (IPPR), London.

Mackenzie, D (1992) 'Europe debates the ownership of life' *New Scientist*, 4 January

Magnien, E. Bevan, M and Planque, K (1991) 'A European BRIDGE project to tackle a model plant genome', *Trends in Biotechnology*, Vol.10, pp13-29.

Mahler, J.L. (1994) 'Coordinating European Biotechnology Efforts' Vol. 12 April, pp. 424

Markusen, A, Graham, J and Nopenen, H (1993) *Trading Industries, Trading Regions: International Trade, American Industry and Regional Economic Development*, The Guildford Press, London.

Mason, G and Wagner, K (1994) 'Innovation and Skill Mix: Chemicals and Engineering in Britian and Germany' National Institute Economic Review, 148 (May), pp. 61-72.

Massey, D (1994) 'Scientists, Transcendence and the Work/Home Boundary' occasional paper series No 10, South East Programme funded by ESRC programme: *High Status Growth? Aspects of home and work around high technology sectors* Milton Keynes:Open University,

-, Henry, N (1993) "Competitive Times in High Tech" occasional paper series No 8 *ibid.*,

-, Quintas, P.,and Wield, D (1992) *High Tech Fantasies: Science Parks, Society, Science and Space*, London: Routledge.

Marcel, T (1990) 'Pharamcie: la Montee en puissance' *Biofutur*, May, pp49-53

Marshall, A (1986) The Principles of Economics (8th edition orginially published in 1890), Macmillian, Basingstoke, Hants

Marsden, D (1986) *The End of Economic Man? Custom and Competition in Labour Markets,* Wheatsheaf, London

May, M (1985) 'Bread before roses: American workingmen, labour unions and that family wage' in Milkman, R (ed) *Women, work and protest: a century of US women's labour history*, Routledge and Kegan Paul, Boston

McCormick, D and Hodgson, J *Jobs in Biotechnology: A Window of Opportunity* Nature, vol 365, 14 October 1993

McGrew, A (1992) 'A Global Society?' in Hall, S, D. held and T. McGrew (eds) *Modernity and its Futures*, Polity Press, Cambridge

McKelvey, M (1991) 'How do national systems of innovation differ: a critical analysis of Porter, Freeman, Lundvall and Nelson', in Hodgson, G.M. and Screpanti, E (eds) *Rethinking Economics*, Edward Elgar, Cheltenham

McNabb, R and Ryan, P (1990) 'Segmented Labour markets' in Sapsford, D and Tzannatos, Z (eds.) *Current Issues in Labour Economics*, pp 151-176 London: MacMillian

-, and Whitefield, K (1993) 'Key issues in the economics of training' *International Journal of Manpower*, 14, 2/3 pp 4-16

-, (1994) 'Market failure, institutional structure and skill formation', *International Journal of Manpower*, 15, 5, pp. 5-15

McNeil, M Varcoe, I and Yearley, S (1990) *The New Reproductive Technologies* , British Sociological Association, MacMillian Press, London

Nettancourt, D de (1991) 'The T-projects of BRIDGE: a new tool for technology transfer in the Community', *Agro Industry Hi-tech*, Vol.2, pp3-9.

Mincer, J (1974) *Schooling Experience and Earnings*, NY :Columbia Univ. Press

Minford, P (1985) *Unemployment - Cause and Cure*, Oxford :Basil Blackwell

Mies, M (1986) *Patriarchy and accumulation of a World Scale : Women in the International Division of Labour*, Zed Books ltd., UK.

Mjoset, L (1992) *Ireland in Comparative Institutional Perspective*, NESC Study no.93, National Economic and Social Council, Dublin

Moffat, A.S (1992) 'Firms revap Bt strategies to overcome resistance problems' *Genetic Engineering News*, March

Morgenthau, H. J. (1948) *Politics Among Nations*, Knopf : New York

Munson, A (1993) 'Genetically manipulated organisms : international policy-making and implications', *International Affairs*, 69, 3, pp 497-517

Murray, R (1971) "The internationalisation if capital and the nation-state" *New Left Review* no 67, pp 84-109

Murphy, C and Tooze, R (1991) *The New International Political Economy*, Lynne Reinner, Colorado

National Institute of Economic and Social Research, The, London and Technische Universitat Berlin (1986) *Relation between education and employment and productivity and their impact on education and labour market policies - a British and German comparison* CEDEFOP -the European Centre for the Development of Vocational Training, Commission of the European Communities 1986, *op.cit.*IRDAC.

Nature (1993) 'UK Brain Drain 'no worse' Vol 366 18 November

Nelson, R.R. (1992) *National Systems Supporting Technical Advance in Industry* Oxford University Press, Oxford.

-, (1993) (ed) *National Innovation Systems: A Comparative Analysis*, Oxford University Press, Oxford

National Economic and Social Council (1993) *Education and Training Policies for Economic and Social Development*, Report No. 95. NESC, Dublin

New Scientist, (1989)'Free Trade in People' 25 November 1989, Vol 124, No 1692.

National Economic and Development Office (NEDO) (1991) *New Life for Industry: Biotechnology, industry and the community in the 1990s,* NEDO, London

Newbold, (1991) *Research Methods,* Wheatsheaf

Northedge, F.S. (1956) *The International Political System*, Faber, London

O'Donnell, R (1993) 'Ireland and Europe: Challenges for the New Century', Policy research series paper no.17, Economic and Social Research Institute, Dublin

Office of Science and Technology (OTA), (1991) *Biotechnology in a Global Economy*, OTA, Government Printing Office,Washington

-, (1987) *New developments in biotechnology - background paper; public perceptions of biotechnology*, OTA-BP-BA.

-, (1984) *Commmercial Biotechnology*, Government Printing Office, Washington

Ohmae, K (1990) *The Borderless World Power and Strategy in the Interlinked Economy*, London: Fontana.

Ohlin, B (1933) *Interregional and International Trade* Harvard University Press, Cambridge

Oman, C (1994) *Globalisation and Regionalisation : The challenge for developing countries* Paris: Organisation for Economic and Cultural Development

Omerod, P (1996) 'National Competiveness and State Intervention' *New Political Economy*, Vol.1 No.1, pp. 119-129.

Organisation for Economic Co-operation and Development (OECD) (1992) *Biotechnology : International Trends and Perspectives*, Paris.

- ,(1989), *Biotechnology and Wider Impacts*, Paris,

- , (1988) *New Technologies in the 1990's: A Socio-economic Strategy*, Paris

-,(1991) *Choosing Priorities in Science and Technology*, Paris

-, (1993) Active Labour Market Policies: Assessing Macroeconomic and Microeconomic Effects,' in *Employment Outlook*, ch.2.

Orsenigo, L (1989) *The Emergence of Biotechnology* London: Pinter Publishers.

PA Consulting Group, (1995) *Biotechnology Potential - Market Segment Study* Report undertaken for Biotechnology Means Business Intitiative, DTI, London.

Papandreou, V (1990) 'Free Movement of Qualified Labour: A Commissioner's Perspective, *Journal of European Integration*, XIII, nos 2-3, Canada

Parsons, D. O (1990) 'The Firms Decision to Train' in Basia, L.J and Crawford, D.L (eds.) *Research in Labour Economics*, Vol. 11 ,1990, pp53-7

Pavitt, K (1991a) 'What makes Basic Research Economically Useful', *Research Policy*, Vol 20, pp.135-170

-, and Patel, P (1991b) 'Large Firms in the production of the world's technology : an important case of non-globalisation, *Journal of International Business studies*, Vol 22, 1 ., pp1-21.

-, (1988) 'The International Distribution and Determinants of Technological Activities' *Oxford Review of Economic Policy*, Vol 4, pp. 196-170

Pearson, R (1989) When will biotechnology mature ? *Nature* vol 341 7 September p.86
-,(1987a) Biotechnology, where to next ? *Nature* vol 328 2 July p. 96
-, (1987b) Biotechnology manpower in the UK *Nature*, Vol 109, 14 June p. 84
-, (1989) 'The Impact of Europe's 1992' *Nature* Vol 338 6 April, p.20

Perroux, F (1955) Note sur la notion de 'pole de croissance', *Economie Appliquee*, Jan-June, pp307-20

Persley, G (1990) (ed.) *Agricultural Biotechnology: Opportunties for International Development*, CAB International, Oxford

Pilger, J (1995)' Newspeak economics' *New Statesman and Society*, 3 March

Pinder, J (1991) *European Community, The Building of a Union*, Oxford University Press, Oxford

Piore, M.J (1979) *Birds of a Passage*, MA:Cambridge University Press
-, and Sabel,C, (1984) *The Second Industrial Divide: Possibilities for Prosperity*, Basic Books, New York.

Pisano, G. P (1991) 'The governance of innovation: vertical integration and collaborative arrangements in the biotechnology industry', *Research Policy*, 20, 3, June, pp.237-250.
-, (1990) 'The R&D boundaries of the firm: an Empirical Analysis' *Administrative Science Quarterly*, 35, pp.153-176.

Pollert, A (1988a) Dismantling flexibility, *Capital and Class*, 34, 42-75
-, (1987) 'The Flexible Firm - A model in search of reality (or a policy in search of practise?)' Warwick Papers in Industrial Relations No.19 Dec
- , (1988b) 'The Flexible Firm: Fixation or Fact ?' *Work, Employment, Society*, Vol.2 No.3 pp.281-316

Polyani, K (1957) *The Great Transformation*, Little Brown, Boston

Porter, M (1990) *The Competitive Advantage of Nations,* The Free Press, New York

Powell, A.P (1986) 'Delay of Disease Development in Transgenic Plants that Express the Tobacc Mosiac Virus Coat Protein Gene' *Science*, 232, pp.738-743.

Prais, S (1989) 'Qualified Manpower in Engineering Britian and Other Industrially Advanced Countries' *National Institute of Economic Review*, No, 127, pp.76-83.
-, (1990) (ed.) 'Productivity, Education and Training: Britain and Other Countries Compared,' National Institute of Economic and Social Research, London.

Psacharopoulos, G (1985) 'Returns to Education: A further international update and implications' J *Human Resources* 20 Fall, pp. 583-604.

Ratledge, C (1992) 'Biotechnology : the socio-economic revolution ? A synoptic view of the world status of biotechnology' DaSilva et al., *op. cit.*,

Ravetz, J. R. (1979) 'DNA as a High Intensity Science' *Trends in Biochemical Sciences* May No.97-98, pp.201-230

Realising Our Potential, Strategy for Science, Engineering and Technology (1993), UK White Paper, London: HMSO

Reich, (1991) *The Work of Nations: Preparing Ourselves for the 21st Century*, London : Simon and Schuster.

-, -, Reich, R (1996) 'The private sector must take a greater role in helping Americans to move from the old economy to the new', *Financial Times*, Wednesday, March 6.

Rich, M (1995) 'Search for Early Symptoms' *Financial Times*, Monday 27 November.

Roberts, E, (1989) *The Public and Biotechnology*, European Foundation for the Improvement of Living and Working Conditions, Dublin

Radford, T (1996) 'Genes for sale - but whose DNA is it anyway ?' *The Guardian*, Saturday, January 13

Romer, P (1986) 'Increasing Returns and Long Run Growth' *Journal of Political Economy*, Vol. 94 No.51 October, pp.1002-37 : Chicago: University of Chicago

Rosen, S (1972) 'Learning and Experience in the Labour Market' *Journal of Human Resources*, Vol. 7 No. 4, pp. 336-42

de Rosnay, J (1984) 'New Research Strategies in Biotechnology' *The World Biotech Report*, Vol1: Europe, Pinner, Middx,: Online Publications, pp 201-205

Robertson R (1990), 'Mapping the Global Condition' *op.cit.* Featherstone.

Robinson, P (1996) 'Skill Shortages and Full Employment : How Serious a Constraint ?' in Michie, J and Grieve Smith, J*Creating Industrial Capacity : Towards Full Employment*, Oxford University Press.

(1995) 'Jobs and Skills: The Programmes of the Employment Department' in A Gillie, (ed), *The Big Spenders, 1995-96,* London : Public Finance Foundation

Rogers, M.D (1982) 'The Japanse Government's role in Biotechnology' *Chemistry and Industry*, 7 August, 1982, pp533-537

Rubery, J (1978) 'Strucutres labour markets, worker organisation and low pay', *Cambridge Journal of Economics,* Vol 2. No.1 :17-36

Ruigrok, W (1995) 'Why nationality is still important' *Financial Times*, 5 January
-, and Van Tulder (1995) *The Logic of International Restructuring*, Routledge, London.

Ruggie, J.G (1993) 'International Regimes, Transactions and Change : Embedded Liberalism in the Postwar Economic Order' in Krasner, S (ed) *International Regimes*, Cornell University Press, New York

Russell, A -, (1990a) International relations theory, biotechnology and war, *Politics and Life Sciences*, Vol.9. No.1, August, pp.3-19.
-,(1990b) 'Biotechnology in the European Community: Promotion and Regulation' *Journal of European Integration*, XIV, no1, Canada, pp 41-63.
-, (1992), 'Biotechnology and International political economy: Knowledge and Intellectual Property issues in the GATT Regime', Paper presented at British International Studies Association (BISA) Univ. of Warwick, 25 February.
-, (1997) 'Technology as Knowledge : Generic Technology and Change in the Global Political Economy' in *op.cit.* Talalay et al.

Sally, R (1994) 'Multinational Enterprises, political economy and institutional theory: domestic embeddeness in the context of deindustrialisation', *Review of International Political Economy*, 1(1) pp 161-94

Salt, J (1988) "Highly skilled international migrants, careers and internal labour markets" *Geoforum* 19, pp 387-399

Sabel, C (1982) *Work and Politics : The Division of Labour in Industry*, Cambridge, Cambridge University Press
-, (1989) 'The re-emergence of regional economies ?' in Hirst, P and Zeitlin, J (eds.) *Reversing Industrial Decline*, Berg, Leamington Spa.
-, and Zeitlin, J (1985) 'Historical alternatives to mass production: politics, markets and technology in the nineteenth century industrialisation'. *Past and Present*, 108, pp.133-76.

Samuels, (1987) *Radical Political Economy,* Wheatsheaf, London

Sapienza, A (1989) R&D Collaboration as a global competitive tactic - Biotechnology and the ethical pharmaceutical industry, *R&D Management*, 19, 4, pp.285-295.

Sapsford, D (1981) *Labour Economics*, London : George Allen and Unwin
-, and Tzannatos, Z, (1995) *Labour Economics*, London: Macmillan

Sargeant, K (1982) 'Notes on three french biotechnology reports: a review paper, *FAST*, no.26, CEC, Brussels.

Sayer, A (1989) Post -Fordism in question. *International Journal of Urban and Regional Research*, 13, pp.666-95.

Saxenian, A (1990) Regional Networks and the resurgence of Silicon Valley, *Calif. Mgt. Review*, 33, (1), 89-112

Servan-Schreiber, J.J (1979) *The American Challenge*, Athanaeum, New York

Schumpter, J.A (1934) *The Theory of Economic Development*, Harvard University Press, Cambridge, MA

-, (1942) *Capitalism, Socialism and Democracy*, Harper & Row, New York

Schultz, T (1963) *The Economic Value of Education* NY: Columbia Univ Press.

Scitovsky, T (1963) 'Two concepts of external economies', reprinted in Agarwala. A.N. and Singh S.P. (eds) *The Economics of Underdevelopment*, pp295-308. Oxford University Press, Oxford

Scott, B (1991) 'Economic Strategy and Economic Policy' Paper presented at the World Bank, Washington, D.C. November 21.

Scott, J (1988) 'Flexible production systems and regional development : the rise of new industrial spaces in North America and Western Europe', *International Journal of Urban and Regional Research*, 12, pp.171-31.

-, (1987) 'High Technology industry and regional development : a theoretical critique and reconstruction' *International Social Science Journal*, 112, p215-232

Seccombe, W (1986) 'Patriarchy destabilised : the construction of the male-bread winner norm in nineteenth-century Britain, *Social History*, Vol.2, No.1, January pp.53-76

Senior Advisory Group On Biotechnology (SAGB)(1990) *Economic Benefits And European Competitiveness*, Brussels :CEC.

Senker J (1989) 'The Biotechnology Directorate's Programmes for Technology Transfer in relation to Small and Medium sized firms', A report prepared for the Biotechnology Directorate, DTI, London.

-, and Faulkner W (1992) 'Industrial Use of Public Sector Research in Advanced Technologies' *R&D Management* 22, 2 , pp. 157-175

Sentance, A and Williams, N (1989) 'Skill Shortages and the CBI Industrial Trends Survey', mimeo, Confederation of British Industry.

Sharp, M (1985) *The New Biotechnology,* Sussex European Paper, No 15, University of Sussex

-, and Galimberti, I (1992) 'Corporate Strategy and Biotechnology : The Case of Europe's large integrated Chemical Companies'.*mimeo* ERSC funded Industrial Economics Study Group , Warwick University, July 1992.

-,(1989) 'European Countries in science based competition: the case of biotechnology', DRC Discussion Paper No72, Science Policy Research Unit, University of Sussex

-,(1991) 'Pharmaceuticals and Biotechnology' in Freeman, C, Sharp, M and Walker, W (eds.) *Technology and the Future of Europe*, London:Pinter Publishers .

-., (1992) "Industrial policy in a Global Environment" paper to Conference on Adjustment of Policies Organisations and Firms to Global Competitions: Seeking New Forms of International Cooperation, San Diego, 2-3 October

Shinohara, M (1982) *Industrial Growth, Trading and Dynamic Patterns in the Japanese Economy*. Univ of Tokoyo Press, Tokoyo.

Sigurdson, J (1996) 'Regional Development and Denationalisation of the National Systems of Innovation' in Kulinski, *Production of Knowledge and The Dignity of Science*, Europe 2010 Series, Warsaw.

Smith, C (1989) Flexible specialisation, automation and mass production. Work, *Employment and Society*, 3, pp.203-20.

Solo, R (1985) 'Across the industrial divide'. *Journal of Economic Issues*, 19, 820-36.

Spalding, B.J (1993) *Bio/technology* 11, pp. 768-770.

Spero, J (1992) *The Politics of International Economic Relations*, Routledge, London

Spencer, B (1986) 'What should trade policy target', in *op.cit*. Krugman

Spinks, A (1980) *Biotechnology : report of the joint working party of ACARD, the ABRC and the Royal Society*, HMSO, London

Stopford, J and Strange, S with Henley J.S (1992) *Rival States Rival Firms Competition for world market shares*, Cambridge, University Press, Cambridge

Storey, D.J, Keasey, K , Watson, R and Wynarczyk, P (1987) *The Performance of Small Firms*, London :Croom Helm.

Stubbs, R and Underhill, G (1994) *Political Economy and the Changing Global Order*, London:MacMillian

Strange, S (1988), *States and Markets,* London, Pinter

-, (1982) 'Cave hic dragones ! A critique of regime analysis' *International Organisation* Vol 36 pp 479-96

-(1987) 'The persistent myth of lost hegemony' *International Organisation*, 41 Autumn, pp.

-, (1991) 'An Eclectic Approach' in *op.cit.* Murphy and Tooze, 1991.

Streeck, W (1989) 'Skills and the Limits of Neo-liberalism: The Enterprise of the Future as a Place of Learning' *Work, Employment and Society* Vol. 3 No 0089-104 March pp 89-104.

Suzuki, D and Knudtson, P (1988) *The Ethics of Engineering Life*, Unwin Hyman Ltd., London.

Tait, J (1992) 'Who's afraid of biotechnology ?' *New Scientist*, 27 June, p.49

Talalay, M and Farrands, C (1993) "Technology, Change and Global Political Economy" Paper presented at British International Studies Association (BISA) Univ. of Warwick, December

-, and Tooze, R (1997) *Technology, Culture, Competitiveness and the World Political Economy*, Routledge, London

Taylor, M and Thrift, N (1982) Industrial Linkage and the Segmented Economy, *Environment and Planning*, 14:

Taylor, R (1995) 'Myth and Reality of Labour in the Global Economy' *Financial Times*, 9 June,

Teague, P (1995) 'Europe of the Regions and the future of national systems of industrial relations', *op.cit* Amin, A and Tomaney, J (eds) (1995b):149-174.

The Guardian, (1994) 'Onocomouse for treatment of leukaemia in Cambridge' 15 December

The Scientist, (1991) 'Profession - Biotech Recruiters look beyond Scientific Credentials', Jan 21 .

The New Yorker, (1993) 'Tremors in the Hothouse' July 19, p32-49

Thomas, S (1993) *Global Perspective 2010 The case of biotechnology*, A Report for the FAST Programme , Brussels :CEC.

- and Sharp, M (1993)"Biotechnology in Europe, Present and Future Trends - Implications for Manpower Training" in Griffin, M, Hayward, S and Curtis,J *Report from a Conference Manpower and Training Needs in Europe in the 90s*, London : BEMET The Biochemical Society.

Thompson, N (1996) 'Supply Side Socialism : The Political Economy of New Labour', *New Left Review*, No. 216

Thurrow, L (1992) *Head to Head: The Coming Economic Battle among Japan, Europe and America*, Nicholas Brealey

Tisdall, S (1994) 'Iraq used US biotoxins in Gulf War' *The Guardian*, Friday, February, 11

Tomaney, J 'A New Paradigm of Work Organisation and Technology ?' in *op. cit* Amin, A.: 157-195

-, Hayward, S, Cornford, A , Pike, A and Thomas, D (1995) *Survey of Redundant Tyneside Ship-Yard Workers,* Report for BBC Radio 5 Live, London.

Tooze, R (1988) 'The Emergence of a New International Political Economy : A Realist View', *Millenium : Journal of International Studies*, Vol. 16, No 3.

Tzannatos, Z (1987) 'A general equilibrium model of discrimination and its effects on incomes, *Scottish Journal of Political Economy*, Vol.34, No.1 February :19-36

Underhill, G (1994) 'Introduction ; Conceptualising the Changing Global Order' in Stubbs and Underhill *op.cit.*

US Government (1993) *Intragency Working Group on Competitive and Transfer Aspects of Biotechnology*, Report published by Elsevier Science Publishers, Amsterdam for McGraw Hill's Biotechnology Newswatch

Walker, M (1994) 'Lethal Exposure' *The Guardian*, Monday June 20

Walshe, A, Hayward, S and Griffin, M (1992) *Positive Actions :Sectoral Survey of COMETT training projects in the Biotechnology Sector*, Survey undertaken by the BEMET UETP in Framework of the COMETT Positive Actions Exercise, COMETT Technical Assistance Office, Brussels,CEC.

Walsh, V, Galimberti, I, Gill, J, Richards, A, Sharma, Y (1991) *The globalisation of technology and the economy: Implications and consequences for the scientific and technology policy of the EC* Vol 12, CEC FAST, Brussels

-, (1993) 'Firms strategies, globalisation and new technological paradigms: the case of biotechnology' in Humbert, *op.cit*

Ward, M (1994a)'EU makes three moves to boost biotech' *Biotechnology* Vol.12 March, p.233

-, (1994b) 'Uk biotech will boom over next few years' *Biotechnology*, Vol.12 March, pp230

-, (1994c) 'European Alliances should double by 2000' *Biotechnology*, Vol. 12 April, pp345

Wastes Management 'UK in Biotechnology' May, 1995

Williams, K., Cutler, T, and Haslam, C (1987) The end of mass production ? *Economy and Society*, 16(3), 405-39.

Williamson. O. E (1975) *Markets and Heirarchies*, The Free Press, New York
-, (1985) *The Economic Institutions of Capitalism*. The Free Press, New York

Willoughby, K (1995) 'The Local Mileux of Knowledge-Based Industries: What can we learn from a Regional Analysis of commerical biotechnology?' in Brotchie, J. Batty, M. Blakely, E., Hall, P. and Newton, P. *Cities in Competition: Productive and Sustainable Cities for the 21 st Century*, Longman Australia.

Wilmut, I Clark, J and Simmonds, P (1988) A Revolution in Plant Breeding, *New Scientist*, 7 July, p56-59.

Wolf, M (1996) 'The global economy myth' *Financial Times*, 13 February.

Womack,J, Jones,D and Roos, D (1990) *The Machine that Changed the World*, New York: Maxwell MacMillian,

Wood, S (ed) (1989) *The Transformation of Work*, Unwin Hayman

Wynarczyk, P, Watson, R, Storey, D.J, Short, H and Keasey, K (1993) Managerial Labour Markets in the Small Firm Sector, London and New York: Routledge,

Vernon, R (1960) *Metropolis, 1985*. Harvard University Press, Cambridge

Van Tulder , R and Junne, G (1987) *European Multinationals in Core Technologies*, New York: John Wiley.

Yoshio, S (1995) 'High Technology', Facts about Japan, The Science and Technology Division, The Japanese Embassy, London

Yoxen, E (1981) 'Life as a productive force : Capitalising the Science and Technology of Molecular Biology' in Levidow, L and Young, B (eds.) *Science, Technology and the Labour Process*, Marxist Studies Vol 1, Blackrose Press, London
-, and Green, K(1990) *Scenarios for biotechnology in Europe* : A Research Agenda, Dublin: European Foundation for the Improvement of Living and Working Conditions

Zysman, J (1993) 'Regional blocs, corporate strategies and government policies: the end of free trade ?' in Humbert *op.cit*