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From commercialising intellectual property to facilitating open innovation: The evolution of UK biotechnology incubators

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This paper investigates the changing landscape of biotechnology incubators in the UK and evidences their evolution from 1999 to 2017. We highlight the changing policy environment for biotechnology incubators and begin to investigate the evolution of UK biotechnology incubators from facilities that primarily support the commercialisation of intellectual property derived from universities to facilities that reuse former pharmaceutical research and development laboratories and collocate with operational pharmaceutical companies. This study uses two desk-based surveys that provide snap-shots of 21 biotechnology incubators taken in December 2012 and December 2017. The surveys provide a detailed examination of the characteristics of UK biotechnology incubators and their tenant companies. We observe the appearance of biotechnology incubators with an economic regeneration remit, funded by and working in partnership with regional government (BioPark Hertfordshire & BioCity Nottingham). We also observe the appearance of corporate biotechnology incubators (Akcomak, 2009) co-located on operational pharmaceutical research and development sites with an open innovation remit e.g. Astra Zeneca (Manchester), GlaxoSmithKline (Stevenage) and Boots (Nottingham). We propose that regional and national policy initiatives and changes in the business model of large pharmaceutical companies have been the main drivers for the evolution of biotechnology incubators in the UK.

1. Introduction

Since the 1990s, public policy makers and private investors have been creating biotechnology incubators with the aim of obtaining a foothold in what many presumed was one of the hottest future industries. Start-ups and early stage life science companies require access to specialist premises, services, technical support and seed investments not traditionally available on science parks and business parks. With its science-based characteristics biotechnology relies on a strong knowledge base that incorporates a number of different scientific disciplines. Its reliance on a series of relatively recent scientific breakthroughs means it is a relatively young sector largely comprising small entrepreneurial firms which rely on having a close relationship to universities and the scientific environment. Public support for biotechnology is mainly driven by the expectation that the exploitation of biotechnology research can provide economic, social and environmental benefits (Reiss 2005). This is made evident by the 'science city' status that UK cities use to boost their local economy. At a broad level national Government have been keen to encourage skills and infrastructure development in the life science sector to cater to their internal healthcare needs and develop an internationally competitive industry whilst connecting with wider social aims such as local economic development and job creation (Misra, 2010).

A favoured policy instrument at a local and regional level has been the introduction of biotechnology incubators to support the growth and prosperity of the biotechnology sector. The justification for government intervention is that systematic failure in the market has limited the ability of small technology-based firms to survive and overcome the early stages of firm creation OECD (1997). The UK biotechnology sector is traditionally clustered near areas of scientific expertise, for example, universities in London and the South East such as Oxford and Cambridge (Smith et al. 2012). Access to venture capital finance is also a contributing factor in the evolution of the UK's biotechnology industry, for the industry to grow investment is required (Lerner 2009). This has meant that biotechnology firms have traditionally grown in localities that are close to financial markets and universities with a strong research base i.e. London and the South East of England

A biotechnology incubator provides premises, facilities, office space and business support specifically tailored to the needs of tenant companies. Their aim is to nurture and encourage growth and sustainability amongst new life science start-up companies. There is a handful of biotechnology incubators that were established during the 1990s in the UK however the majority have opened more recently over the last fifteen years. Some biotechnology incubators were purpose built and others regenerated former large pharmaceutical research and development laboratories that had closed down. The common theme that is shared between all biotechnology incubators in the UK is their provision of laboratory space (either chemical or biological), write-up space or office space and one form or another of infrastructure support for new and emerging biotechnology and medical technology companies.

The first biotechnology incubators appeared in the UK during the 1990s in response to government policy initiatives that were aimed at increasing the commercialization of intellectual property from UK universities (Cooke 2004). Biotechnology incubators have been used in a number of ways, Regional Development Agencies (RDA's) had begun to use biotechnology incubators as a mechanism to attract inward investment and create highly skilled jobs (Ehret et al. 2012). Science parks were using biotechnology incubators as a method to link small agile biotechnology firms with large established companies (Bernasconi et al. 2006). Finally, hospitals have started to work with small life science companies to develop therapeutics and medical devices and large pharmaceutical companies used biotechnology incubators as a method to actively support open innovation (Chesbrough 2006).

2. Literature

2.1 Biotechnology incubation

A primary purpose of 'business incubation' is based upon the aim of reducing the rate of start-up failure in small businesses by providing assistance during the critical stage of business development in the early years (Aerts, 2007). The concept of a traditional business incubator involves the utilisation of a building in which a group of new or growing businesses locate in or operate from with lower overhead costs such as subsidised rental rates for their accommodation (Kuratko and Lafollette 1987). An extension to this definition is provided by Hannon (2004), the purpose of the business incubator is to provide the opportunity for accelerating growth and development of the incubatees so more could be achieved than in the 'external' natural environment. Grimaldi et al. (2005) argued that the incubator environment aims to link technology, capital and know-how to leverage entrepreneurial talent and speed up the development of new technologies.

Biotechnology incubators differ from traditional business incubators in terms of the type of tenant companies that biotechnology incubators support. Unlike in other high tech industries such as IT, nanotechnology, clean technology and food technology it can take up to 20 years for a biotechnology company to successfully to bring a drug to market (Pisano, 2006). The main purpose of biotechnology incubators is to speed-up the business development of life science companies by providing access to early stage seed investment, reducing the uncertainty in the early phases of development, and shortening the 'time-to-market.' Biotechnology incubators are a supportive environment designed to hatch new biotechnology companies (BERR, 2008).

Reiss et al. (2005) noted that public support for a growing biotechnology sector is mainly driven by the assumption that the exploitation of biotechnology research can provide economic, social and environmental benefits. Similarly, Misra (2010) observed that at a broad level Governments are keen to encourage skills and infrastructure development in the life science sector to cater to their internal healthcare needs and develop an internationally competitive industry whilst connecting with wider social aims such as local economic development and job creation. A favoured policy instrument at a local and regional level was the introduction of biotechnology incubators to support the growth and prosperity of the biotechnology sector. The justification for Government intervention is that systematic failure in the market limited the ability of small technology-based firms to survive and overcome the early stages of firm creation OECD (1997).

2.2 Biotechnology clusters

The structure of the biotechnology sector is different to the pharmaceutical industry. While the pharmaceutical industry comprises a small number of widely dispersed large companies, in contrast the biotechnology sector comprises a large number of small companies. According to Lawton-Smith (1999) a characteristic of the biotechnology sector is its intimate and continuing relationship with university research. Similarly, Swann (1998) noted that a distinctive attribute of the biotechnology sector in terms of growth is its tendency to cluster.

The literature on biotechnology clusters can be separated into three distinct areas i) research that defines the concept of clusters, ii) research that investigates the advantages of industry clustering for high tech firms, and iii) biotechnology clustering in the UK covering both the North and South of England. The phenomenon of industry clusters has been investigated within several different contexts including the cotton industry in the early 19th century, the emergence of the computing industry in the 20th century and the growth of the biotechnology sector in the 21st century. Clustering is not a new concept however it has only relatively recently been applied as a tool of analysis to an emerging biotechnology sector.

Research undertaken by Swann (1998) and Cooke (2002) pointed towards a tendency for biotechnology companies to cluster near universities, centres of research excellence and large pharmaceutical companies. One key feature of the biotechnology sector is its reliance on a source of scientific knowledge. In addition to the work carried out by Cooke (2006) and Swann (1998), Bernasconi et al. (2006) and Lawton-Smith et al. (2005) stated that the UK biotechnology sector was developed with clusters of activity in the East and South East very close to universities and large pharmaceutical companies. Swann et al. (1998) noted the impact of the pharmaceutical industry clustering in the UK.

These knowledge sensitive biotechnology firms increasingly created clusters in Cambridge, Oxford and London (Cooke 2003). This feature of agglomeration of life science activity and the growth of biotechnology clusters was well established in London and the South East by the early 1990s . Cooke (2001) noted that there was close collaboration between local biotechnology firms in Oxford and that a number of significant biotechnology firms were Oxford University spin-outs. According to Bernasconi et al. (2006) and Cooke (2001) this relatively young biotechnology sector largely comprised small entrepreneurial firms that relied on close relationships to universities and the scientific environment in order to form clusters of activity.

In addition to close connections to the local science base, biotechnology clusters were also geographically close to large pharmaceutical companies, for example in the East of England. The competitive advantage to be gained was that co-financing new biotechnology firms were often provided by pharmaceutical companies such as GlaxoSmithKline, MERCK and ROCHE all of which had research and development facilities within a 25 mile radius of Cambridgeshire (Garnsey 2005). As described by Marshall (1920) and Porter (1996), there were specific competitive advantages that can be gained from industry clusters.

The literature suggests that biotechnology clusters have not developed in all regions of the UK, there was relatively very little in the way of biotechnology clusters in the Midlands and Yorkshire & Humberside. This is partly due to the geographical distribution of biotechnology clusters. They are closely linked to the sources of scientific knowledge i.e. universities that are major centres of life science research. Therefore we can expect biotechnology cluster to be unevenly distributed across the UK because universities with a strong life science base are unevenly distributed, with the major centres in the South and South East. Hence Cities in the Midlands and Yorkshire & Humberside do not feature any biotechnology clusters in the analysis of UK biotechnology clusters undertake by Swann (1998 p214) and Cooke (2001).

2.5 Growth and development of incubators

It has been proposed by Allen (1990) that the life cycle of an incubator consists of three stages, stage one is gaining control of a site, successfully securing finance for construction and renovation and attracting initial tenants. Stage two is business development and the nurturing of new businesses. Similarly, Bergek (2008) noted that making links with professionals and consultants that can provide management advice to tenants firms. Stage three is maturity, the facility

begins to tighten entrance policies, accelerate graduation and exit strategies which involve tenants moving on into the big wide world or expanding operations into new geographical areas or new markets. According to Bergek (2008), as the incubator moves through this life cycle the quality and quantity of development outcomes are higher. Hamdani (2006) also makes use of the life cycle of a business incubator to conceptualise and measure the incubation process.

Gassman (2006) took a resource-based view to provide an explanatory model that measures the intangible resources and tacit knowledge that are difficult to detect within a corporate incubator. This was achieved by differentiating between the characteristics of non-profit and for profit incubators within the context of corporate incubators by focusing on the nature of relationships between the corporate incubator and the parent corporation and the analysis of the resource from and to the corporate incubator. *Figure 1* shows how the incubator evolved since the classic business incubators were first established. Kuratko and Lafollette (1987) also list four major types of incubator, these include publically sponsored, non-profit sponsored, university-related and privately sponsored incubators. All of these examples provided tenants with freedom from maintenance costs, access to shared equipment and services, increased awareness of access to financial and technical assistance, lower anxiety of starting up alone and increase visibility of the tenant firm. Two decades later after Kuratko and Lafollette (1987) listed their incubator types, Ackomok (2009) provided a description of the evolution of incubators. Incubators have evolved from non-profit and traditional business incubators to for-profit corporate incubators with a specific purpose of supporting a particular industry or sector *(Fig.1).* Biotechnology incubators might be placed in close proximity to corporate incubators and venture capital incubators because of their specificity and requirement to make a profit.

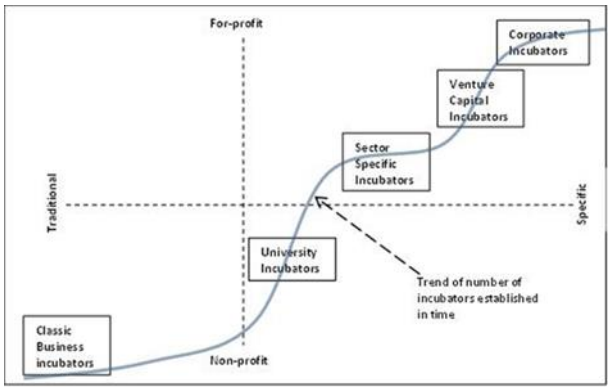

Figure 1. Evolution of Incubators

Source (Ackomok 2009 p6)

The evolution of incubators (Fig. 1.) shows how the purpose of an incubator changed over time. They have become less 'traditional' and more 'specific' in terms of the tenant's that they support and the type of support services that are provided. Ackomok (2009) argues that the corporate incubator is the most recent type to be established and houses a specific type of tenant company. Corporate incubators are units that hatch new businesses and enhance the technological base to assist overall development and growth to support internal start-up and entrepreneurs with promising business ideas or technologies. Ackomok (2009) investigated the typology and evolution of incubators and used 'for profit' and 'not for profit' as a framework to illustrate their evolution. Allen and McCluskey (1990) included these descriptors in their model and analyse these incubator types according to their primary and secondary objectives.

2.4 Potential drivers for the creation of new biotechnology incubators

Biotechnology incubators appeared in the UK during the early 1990's and have appeared within emerging clusters of biotechnology company activity as the life science sector has grown. There are various factors that may lead to the creation of a new biotechnology incubator and these factors are often localised and are linked to either a source of knowledge that leads to the exploitation of intellectual property or the reconfiguration of the pharmaceutical industry.

There are a number of drivers that may lead to the creation of new biotechnology incubators, these include

i) Changes in public policy that affect the way that universities transfer and commercialise their intellectual property through the spin-off process

ii) Reconfiguration of the pharmaceutical industry, specifically changes from a closed business model of innovation to an open business model of innovation.

iii) Local economic regeneration as a consequence of the closure of large research and development laboratories.

2.4.1 Changes in public policy: Universities

The mechanism that supports academic entrepreneurship is the commercialisation of technology and the application of information in order to undertake a specific task (Debackere & Veugelers 2005). According to Steffensen (2000) this normally involves a source of technology that requires specialised technical skills. A transfer of this technology to an organisation that does not possess these skills takes place because for whatever reason, they are unable to develop or create these skills themselves. The creation of a spin-out company is one example of a mechanism that supports technology transfer from a university to industry (Debackere & Veugelers 2005). Spin-out companies are also created to commercialise a specific technology which originated in either a government funded academic research and development laboratory, a university or a private research and development organisation.

Government policy initiatives that have supported the growth of university based biotechnology incubators include the Lambert review of Business and University Collaboration (2003), Future of Higher Education white paper (2003), 'Race to the Top' Sainsbury report (2007), 'Higher Ambitions' initiative (2009) and the 'Science For All' initiative (2010). Other policy interventions have also contributed to the high number of biotechnology incubators that are physically connected to universities. These are: Universities collaborative research, centres of excellence located within universities, knowledge transfer partnerships (KTP), innovation voucher schemes, Knowledge Transfer Networks (KTN), collaborative research and development grants, industry and enterprise fellowships and CASE studentships. All of which were aimed to bridge the gap between industry and universities.

In the UK, according to Lawton-Smith et al. (2005), government policy in relation to academic entrepreneurship involved three phases. The first phase ended the monopoly of the British Technology Group (BTG) over breakthroughs from publicly funded research in universities in 1983 (New Scientist 1983), along with the 1988 White Paper, DTI: Department for Enterprise (DTI 1988), signalled the government's willingness for universities to display more independence in the commercial exploitation of intellectual property generated by their staff. Hence universities were encouraged to create income for themselves and contribute to national wealth creation.

The decentralization of technology transfer represented a turning point in the development of academic entrepreneurship in the UK. The second phase occurred in the early in the 1990s, the White Paper Realising Our Potential (DTI, 1993) led to the restructuring and privatization of the national scientific laboratories and marked a shift in science policy in favour of universities (Lawton-Smith et al. 2005). Finally, the third piece of the jigsaw came with the election of a Labour administration in 1997, which marked a shift towards a regional approach to innovation with the creation of the regional development agencies (RDAs) and a significantly higher priority given to the knowledge economy (DTI 1998).

2.4.1 Reconfiguration of pharmaceutical industry

The UK has seen a shift from the traditional large pharmaceutical company model with vast research and development departments that carried out research 'in-house', with an objective to find the next blockbuster drug and hold the patent for 20 years. Many of these large pharmaceutical companies with operations in the UK have re-organized and closed some of their research and development sites for example Astra Zeneca in Loughborough, ROCHE in Hertfordshire, BASF in Nottingham and MERCK in Scotland. According to Pisano (2006) pharmaceutical companies now have the ability to de-risk early stage drug development and are less likely to be directly involved during the very early stages of drug development. This had been the main driving force for the growth of the biotechnology industry in the UK.

The past twenty years saw the emergence of the 'biotechnology' segment of the pharmaceutical industry, i.e. the industrialisation of drug research and development. Pisano (2006) proposed that the evolution of the biotechnology sector and the rapid increase of technology and drug in-licensing of major pharmaceutical firms has been a contributing factor to the growth of the sector. Recent developments in the form of changes of pharmaceutical firms' business models to an

open innovation model and the closure of large pharmaceutical research and development sites have also contributed to the growth of the biotechnology sector.

The pharmaceutical companies' role has altered the dynamics of the biotechnology sector. Large pharmaceutical companies have started to move away from purely in-house drug research, they are now outsourcing early drug development, concentrating on the later stages of drug development. This new model centres around biotechnology firms that have the advantage of being smaller more agile companies that can change in line with market demands much quicker than a large pharmaceutical company. This change has provided many areas of growth for small biotechnology companies and the physical infrastructure for some of the UK's largest biotechnology incubators.

2.4.3 Local economic regeneration

In response to the reconfiguration of the pharmaceutical industry, organisations tasked in local economic regeneration have become involved in the creation of new biotechnology incubators. The structural changes in the pharmaceutical industry had led to the closure of large research and development laboratories, accompanying these changes are job losses and the spill over of skills and knowledge, (Audretsch, & Keilbach 2007). Local Authorities and Regional Development Agencies were tasked with supporting, developing and growing their local economies. When a large pharmaceutical companies closes there R&D facilities there are inevitably job losses affecting highly skilled scientists and technicians. Organisations involved in local economic regeneration use the closure of these facilities as an opportunity to retain commercial and industry knowledge that would have otherwise been lost, hence new biotechnology incubators are created that are funded by local, regional government and European funding.

Regional Development Agencies were established in the early 2000's and subsequently abolished in 2010 The RDA's would provide financial support to build the physical infrastructure of biotechnology incubators and provide soft infrastructure support to include networking and mentoring schemes, regional venture capital funds, incubator development and a Proof of Concept fund aimed at providing development funds to encourage commercialisation. In 2003 the House of Commons Trade and Industry committee identified the importance of the biotechnology industry is heavily dependent on a continuous stream of high-quality basic research to provide the discoveries upon which commercial biotechnology is built (House of Commons 2003).

2.6 Gaps in Literature:

The number of biotechnology incubators in the UK has increased from five during the early 2000s to twenty five by 2017. There was an assumption in the literature that biotechnology incubators were primarily concerned with the commercialisation of predominantly university and academic life science knowledge. The vast majority of studies concentrate upon individual biotechnology incubators, there are few studies that investigate all biotechnology incubators in the UK. Researchers have differentiated between different types of business and technology incubators however few have investigated biotechnology incubators. The evolution of biotechnology incubators has been taking place since the early 2000s however it is evident that few academic studies concentrate on UK biotechnology incubators and literature relating to biotechnology incubators concentrates on individual biotechnology incubators.

There are few examples of academics investigating the phenomenon of biotechnology incubators, Feldman (2003) undertook a study of biotechnology incubators in Maryland USA and argued that generic incubators are not appropriate to life science companies, in fact they require incubators with sophisticated and costly wet laboratory space. Smith and Ehret (2012) investigated a biotechnology incubator in the East Midlands and showed that this particular incubator supported a mix of service based and intellectual property based companies. Finally Lawton-Smith (2002) investigated a biotechnology incubator in Manchester, this study, like many others concentrate on either a single biotechnology incubator. An interesting observation of the literature is that there seems to be very few recent studies that investigate biotechnology incubator activity across the entire UK since the early 2000s.

The rare group of studies of biotechnology incubators in the UK is centred on The East and the South East of England. For example Lawton-Smith (2007) concentrates on Oxfordshire, Capser et al. (2003) concentrates on the Cambridge Biotechnology cluster and reports released by the Office for Business Innovation and Skills (BIS) and the department of Trade and Industry (DTI) use case studies based on activity in the South East of England. One purpose of this study is to

broaden the horizon and elucidate biotechnology incubation technology in the whole regional spectrum of the UK. As far as can be ascertained, no research has been carried out that explores biotechnology incubator activity beyond regions where established clusters already exist. To address these gaps in the current literature this study will investigate the evolution of biotechnology incubators across the UK.

3. Methodology:

This study uses two desk-based surveys that provide a snap-shot of 21 biotechnology incubators taken in December 2012 and December 2017. The surveys provide a detailed examination of the characteristics of UK biotechnology incubators and their tenant companies. The surveys includes data on 480 tenant companies and their key attributes such as age, business model (service or IP based) and industry type (bio/pharma or med tech). Key variables for biotechnology incubators include the size of the incubator, number of tenant companies and the various types of technical and business support offered to tenants.

Key variables for biotechnology incubators include the size of an incubator measured in square feet, number of tenants, technical and business support offered to tenant companies, location of incubator in terms of its geographical proximity to centres of expertise and knowledge such a university, hospital, a science park or a large pharmaceutical company and the tenant mix of the incubator. Key variables for tenant companies includes company age and business model employed by the tenant company (intellectual property based or service based). Additional metrics include the industry type of the tenant company for example biotechnology, medical technology, green technology, food technology or the provision of sector specific business support.

4. Findings

In order to describe the evolution of biotechnology incubators we must first provide a simple classification of the different kinds of biotechnology incubators that have appeared since the early 1990s. The classification used in this paper relates to the geographic proximity of the biotechnology incubator to organisations and establishments that create a particular kind of knowledge. Once this classification is established Biotechnology incubators operating in the UK are analyses in terms of their age and classification in order to illustrate trends that exist across the various types of biotechnology incubators.

4.1 Classification of biotechnology incubators

For the purposes of this paper the various UK biotechnology incubator have been classified into four groups, this classification relates to the proximity to particular establishments namely, universities, hospitals and pharmaceutical companies. Using geographic proximity to these establishments we have devised a simple classification system to help illustrate the evolution of biotechnology incubators.

Four categories of UK biotechnology incubators

1. University based biotechnology incubators - i.e. incubators located on a university campus close to *academic knowledge*, with a role to commercial intellectual property.
2. Hospital based biotechnology incubators - i.e. incubators located on a hospital site close to *medical and clinical knowledge*, with a role to develop medical technology products.
3. Stand-alone biotechnology incubators - i.e. no close geographic links to a traditional sources of life science knowledge but close links to *commercial and industry knowledge*, with a role in economic and regional development.
4. Large pharmaceutical company based incubators – i.e. incubators located on a currently operational pharmaceutical company site with close links to commercial and industry knowledge, with an open innovation remit.

4.1.1 University based biotechnology incubators

University based incubators are usually owned by a university, based on the university or research campus and they are typically purpose built biotechnology incubators. University based Biotechnology incubators are likely to be small to medium sized (1000 to 7000 sq. m) and generally support less than 12 tenant companies. There is the potential for a continuous source of new spin-out companies from the university life science departments. One example is the Imperial Bioincubator, with its close physical connection to Imperial College University the incubator provides a steady supply of new tenant companies. Academic research knowledge derives from universities that are research intensive in the life sciences and in the UK are often Russell group universities with high research outputs in the life sciences. One example of how life science knowledge can be transferred from a university is the university spin-out company. This is where the research of an academic member of staff at the university forms the basis of a university spin-out company in order to 'take to market' the outcome of academic research (McQueen et al., 1982; Steffensen et al., 2000). Quite literally academic knowledge is encouraged to be spun-out from the university into a new start-up company.

4.1.2 Hospital based biotechnology incubators

Hospital based biotechnology incubators are all physically located on a hospital site with close working relationships to the hospital. Clinicians or clinical nurses are often co-located within the biotechnology incubator and share facilities such as a café and restaurant with tenant companies. The following incubators are physically connected to a hospital site; CTRIC, The Cardiothoracic Bio Incubator (CTBI), Institute of Life Sciences (ILS) in Swansea (also university based) and Edinburgh Bioquater. The main distinguishing features of hospital based incubators are that they are usually purpose built and a small to medium size incubator with less than twelve tenant companies. Clinical and medical life science knowledge is often found close to hospitals. Clinicians that are involved in the processes of innovation and development of new medical products provide a source of life science knowledge that can be potentially be converted into a new life science company. The geographical proximity to clinical and medical knowledge potentially provides greater access to the NHS market for new medical devices and technologies and spill overs of tacit knowledge from practitioners located in the hospital.

4.1.3 Stand-alone biotechnology incubators

Stand-alone biotechnology incubators are not usually purpose built. Typically they are based in former large pharmaceutical company research and development laboratories that have been converted into biotechnology incubators. Since the late 1990s big names in the pharmaceutical industry such as MERCK, BASF, ROCHE and Astra Zeneca consolidated large sections of their UK research and development activities. The following examples detail some of the closures in the UK. Although many of these big pharmaceutical companies have recently closed their research and development facilities, the buildings and their very expensive laboratory facilities have not been indefinitely closed or destroyed, they have found a new use. For each of the large pharmaceutical companies previously mentioned, a regeneration of the facilities has taken place. They provide a space that facilitates biotechnology company start-ups and provides the necessary physical infrastructure to support a growing biotechnology sector. Stand-alone incubators have the highest proportion of business support tenants, between 26% and 32% of tenants that offer some type of business support and are amongst the largest in size providing up to 60,000sq m of case and housing up to 70 tenant companies.

4.1.4 Large pharmaceutical biotechnology Incubators

Large pharmaceutical biotechnology incubators are co-located on fully operational sites owned and operated by large pharmaceutical companies such as GlaxoSmithKline (GSK) in Stevenage and AstraZeneca (AZ) in Manchester. The aim of these types biotechnology incubators is to create networks that can facilitates the transfer and absorption of commercial and industry life science knowledge by using an 'open' model of innovation. New and emerging life science companies have the opportunity to interact with well-established large pharmaceutical companies in addition to the more traditional support provided within a biotechnology incubators. New life science companies have access to additional routes to market via the large pharmaceutical company as well as the potential access to technical knowhow and technical equipment that large pharma possess. In turn, this arrangement provides large pharmaceutical companies with access to

early stage drug development pipeline without the risks and high attrition rates associated with early stage research and development.

4.2 Evolution of biotechnology incubators

The evolution of biotechnology incubators in the UK is illustrated in *table 1*, this shows the appearance of subsequent generations of biotechnology incubators from 1998 to 2016. This table shows the year each biotechnology incubator was opened and the institution the incubator is physically connected to. During the late 1990s and early 2000s there were only a few biotechnology incubators that were specifically designed to support new life science firms. Sainsbury (1999) and Cooke (2001) noted that there were only a handful in operation throughout the UK hence their presence did not appear to play a significant role in the growth of the life science industry or biotechnology sector in the UK during this period. By 2010 there were at least thirteen biotechnology incubators operating in the UK and by 2016 there were twenty-one.

Table 1. Generations of biotechnology incubators

Biotechnology Incubator	Institution	Date Opened
First Generation - University based biotechnology incubators		
Imperial Incubator (London)	Imperial College London	2006
London Bioscience Innovation Centre	Royal Veterinary College	2001
Mersey Bio Incubator	University of Liverpool	2004
Queen Mary Bio science Innovation Centre	Queen Mary University of London	2008
Sheffield Bio Incubator	University of Sheffield	2006
Bradford Laboratories	University of Bradford	2006
Babraham Bioscience incubator	Babraham institute	1998
Second Generation - Hospital based biotechnology incubator		
Cardiff Medicentre	Heath Hospital	1992
Cardiothoracic bio Incubator (Papworth)	Papworth Hospital	2006
C-TRIC (Northern Ireland)	Altnagwlvin Hospital	2009
ILS (Swansea)	Singleton Hospital	2012
Edinburgh bio Quarter	Edinburgh Royal Infirmary	2013
Third Generation – Stand alone biotechnology incubator		
BioCity Nottingham	Former BASF/Boots	2003
BioPark Hertfordshire	Former ROCHE	2006
DiagNox (Oxford)	Purpose Built	2003
CELS Bio Incubator (Newcastle)	Purpose Build	
BioCity Scotland	Former MERCK	2011
Fourth Generation Large pharmaceutical biotechnology incubators		
Stevenage Bioscience Catalyst	GlaxoSmithKline	2011
BioHub (Alderley Park)	AstraZeneca	2014
Medicity (Boots)	Boots	2013

The data from *table 1* has been used to analyse the age of biotechnology incubators within each generation. *Figure 2* shows the average age for each incubator type and the biotechnology incubators that have been in operation for the least amount of time (newest) and the most amount of time (oldest). *Figure 2* shows that the average age of university based incubators in 15 years with the oldest incubator opening 26 years ago. The average age of the stand-alone incubators is 13 years with the oldest incubator opening 15 years ago. The most recent type of biotechnology incubators to appear are the large pharmaceutical based incubators with an average age of 4 years and the oldest incubator in this generation was only opened 7 years ago.

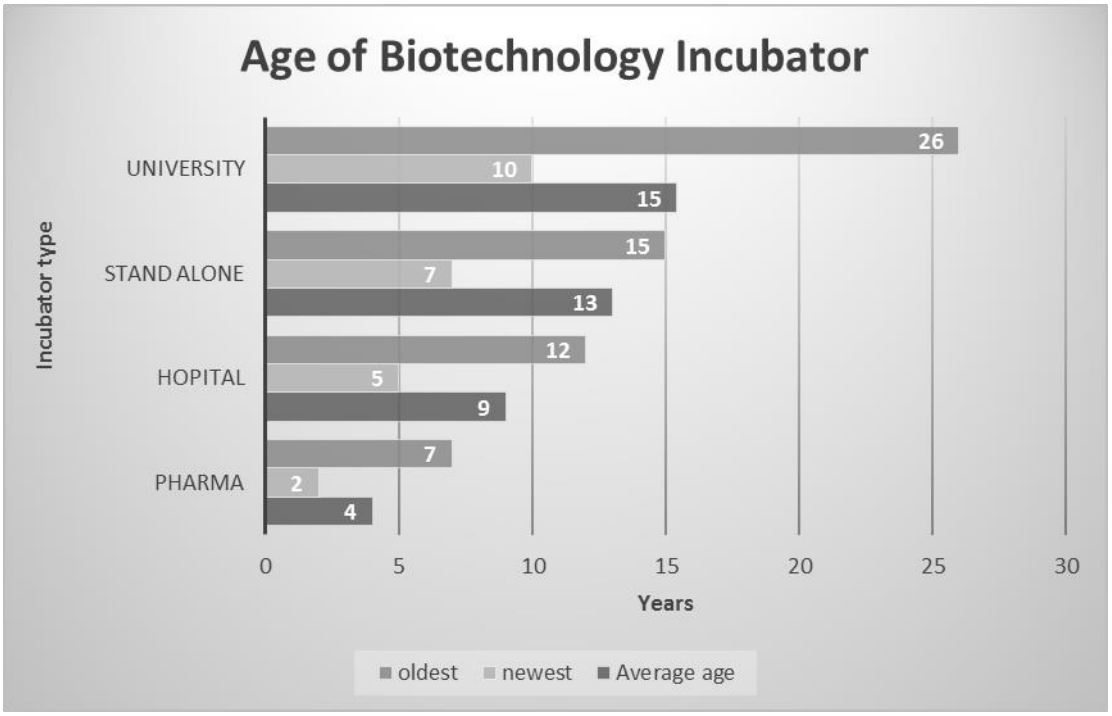

Figure 2. Age of biotechnology incubator

4.3 Successive generations of biotechnology incubators

First generation biotechnology incubators are university based incubators that are closely related to academic entrepreneurship and the commercialisation of university created intellectual property. The rollout of government policy initiatives between 2003 and 2010 coincide with the appearance of university based biotechnology incubators. Initiatives such as the Lambert review of Business and University Collaboration (2003), Future of Higher Education white paper (2003), 'Higher Ambitions' initiative (2009) and the 'Science For All' initiative (2010) supported the creation of these biotechnology incubators. University based incubators were mainly established between 1998 and 2006 with changes in public policy that encouraged the commercialisation of intellectual property through spin-off companies as a major driver.

Second generation biotechnology incubators are hospital based incubators, these are closely related to clinical and medical knowledge. It seems that there has not been the same clear time frame for specific policy initiates that led to the creation of hospital based biotechnology incubators. These incubators have appeared over a much wider time span, hospital based incubators first appeared in 1992 and the most recent opened in 2013. These incubators are often associated with the development of medical products and devices and provide close links to clinical nurses and clinicians.

Third generation biotechnology incubators are stand-alone incubators, these are mainly facilities that re-use former pharmaceutical research and development laboratories, there are two examples of stand-alone incubators that are purpose built however these are often significantly smaller than former large pharmaceutical R&D laboratories. The driver for these incubators is local economic regeneration with regional government between 2003 and 2002 heavily involved during the inception phase and providing substantial financial assistance to repurpose the former laboratories.

Fourth generation biotechnology incubators are large pharmaceutical incubators, these are closely related to industry and commercial knowledge. They are the most recent type of biotechnology incubator and first appeared in 2012, they are located on the sites of existing pharmaceutical companies that are currently in operation such as GSK and AstraZeneca. The main driver for these fourth generation biotechnology incubators is the shift in large pharmaceutical companies from a vertically integrated, closed business model of drug research and development to an open model. This open model of innovation provides more opportunities for smaller life science firms seeking an acquisition or licensing deals in order to capture the value of their intellectual property.

5. Conclusion

This paper investigates the changing landscape of biotechnology incubators in the UK and evidences their evolution from 1999 to 2017. Biotechnology incubators were initially created for the primary purpose of commercialising intellectual property within a university and to develop new medical technology products created by academics researchers and clinicians. The role of biotechnology incubators has evolved to include economic regeneration objectives and the facilitation open innovation within the pharmaceutical industry. This study evidences the changing policy environment for biotechnology incubators and begins to investigate the evolution of UK biotechnology incubators from facilities that primarily support the commercialisation of intellectual property to facilities that reuse former pharmaceutical research and development laboratories and collocate with operational pharmaceutical companies.

This study evidences the growth of biotechnology incubators from five in 2000 to twenty-one in 2017. We propose that regional and national policy initiatives and changes in the business model of large pharmaceutical companies have been the main drivers for the evolution of biotechnology incubators in the UK. Initially biotechnology incubators were co-located on university and hospital sites for the primary purpose of commercialising intellectual property and product development. Then there were several new biotechnology incubators with an economic regeneration remit, usually making use of redundant pharmaceutical R&D laboratories. More recently we have observed the appearance of corporate biotechnology incubators co-located on operational pharmaceutical research and development sites with an open innovation remit e.g. Astra Zeneca (Manchester), GlaxoSmithKline (Stevenage) and Boots (Nottingham).

This study extends the work undertaken by Akcomak (2009) in terms of the evolution of incubators and provides the groundwork for further investigation into characteristics and roles of this new type's biotechnology incubator. This evidence can be used to differentiate between the types of biotechnology incubators in the UK and is potentially useful for policy makers and organisations involved in supporting new life science companies because it provides a greater degree of granularity and precision when classifying biotechnology incubation processes. This study can provide policy makers with evidence for better informed decisions in terms of supporting new and emerging life science industry in their regions.

6. References

Aerts, K., Matthyssens, P. and Vandenbempt, K., 2007. Critical role and screening practices of European business incubators. Technovation, 27 (5), 254-267.

Akçomak, İ.S., 2009. Incubators as tools for Entrepreneurship Promotion in Developing countries. Research paper/UNU-WIDER.

Allen, D.N., and McCluskey, R., 1990. Structure, policy, services, and performance in the business incubator industry. Entrepreneurship: Theory and Practice, (Winter), 61-78.

Audretsch, D.B., and Keilbach, M., 2007. The theory of knowledge spillover entrepreneurship. Journal of Management Studies, 44 (7), 1242-1254.

Bergek, A., and Norrman, C., 2008. Incubator best practice: A framework. Technovation, 28 (1-2), 20-28.

Bernasconi, M., Harris, S. and Moensted, M., 2006. High-tech entrepreneurship: managing innovation, variety and uncertainty. Routledge.

Casper, S., and Matraves, C., 2003. Institutional frameworks and innovation in the German and UK pharmaceutical industry. Research Policy, 32 (10), 1865-1879.

Casper, S., and Karamanos, A., 2003. Commercializing science in Europe: the Cambridge biotechnology cluster. European Planning Studies, 11 (7), 805-822.

Chesbrough, H.W., 2006. Open innovation: The new imperative for creating and profiting from technology. Harvard Business Press.

Cooke, P., 2004. Life sciences clusters and regional science policy. Urban Studies, 41 (5-6), 1113-1131.

Cooke, P., 2003. Biotechnology clusters," Big Pharma" and the knowledge-driven economy. International Journal of Technology Management, 25 (1), 65-80.

Cooke, P., 2002. Towards Regional Science Policy?: The Rationale from Biosciences. Regional Industrial Research Centre for Advanced Studies, UWCC.

Cooke, P., 2001. Biotechnology Clusters in the UK: Lessons from Localisation in the Commercialisation of Science. Small Business Economics, 17 (1-2), 43-59.

Debackere, K., and Veugelers, R., 2005. The role of academic technology transfer organizations in improving industry science links. Research Policy, 34 (3), 321-342.

Ehret, M., Daniel McDonald-Junor and Smith, D., 2012. High Technology and Economic Development: The BioCity Nottingham Technology Incubator. The International Journal of Entrepreneurship and Innovation, 13 (4), 301-309.
Garnsey, E., and Heffernan, P., 2005. High-technology clustering through spin-out and attraction: The Cambridge case. Regional Studies, 39 (8), 1127-1144.
Gassman, O., and Becker, B., 2006. Towards a Resource-Based View of Corporate Incubators. International Journal of Innovation Management, 10 (1), 19-45.
Grimaldi, R., and Grandi, A., 2005. Business incubators and new venture creation: an assessment of incubating models. Technovation, 25 (2), 111-121.
Hamdani, D., and Statistics Canada. Science, Innovation and Electronic Information Division, 2006. Conceptualizing and measuring business incubation. Statistics Canada, Science, Innovation and Electronic Information Division.
Hannon, P.D., 2004. A qualitative sense-making classification of business incubation environments. Qualitative Market Research: An International Journal, 7 (4), 274-283.
House of Commons (2003). House of Commons Trade and Industry Committee UK Biotechnology Industry Twelfth Report of Session 2002–03
Kuratko, D., and LaFollette, W., 1987. Small business incubators for local economic development. Econ. Dev.Rev, 59 (2), 44–55.
Lerner, J., 2009. Boulevard of broken dreams why public efforts to boost entreprenuership and venture capital have failed and what to do about it (harback).
Marshall, A., 1920. Principles of economics: an introductory volume.
Misra, G., 2010. The Funding Landscape for Small Biopharma Ventures, 2010-2015: Trends, strategies and priorities .
Pisano, G.P., 2006. Can Science Be a Business? Lessons from Biotech. Harvard Business Review, 84 (10), 114-125.
Porter, M.E., 1996. Competitive advantage, agglomeration economies, and regional policy. International Regional Science Review, 19 (1-2), 85-90.
Reiss, T., and Dominguez-Lacasa, I., 2005. Indicators for benchmarking biotechnology innovation policies. Fraunhofer ISI, Karlsruhe, .
Sainsbury, D., and Britain, G., 1999. Biotechnology clusters: Report of a team led by Lord Sainsbury, Minister for Science. Dept. of Trade and Industry.
Smith , H., Lawton, 2005. Regulating science and technology: the case of the UK biotechnology industry. Law and Policy, 27 (1), 189-212.
Smith, D.J., and Ehret, M., 2012. 'Beyond the golden triangle': Biotechnology incubation in the East Midlands region of the UK. Local Economy, .
Steffensen, M., Rogers, E.M. and Speakman, K., 2000. Spin-offs from research centers at a research university* 1. Journal of Business Venturing, 15 (1), 93-111.
Swann, G.M.P., Prevezer, M. and Stout, D.K., 1998. The dynamics of industrial clustering: International comparisons in computing and biotechnology. Oxford University Press, USA.