# Innovation Ecosystems for Sustainability Transition:
# From Policy Intervention to Stakeholder Coalition

Michael Zhang
Nottingham Business School
Nottingham Trent University
Nottingham, UK
ORCiD: 0000-0001-8033-8420

**Abstract**

In this paper I develop and compare two models of innovation. Following literature review a conventional model of technological innovation is constructed which focuses primarily on new product or new process development. In recent years through my research, teaching and editorial experience, I develop an emerging model of innovation ecosystems which offer a broader framework for innovation studies. I use the automotive industry as a case in point and argue that technological innovation to reduce $CO_2$ emissions from the transport sector has been primarily driven by policy interventions as exogenous forces. Innovation ecosystems are a more effective approach to helping us embark on the transition to sustainability. Key to innovation ecosystems are stakeholder coalition, a combination of both exogenous and endogenous forces to innovation ecosystems. Considering the relative efficiency of innovation development by product producers vs. product intermediate users I conclude that product intermediate users augmented innovation ecosystem is more effective and efficient than policy-intervention model.

Keywords: innovation ecosystems, sustainable entrepreneurship, intermediate user-led innovation, policy intervention, stakeholder coalition

## Introduction

In recent years research on innovation ecosystems has attracted interest from academics and practitioners alike (Adner and Kapoor, 2010; Gawer and Cusumano, 2014; Jacobides et al., 2018). Innovation ecosystem is a system comprising a large number of actors and resources that interdependently contribute to innovative activities (Adner and Kappor, 2010). Firms compete increasingly in a more globalised economy and open networks of knowledge generation, any innovative activity in an organisation, be it new product development or new process development, cannot take place alone. The external changes put pressure on the organisation, the focal firm, to innovate. The focal firm needs to understand its interdependent relationships with other firms (actors) in the network. Without embedding itself within an ecosystem of interdependent collaboration, the focal firm cannot succeed in any innovative activities and articulate feasible value propositions to customers (Talmar et al., 2018).

In contrast, technological innovation in low-carbon propulsion technologies to reduce $CO_2$ emissions in the automotive industry has primarily been driven by policy interventions, which are regarded as exogenous forces to firms' innovation. In recent years an alternative approach to innovation to reduce $CO_2$ emissions and urban congestion is taking place in the transport sector in a number of countries. Key to these emerging innovation ecosystems are not large vehicle producers, but intermediate users of vehicles for delivering goods or providing services to end users. Moderating this kind of innovation ecosystem to achieve sustainable mobility are stakeholder coalitions, a combination of both exogenous and endogenous forces to the intermediate users' innovation. Considering the relative efficiency of innovation development by product producers vs. product users (Hienerth, von Hippel and Jensen, 2014), I contend that stakeholder-coalition model is more efficient than policy-intervention model in stimulating vehicle producers' technological innovation. Further, the stakeholder-coalition model is more effective than the policy-intervention model in inducing changes in vehicle producers' innovation strategy to align their corporate responsibility with the articulated strategic purpose.

The paper is organised as follows. After introducing the context and motivation of this paper, I use the extent review of the literature streams on technological innovations and policy interventions to delineate a technological innovation model moderated by policy intervention in the next section. This is followed by further review of the literature streams of innovation ecosystems and intermediate user-led innovation to depict an innovation ecosystem model moderated by a coalition force. This paper is primarily theoretical and conceptual, using prior theories and secondary data. In conclusion I will discuss the findings and implications for future research.

## Technological innovation and policy intervention

### *Locus of Innovation*

Innovation and entrepreneurship are regarded as the engine of economic growth and development (Dosi, 1988; Nelson and Winter, 1982; Schumpeter, 1934). Until recently manufacturing in developed economies has been "rooted in technological innovation" (Spring et al., 2017: 6). Manufacturing companies in the automotive industry have invested in both product innovation to sustain market competition and in process innovation to improve operational efficiency and product quality (Clark and Fujimoto, 1991; Womack et al., 1990). In the field of operations management, innovation development is linked with manufacturing strategy (Spring et al., 2017; Skinner, 1969). Spring et al. (2017) argue that the intensified competition by manufacturing companies from developing economies, in particular from Japan in the 1970s and 1980s, caused changes in policy and strategy in the US and UK. Manufacturing companies followed Japanese innovation approaches and invested in process innovation focusing on quality control and waste reduction, of material in terms of Lean principles and of time in terms of JIT (Oehmen and Rebentisch, 2010; Voss, 2005). This is followed by a strategic move from the 1990s onwards to improve managing resources and capabilities (Barney, 1991; Teece et al., 1997) for knowledge generation, entrepreneurial orientation, and organisational learning, in companies big and small (Grant, 1996; Lumpkin and Dess, 1996; Nonaka, 1994; Zhang et al., 2006). More recently in light of the current debate of corporate responsibility strategy for sustainability, which is derived from the concept of sustainable development as a national development framework, firms start to re-assess their strategic purpose and formulation (Haigh and Hoffman, 2012; Smith et al., 2010), which was "all but irrelevant in the 1980s" according to Spring et al. (2017).

### *Innovation strategy and policy intervention*

Not only do firms regard innovation as a strategic objective to enhance competitiveness, governments also recognise the pivotal role played by innovation for economic development. However, they approach to innovation development differently. In direct response to the exogenous force of market competition, firms' capital investment in resources and capabilities such as R&D expenditure is an endogenous force for innovation development. In contrast, governments apply policy interventions to improve the wider socio-technical system, which in turn indirectly supports the firms to sustain competitiveness (Smith et al., 2010; Spring et al., 2017). Governments can also use policy interventions as regulatory power to change firms' behaviour and strategy if and when the latter's activities create social inequality and environmental pollution (Penna and Geels, 2015; Spring et al., 2017). Penna and Geels (2015) documented detailed changes in firms' innovation strategies and government policies in the US automotive industry during its sustainability transition in the years between 1979 and 2012. They note that the US big three preferred 'self-regulation' to government policy intervention regarding technological innovation in response to climate change and reduction of vehicular emissions. They defended that any change in their core technology, internal combustion engines (ICEs), is risky and costly given the firms' capital-intensive "sunk investments in factories, skills and supply chains" (Penna and Geels, 2015: 1029).

Since the early 1970s US regulators, the Environmental Protection Agency (EPA) in particular, exercised various policy interventions in the automotive industry only to see incremental changes and innovations by the US automakers. In 1955, the Department of Health, Education, and Welfare started to study the impact of air pollution on public health. And it was revealed in 1962 that the automobile engine emissions were the source of more than 40% of airborne pollutants, making the automobile the largest single contributor to air pollution. In 1963, the US Congress passed the Clean Air Act. Subsequently the Environmental Protection Agency promulgated automotive emission standards to regulate automotive engine fuels and fuel additives. In essence US policy interventions focused primarily on fuel economy, by measuring fuel consumption in unit of miles per gallon (mpg) following the Corporate Average Fuel Economy (CAFE) test procedure. An et al. (2007) report that in the US CAFE standard for passenger cars was set at 27.5mpg in 1985 and has since remained unchanged. Following the principle of public-private partnership (PPP), in 1993 the US government and the big three automakers formed an alliance, Partnership for a New Generation of Vehicles (PNGV), to develop more fuel-efficient vehicles. PNGV's aim was extremely ambitious with a technical target of achieving up to 80 mpg fuel efficiency between 1993 and 2003, almost three times the CAFE standard set in 1985. As a result of changes in political and economic circumstances in the United States, the 300 million US dollars programme failed to complete its term and was terminated in 2001.

Another broad approach to setting vehicle standards is from the European Commission. European policy goals aim to measure the reduction of $CO_2$ emissions from passenger vehicles in unit of grams of $CO_2$ equivalent per kilometre (g/km), following the New European Drive Cycle (NEDC) test procedure. The European Commission and members of the European Automotive Manufacturing Association (ACEA) concluded a voluntary agreement on vehicular $CO_2$ emissions in 1998 and set a target of 140 g/km by 2008. In 2009 a new regulation (EC Regulation No. 443/2009) became effective with a measure of $CO_2$ emissions reduction to 130 g/km by 2015, and 95 g/km by 2020 (Department for Transport, 2014).

Following the influential Stern Review (Stern, 2007) the U.K. government adopted a low-carbon agenda for economic growth and development. The UK government and the automotive industry formed a government-business partnership, similar to the US PPP mentioned above, whilst a New Automotive Innovation Growth Team (NAIGT) was established in 2008 (BERR, 2009). NAIGT envisaged Technology Roadmaps delineating U.K. low-carbon automotive technology innovation paths to 2040 and beyond. NAIGT (ibid.: 90) acknowledged that most vehicles in the U.K. could not meet the EU 2012 regulatory requirement of $CO_2$ emissions reduction to 130 g/km. Further, they proposed a new method to measure new car registration taking into consideration of the increasing use of alternative fuels. Examining the evolutionary path of innovation in low-carbon automotive technologies, NAIGT compared emerging competing technologies for engine development such as battery-powered electric vehicles (BEVs), fuel cell vehicles (FCVs), hybrid electric vehicles (HEVs), and plug-in hybrid electric vehicles (PHEVs) against the conventional dominant Internal combustion engine vehicles (ICEVs).

Banister (2008) notes that in the UK the persuasion and promotion of using public transport, cycling and walking has not achieved the expectant result of reducing car dependence. Neither has incremental technological innovation in engine development and car design helped to reduce the accumulative $CO_2$ emissions. This is due in part to the fact that both travel distances and travel speeds have increased whilst travel time have remained for the most part constant in the cities (ibid.: 73).

Across the OECD countries, negotiations on flexible mechanisms for emissions reduction became intensified during and after the Kyoto conference in December 1997. In the words of the OECD, "although approximately one-third of all emissions from fossil fuel combustion are attributable to transport activity, OECD countries are struggling to find policies to effectively curb emissions from this sector." (OECD, 1998: 11)

As a latecomer in mass-production of automotive vehicles, China's automotive industry developed rapidly since the mid-1990s. In 1995 China produced 1.45 million vehicles in total including only 325,400 cars. In 2009 total output of automotive vehicles reached 13.8 million units taking over both Japan and the US as the largest automotive producing country in the world. China's vehicle stock grew from 16 million in 2000 to 154 million in 2014. However rapid industrial development has also caused increase in environmental degradation such as air pollution. By 2007 China overtook the U.S. as the world's largest $CO_2$ emitting country. Deteriorating air quality in many parts of the country in general, and in big cities in particular, pushed the government to revise their policy interventions and investment priorities. The government issued fuel economy standards in 2004 and revised in 2011 (Beijing Municipal Environmental Protection Bureau, 2014). In 2009, the government invested 5 billion yuan ($806.5 million) in accelerating the scrappage of old inefficient vehicles. In 2012 the government promulgated the Industry Development Plan for Energy Saving and New Energy Vehicles (NEVs) to promote sales of battery electric vehicles and plug-in hybrid electric vehicles (Chinese State Council, 2012). In 2013 It was reported that China invested 275 billion US dollars over five years with a specific focus on mitigating smog and stimulating the development of China's low-carbon automotive technologies (The Economist, 2013).

*Vehicular $CO_2$ emissions and climate change*

Notwithstanding the producers' investment in technological innovation and government policy interventions, at times with huge amount of financial support to the industry, the world witnessed a continuous trend of increase in $CO_2$ emissions, which largely contribute to climate change.

US total $CO_2$ emissions slightly increased from 4356.8 million tonnes in 1971 through 4823.6 million tonnes in 1990 to 5186.2 million tonnes in 2013. In contrast, $CO_2$ emissions from transport as percentage of total fuel combustion significantly increased from 25.3% in 1971 through 29.7% in 1990 to 33.2% in 2013.

While $CO_2$ emissions in China registered a very low level of 876.6 million tonnes in 1971, the speed of increase accelerated from the late 1990s till 2006 when China's $CO_2$ emissions surpassed the US', with a continuous increase to 10249.5 tonnes, accounting for 197.6% of the US figure. This is against the background in which $CO_2$ emissions from transport as percentage of total fuel combustion account for merely 7.5% in 2006 and 8.4% in 2013.

The newly published Synthesis Report (SYR) on Climate Change by the Intergovernmental Panel on Climate Change (IPCC, 2015) shows that there is increasing scientific evidence of anthropogenic impact on global climate change. Of particular concern are the continued increases of $CO_2$ emissions and $CO_2$ concentration in the atmosphere. The magnitude of annual $CO_2$ emissions was 30.3 gigatonnes in 2010 and the level of $CO_2$ concentration reached 400 parts per million (ppm) in 2013 (IEA, 2012; IPCC, 2013). Over the period of 23 years between 1990 and 2013 the level of $CO_2$ concentration rose from 353 ppm to 400 ppm giving it an average annual increase of 2.04 ppm/yr. The IPCC experts estimate with high confidence that about 50 percent of the cumulative $CO_2$ emissions generated by human activities during the industrial period between 1750 and 2011 occurred in the last 40 years (IPCC, 2015: 45). Indeed, in the last 30 years we have seen marked increase in $CO_2$ emissions by some leading nations. As the leading industrialised country the US had been the largest $CO_2$ emission contributor until 2007, overtaken by China.

From the foregoing literature review and discussion, I construct an innovation model delineating the relationship between producers' innovation strategy and government policy interventions as shown in Figure 1 below.

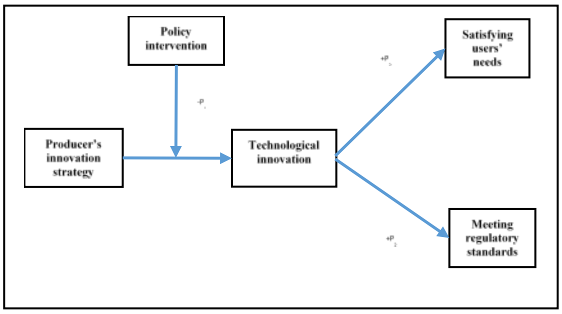


**Figure 1. Technological innovation and policy intervention**

As the model shows, manufacturing producer's innovation strategy is fundamentally rooted in technological innovation, initially aiming to satisfy users' needs. Users in this scenario consist of both end consumer users and intermediate users. When the use of producers' products generates environmental pollution such as $CO_2$ emissions, government will attempt to regulate the industry with policy interventions. As elaborated above, in market-based economies, policy interventions are likely to meet resistance from the producers lobbying for voluntary self-regulation. Even when producers and the government agreed to establish a public-private partnership, often the result cannot be satisfactory for various reasons, not least because of the changes in the very policy interventions the government initiated in the first place. As a result, the goals of meeting regulatory standards cannot be achieved within the timeframe, which in turn can be costly for the producers as well as the government.

Following Hienerth et al. (2014) I contend that the relative efficiency of innovation development by the intervention model is low.

*Proposition 1*: Efficiency of innovation development with a focus on technological innovation under policy intervention is low and more likely to cause negative response.

Due largely to producers' innovation strategy, which is technology-oriented, the goal of satisfying the end-users is prioritized over the responsibility to meet regulatory standards. Therefore I have the following two propositions:

*Proposition 2*: Producer's technological innovation is aimed at satisfying end-users' needs which help build positive relationship between the producer and the end-users.

*Proposition 3*: Caused by producer's negative response to policy intervention ($P_1$) producer is reluctant to implement strategies to meet regulatory standards, and therefore results in negative relationship.

Due to the lack of efficiency in the current model of innovation development we are motivated to seek for an alternative innovation model to foster positive relationships between partners involved in achieving sustainability transition.

## Innovation ecosystems and stakeholder coalition

*Innovation ecosystems and intermediate users*

Innovation ecosystem is a system comprising a large number of actors and resources that interdependently contribute to innovative activities (Adner and Kappor, 2010). Firms compete increasingly in a more globalised economy and open networks of knowledge generation, any innovative activity in an organisation, be it new product development or new process development, cannot take place alone. The external changes put pressure on the organisation, the focal firm, to innovate. The focal firm needs to understand its interdependent relationships with other firms (actors) in the network. Without embedding itself within an ecosystem of interdependent collaboration, the focal firm cannot succeed in any innovative activities and articulate feasible value propositions to customers (Talmar et al., 2018). Gomes et al. (2018) note that there are some similarities between the concept of innovation ecosystems and that of national innovation systems (Freeman, 1995; Lundvall, 1992; Nelson, 1993), and sectoral systems of innovation (Breschi and Malerba, 1997; Smith and Zhang, 2014). In all systems of innovation at various levels, actors, networks, and institutions are key elements. Although all actors are regarded as key players for change, the systems of innovation frameworks cannot help identify the initial driver moving the systems. Theoretical development in innovation ecosystems place focal firms at the centre of innovative changes. Further, research on sustainable entrepreneurship also sheds light on this critical debate (Dean and McMullen, 2007; York and Venkataraman, 2010; Zhang, 2018). The process of entrepreneurial discovery (Kirzner, 1997; Shane and Venkataraman, 2000) emphasises three interrelated concepts of the entrepreneurial role, the role of discovery, and rivalrous competition. On the role of entrepreneur, Kirzner notes that entrepreneurs possess natural alertness to possible opportunities. In addition, knowledge or knowledge base is critical during the discovery process (Hayek, 1948). It is the process of entrepreneurial opportunity creation (Aldrich and Fiol, 1994; Sarasvathy, 2001) that sustainable entrepreneurs contribute to creating new knowledge, new businesses and new markets for sustainability-oriented products and services.

In addition, within the literature on innovation, von Hippel's (1986) research shows the critical contribution by product lead users in the producers' innovation development. He argues that lead users can "serve as a need-forecasting laboratory" (ibid.: 791). Further, Bogers et al. (2010) differentiate users into two groups, one group of end-consumer users and the other intermediate users. They define the former as consumers who use the products to satisfy their personal needs, whereas the latter as business users who use the products as inputs to their own production processes (ibid.: 857). The concept of intermediate users as innovators is pertinent to my research on sustainable mobility but the scope of inference is rather limited. I argue that the literature on innovation ecosystems will enhance our conceptual development.

As elaborated above, automotive producers' reactive response to government policy interventions and slow progress of innovation development in the market for sustainable mobility products has rendered market opportunities for sustainable entrepreneurs in the transport sector. Pure electric cars designed and arguably mass-produced by Tesla Motors are to cause disruptions to the more conservative automotive industry. Capital investment in Tesla Motors is significant and a 350 million US dollars loan-guarantee was provided to Tesla in 2009 from the Department of Energy. The innovation efficiency debate remain unanswered.

The anticipated disruptive impact has not been materialised due to a number of reasons, amongst them range anxiety is one. And some initiative solutions have taken place. In the US there were more than 6,000 public charging stations in 2013. In addition, some private companies provided their employees with free charging spaces (van den Steen, 2015). This change of business model involving various stakeholders, be it public or private, is an innovation in its own right. Furthermore, it is argued that for electric vehicle drivers 'range anxiety' is a barrier of psychological fear rather than a real travel constraint. According to the 2009 data from the US Department of Transportation the average trip was less than 10 miles, with less than 1% of trips exceeding 100 miles (van den Steen, 2015). Therefore changing motorists' behaviour and adopting multimodal transport systems are as important as investing in the development of new technologies to expand the driving range.

In reviewing and researching on sustainable mobility I have been inspired by some new initiatives taken by some unlikely actors and networks of actors in the transport sector. Insights from my teaching, research, and editorial experience on sustainable mobility and smart urban networks inspired my theoretical and conceptual development in this paper.

Last mile delivery service is to change the way in which goods are transported. Goods have been hitherto transported using heavy goods vehicles (HGVs) into cities and urban environment, which causes significant level of congestion and air pollution. The design, planning and provision of last mile delivery systems in cities and densely populated areas using alternative modes of transportation such as EVs will help in no small measure reduce congestion and pollution at local and national levels. In a similar vein, vehicle sharing by commuters in urban centres will also achieve the same effect for urban office workers as last mile delivery services do for goods delivery.

A number of entrepreneurial logistic firms in the UK have just started to make such innovative changes in multimodal transport systems and drivers' behaviour. They are small entrepreneurial businesses with passionate leadership for sustainable transport solutions and innovations. Being small in size, as in any small business, the companies face severe challenges of resource constraints. The sustainable entrepreneurs use the knowledge and skills base, accumulated in the sector from the past experience, to augment an innovation ecosystem and develop networks of stakeholders including existing and potential customers, suppliers, and local authorities. As a result, unlikely stakeholder coalitions have been formed in the innovation ecosystem, to many parties' surprise including the entrepreneurs themselves. Nonetheless, as low-carbon vehicles require heavy capital investment, both companies are faced with a critical question: How can they grow the economies of scale to become competitive in the emerging market? To help answer this question, I have developed a conceptual framework, a coalition-led intermediate user' innovation ecosystem as shown in Figure 2, as Banister (2008: 79) envisaged that car users significantly change their behaviour and a network of stakeholder coalitions develops, including "specialists, researchers, academics, practitioners, policy makers and activists".

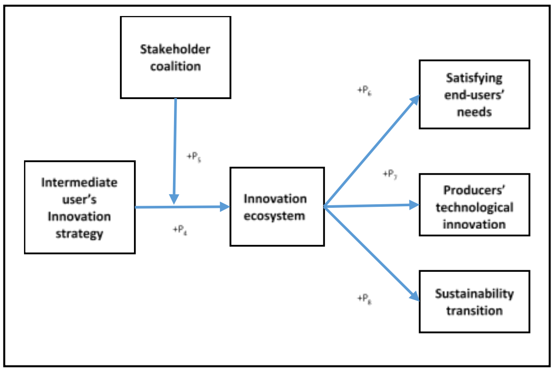


**Figure 2. Innovation ecosystem and stakeholder coalition model**

In the proposed model, the driving force of the innovation ecosystem are the intermediate users of producers' products. This is not because they can become a need-forecasting laboratory as delineated by Borger et al. (2010), but more critically they can help form a stakeholder coalition as an initial force or catalyst, leading to the formation of an innovation ecosystem.

> *Proposition 4*: Intermediate user's innovation strategy aims to create an innovation ecosystem for sustainable mobility by forming a stakeholder coalition.
>
> *Proposition 5*: Stakeholder coalition contribute positively to the innovation ecosystem because of their strategic goal alignment.

The augmented innovation ecosystem will perform three functions simultaneously: (1) satisfying the end-consumer users' needs; (2) helping the producers to engage in cost-effective innovation development; and (3) ultimately accomplish the transition to sustainability as a complete system. Therefore,

> *Proposition 6*: The augmented innovation ecosystem satisfies the end-consumer users' needs with value-added cost benefit.
>
> *Proposition 7*: The augmented innovation ecosystem will help producer's technological innovation development with increased efficacy than in the policy intervention model.
>
> *Proposition 8*: The augmented innovation ecosystem will help achieve the desired sustainability transition.

We note that in the user-led coalition one missing actors are the vehicle producers and large logistics companies. This is so in this research context because the focus is on small sustainable entrepreneurial firms. And it is revealed that it is one of the great challenges facing the sustainable entrepreneurs to persuade them join the coalition. This is also a future research direction.

If Tesla and other EV automakers can join force to manufacture low-carbon vehicles at a much lower cost for last mile delivery services companies and urban car sharing services providers to purchase, the 'range anxiety' will be conveniently eliminated. At the same time production costs can also be markedly reduced. By the same token, large logistics companies such as DHL can also contribute to innovation ecosystems on sustainable mobility by joining the coalition to help small goods delivery companies to embark on a healthy growth trajectory, which in turn will help the large companies to generate more innovative services through a positive feedback loop.

## Discussion and contribution

In this paper I have attempted to compare two alternative models of innovation. In the first part I have elaborated an innovation model with a focus on technological innovation and policy intervention. I conceptualise the model in the context of developing low-carbon propulsion technologies to help reduce $CO_2$ emissions, which contribute to global climate change. This is an important subject for discussion given the recent conclusion from IPCC's scientific panel that there is increasing scientific evidence of anthropogenic impact on global climate change (IPCC, 2015). Of particular concern are the continued increases of $CO_2$ emissions and $CO_2$ concentration in the atmosphere. I have used data from the World Bank and other national and international bodies to show that China and the US are major contributors in this regard and for this reason I have chosen the two countries for comparison in the first part. The US automotive producers are one of the oldest as well as technologically most competitive players in the world. Technological innovation has been the root of their competitiveness. From the 1970s onwards they have been bargaining with the US regulators, represented by the EPA, to reinforce their technological advantages with technological innovation, primarily on fuel efficiency. In so doing they have managed to avoid committing their R&D investment in more radical innovations for the development of low-carbon propulsion products. Although the relationship between the Big Three and the regulators remain more negative than positive, the resultant innovative products satisfied the end-users in terms of quality, fuel consumption, and driving experience.

In stark contrast, Chinese automotive producers are relatively late-comers in both production and design. Along with China's rapid economic development since the mid-1990s, its automotive industry grew from producing 1.45 million vehicles in 1995 to becoming the largest automotive producing country in the world with outputs of 13.8 million units in 2009 taking over both Japan and the US. China's vehicle stock grew from 16 million in 2000 to 154 million in 2014.

Consequently, rapid industrial development has also caused increase in environmental degradation such as air pollution. Data show that China overtook the U.S. as the world's largest $CO_2$ emitting country in 2007. Chinese government promulgated policies and standards to regulate the sector's industrial development, in a similar manner of the US policy interventions. In addition, the governments, at both the national and the local levels, invested in technological innovation such as the Industry Development Plan for Energy Saving and New Energy Vehicles (NEVs) to promote sales of battery electric vehicles and plug-in hybrid electric vehicles (Chinese State Council, 2012). It is again not unlike the US approach to technological innovation. Without a new approach to innovation for sustainable mobility, I contend that neither China nor the US will succeed in decarbonisation in the transport sector.

In the second part of my conceptualisation, I have proposed an alternative approach to innovation, which is innovation ecosystem driven by intermediate users. The intermediate users help augment an innovation ecosystem at the centre of innovative activities, supported by a stakeholder coalition. Moreover, the coalition is primarily formed by various stakeholders related to an industry sector or a small number of related sectors. Using recent development of entrepreneurial firms in the UK I demonstrate the feasibility and applicability of the new approach to achieve the transition to sustainability in the context of low-carbon vehicle development, decarbonisation of the transport sector, and design of smart cities, not only in the UK, but also replicable to China and the US.

Two limitations are present in this paper. One is that the paper and my research remain at the early conceptual stage. It is my hope that this paper will generate critical discussion on this important topic with colleagues in the same field and to invite constructive feedback my further conceptual and theoretical development. The other is the national context. In comparison to China and the US, UK is a relatively small country in geographical terms. Applying the innovation model to large cities in China and the US may be problematic without revision and adaptation.

**References**


Adner, R. and Kapoor, R. (2010). Value creation in innovation ecosystems: How the structure of technological interdependence affects firm performance in new technology generations. *Strategic Management Journal* 31: 306-333.

An, F., Gordon, D., He, H., Kodjak, D. and Rutherford, D. (2007). *Passenger Vehicle Greenhouse Gas and Fuel Economy Standards*, The International Council on Clean Transportation (ICCT), Washington, DC.

Banister, D. (2008). The sustainable mobility paradigm. *Transport Policy* 15: 73–80.

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management* 17: 99-120.

Beijing Municipal Environmental Protection Bureau (2014). *PM2.5 Source Apportionment in Beijing*. Beijing, China.

Bogers, M., Afuah, A. and Bastian, B. (2010). Users as innovators: A review, critique, and future research directions. *Journal of Management* 36(4): 857-875.

Breschi, S. and Malerba, F. (1997). Sectoral innovation systems: Technological regimes, Schumpeterian dynamics and spatial boundaries, in Edquist, C. (ed.) *Systems of Innovation: Technologies, Institutions and Organisations*, Pinter, pp.130-156.

Chinese State Council (2012). *Industry Development Plan for Energy Saving and New Energy Vehicles*. Beijing, China.

Clark, K. and Fujimoto, T. (1991). *Product development performance: Strategy, organization, and management in the world auto industry*. Boston, MA: Harvard Business School Press.

Cooke, P., Uranga, M. and Etxebarria, G. (1998). Regional systems of innovation: An evolutionary perspective. *Environment and Planning A* 30: 1563 – 1584.

Department for Business Innovation & Skills (2009), *Government Response to the New Automotive Innovation and Growth Team Report*, November 2009, BIS, London, published by TSO, Norwich, UK.

Department for Business, Enterprise & Regulatory Reform (2009), *An Independent Report on the Future of the Automotive Industry in the UK*, New Automotive Innovation and Growth Team (NAIGH), May 2009, BERR, London.

Department for Transport (2014) "Cars and carbon dioxide", DfT VCA online

Dosi, G. (1988). Sources, procedures and microeconomic effects of innovation. *Journal of Economic Literature* 26 (3): 1120–1171.
Edquist, C. (1997). *Systems of Innovation: Technologies, Institutions and Organisations.* London: Pinter.
European Commission (2012). *Reducing emissions from transport*. European Commission
Freeman, C. (1995). The National System of Innovation in Historical Perspective. *Cambridge Journal of Economics* 19: 5–24.
Gawer, A. and Cusumano, Mi. (2014). Industry platforms and ecosystem innovation. *Journal of Production Innovation Management*, 31: 417-433.
Gomes, L., Facin, A., Salerno, M. and Ikenami, R. (2018). Unpacking the innovation ecosystem construct: Evolution, gaps and trends. *Technological Forecasting & Social Change*, 136: 30-48.
Haigh, N. and Hoffman, A. (2012), "Hybrid organizations: The next chapter of sustainable business", *Organizational Dynamics*, 41, 126-134.
Hienerth, C., von Hippel, E. and Jensen, M.B. (2014). User community vs. producer innovation development efficiency: A first empirical study. *Research Policy* 43: 190-201.
IEA (2012). *$CO_2$ Emissions from Fuel Combustion*, IEA Statistics, International Energy Agency, Paris.

IPCC (2015). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* IPCC, Geneva, Switzerland.
Jacobides, M., Cennamo, C. and Gawer, A. (2018). Towards a theory of ecosystems. *Strategic Management Journal*, 39, 2255-2276.
Jacobsson, S. and Bergek, A. (2004). Transforming the energy sector: the evolution of technological systems in renewable energy technology. *Industrial and Corporate Change* 13(5): 815–849.
Lumpkin, G. and Dess, G. (1996). Clarifying the entrepreneurial orientation construct and linking it to performance. *Academy of Management Review* 21(1): 135–172.
Lundvall, B-A. (1992). *National Innovation Systems: Towards a Theory of Innovation and Interactive Learning*, London: Pinter.
Nelson, R. (1993). *National Innovation Systems: A Comparative Analysis*. New York and Oxford: Oxford University Press.
Nelson, R. and Winter, S. (1982). *An Evolutionary Theory of Economic Change*. Cambridge, MA: Harvard University Press.
Oehmen, J. and Rebentisch, E. (2010). *Waste in Lean Product Development.* Cambridge, MA: MIT Press.
Penna, C. and Geels, F. (2015). Climate change and the slow reorientation of the American car industry (1979-2012): An application and extension of the Dialectic Issue LifeCycle (DILC) model. *Research Policy* 44: 1029-1048.
Schumpeter, J. (1934) *The Theory of Economic Development*, Harvard University Press, Cambridge, MA.
Skinner, W. (1969). Manufacturing - missing link in corporate strategy. *Harvard Business Review* (May-Jun): 136-145.
Smith, A., Vob, J. and Grin, J. (2010). Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. *Research Policy* 39: 435-448.
Smith, D. and Zhang, M. (2014). Linking, leveraging and learning: Sectoral systems of innovation and technological catch-up in China's commercial aerospace industry. *Global Business and Economics Review* 16(4): 349-368.
Spring, M., Hughes, A., Mason, K. and McCaffrey, P. (2017). Creating the competitive edge: A new relationship between operations management and industrial policy. *Journal of Operations Management* 49-51: 6-19.
Stern, N. (2007). *The Economics of Climate Change: The Stern Review*. Cambridge, UK: Cambridge University Press.
Talmar, M., Walrave, B., Podoynitsyna, K., Holmström, J. and Romme, A. (2018). Mapping, analyzing and designing innovation ecosystems: The Ecosystem Pie Model. *Long Range Planning*
Teece, D., Pisano, G. and Shuen, A. (1997) Dynamic capabilities and strategic management. *Strategic Management Journal* 18: 509–533.
Van den Steen, E. (2015). Tesla Motors. *Harvard Business School Case* 714-413, the Case Centre. Cranfield University, UK.

Von Hippel, E. (1986). Lead users: A source of novel product concepts. *Management Science* 32(7): 791-805.
Voss, C. (2005). Paradigms of manufacturing strategy re-visited. *International Journal of Operations Production Management* 25(12): 1223-1227.
Womack, J., Jones, D. and Roos, D. (1990). *The machine that changed the world.* New York: Simon and Schuster.
Zhang, M., Macpherson, A. and Jones, O. (2006). Conceptualizing the Learning Process in SMEs: Improving Innovation through External Orientation, *International Small Business Journal*, 24(3): 299-323.