

At the Edge of Innovation:

Why shifts in the boundaries of innovation matter



AIM Innovation Fellows Cohort

AIM – the UK’s research initiative on management

The Advanced Institute of Management Research (AIM) develops UK-based world-class management research. AIM seeks to identify ways to enhance the competitiveness of the UK economy and its infrastructure through research into management and organisational performance in both the private and public sectors.

AIM consists of:

- Over 250 AIM Fellows and Scholars – all leading academics in their fields...
- Working in cooperation with leading international academics and specialists as well as UK policymakers and business leaders...
- Undertaking a wide range of collaborative research projects on management...
- Disseminating ideas and shared learning through publications, reports, workshops and events...
- Fostering new ways of working more effectively with managers and policymakers...
- To enhance UK competitiveness and productivity.

AIM’s Objectives

Our mission is to significantly increase the contribution of and future capacity for world class UK management research.

Our more specific objectives are to:

- Conduct research that will identify actions to enhance the UK’s international competitiveness
- Raise the quality and international standing of UK research on management
- Expand the size and capacity of the active UK research base on management
- Engage with practitioners and other users of research within and beyond the UK as co-producers of knowledge about management

Current AIM research projects focus on:

UK productivity and performance for the 21st century

How can UK policymakers evaluate and address concerns surrounding the UK’s performance in relation to other countries?

National productivity has been the concern of economists, government policymakers, and corporate decision-makers for some time. Further research by scholars from a range of disciplines is bringing new voices to the debates about how the productivity gap can be measured, and what the UK can do to improve the effectiveness of UK industry and its supporting public services.

Sustaining innovation to achieve competitive advantage and high quality public services.

How can UK managers capture the benefits of innovation while meeting other demands of a competitive and social environment?

Innovation is a key source of competitive advantage and public value through new strategies, products, services and organisational processes. The UK has outstanding exemplars of innovative private and public sector organisations and is investing significantly in its science and skills base to underpin future innovative capacity.

Adapting promising practices to enhance performance across varied organisational contexts.

How can UK managers disseminate their experience whilst learning from others?


Improved management practices are identified as important for enhancing productivity and performance. The main focus is on how evidence behind good or promising practices can be systematically assessed, creatively adapted, successfully implemented and knowledge diffused to other organisations that will benefit.

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About AIM Innovation Fellows

AIM Innovation Fellows are mid career scholars focusing specifically on innovation. Innovation – both in terms of exploration and exploitation – is key to the UK's future. In an age dominated by open innovation, understanding processes of innovation and their diffusion through firms is essential. In addition to the AIM Innovation Fellows, AIM also hosts a £2 million targeted initiative on innovation.



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Executive Summary

History shows that the boundaries of innovation are constantly changing. It also suggests that those UK organisations that are able to successfully monitor, acknowledge and react to such changes, are more likely to survive and prosper in the long-term.

The innovation cohort at the Advanced Institute of Management (AIM) Research, in a series of wide ranging research projects, examined how these innovation boundaries – geographical, technological, and organisational – are changing and the implications of those changes for both practitioners and policymakers.

Whilst not an exhaustive account of the work of the innovation cohort, this report highlights some of the group's research findings, and the broader issues at stake regarding shifting innovation boundaries.

Section 1: Geographical boundaries

The innovation trade balance – It is clear that innovation has become a global activity, with global inflows and outflows regarding the provision of many different kinds of innovation. The UK, judged on a number of measures, is currently running a net surplus of innovation activity – in that more innovation activity takes place in the UK, than is offshored elsewhere – to India and China, for example.

The internationalisation of innovation – For firms, particularly multinational firms, the internationalisation of innovation is likely to take place, whether actively initiated or not. To follow the example of a company like Tesco plc, which has successfully managed both bottom-up and top-down dissemination of knowledge throughout its global operations, UK firms should be considering what mechanisms need to be in place to maximise the competitive advantage available from the internationalisation of innovation.

The impact of global challenges – Major global challenges such as climate change will impact on collaboration across geographical boundaries, but not necessarily in ways that might be expected. Research evidence suggests that because the effects of global challenges are heterogeneous, responses to global challenges may lead to the entrenchment of national and regional policy, as much as they do increased international collaboration.

Section 2: Technological boundaries

Advancing technology creates improved technological tools for collaboration which in turn leads to greater innovation. The task for firms is to find ways of managing the challenges that arise from these new forms of collaboration.

Crossing technological boundaries – While the UK has the ability to be a global leader in a number of technological areas, to fulfil its promise UK universities and firms need to surmount the challenge of collaboration across technological boundaries. A promising sector such as plastic electronics involves the convergence of many industries, scientific disciplines and sectors that do not conventionally choose to work together. This in turn raises difficult questions – about issues such as intellectual property, for example.

Embrace collaboration – The research shows that a diverse range of sectors and professions from the hotel sector, to the NHS, must embrace collaboration, instead of lagging behind, and make the necessary investment in expertise in order to benefit from the shifting technological boundaries.

Promote user communities – Traditionally organisations have been wary of user involvement in innovation and user modification of existing products, treating these as an infringement of proprietary technology and intellectual property. Evidence from Microsoft, Sony and Nintendo's interaction with user communities, however, suggests that firms can benefit from a more relaxed approach to this type of interaction. Additionally, AIM research shows that there are considerable educational and training benefits for society at large available from such activities.

Demonstrating the value of new technology – A project evaluating the use of demonstration projects and trials shows that they have real value in terms of accelerating the development and adoption of new technologies, such as new energy technologies.

Section 3: Organisational boundaries

Shifting organisational boundaries are creating new routes of innovation, with open innovation increasingly common, involving multiple organisations acting together. Equally, innovation confined to the R&D or innovation department is less likely, instead being a shared responsibility involving several departments.

Driving factors behind change – A number of factors are behind shifting organisational innovation boundaries: the need to leverage external talent to create sufficient value from innovation to meet growth targets; globalisation of markets; increasingly diverse specialist knowledge; the advance of enabling technologies such as the Internet allowing organisations to reach beyond organisational boundaries; increased costs and decreased productivity of traditional internal R&D.

Managing conflicts – Research shows, however, that open innovation comes with caveats attached. For manufacturers, loose organisation boundaries combined with rapid innovation and high-technological complexity of specialisation makes it difficult to combine innovation and dependability. Managing open innovation, means managing conflicting criteria and rationales – conflicts between innovation and dependability, flexibility and efficiency, flexibility and reliability.

A new breed of organisation – Our studies show that new types of organisation are emerging that may come to dominate the world where open innovation prevails. Systems integrators, for example, emphasise the advantages of specialisation and a division of labour, bringing together a range of third party specialist individuals and organisations, both upstream and downstream, to create innovative products and services.

Capturing collaborative value – The changing nature of organisational boundaries means organisations must reconfigure their business models to create and capture value. In doing so, however, they must make sure that the costs of collaboration do not outweigh the value created. Our research shows that for UK biotech companies partnering with a major pharmaceutical company in the fifth or six year of life is likely to be unprofitable, or for a university partnering with more than three partners, is equally unproductive.

The challenges of collaboration – Finally, while acknowledging the benefits of open innovation and collaborative models, our research reveals many challenges;

- Collaboration and the dispersal of relevant knowledge across firms might lead to rapid innovation but it also poses considerable problems regarding coordination, not least the fragmentation of intellectual property across many partners, and sustaining multiple organisational relationships.
- If traditional business models of capturing value using patents or copyright protection are no longer workable, how can value be equitably appropriated?
- Reliance on partnerships not only requires greater clarity for the performance aspect of the relationship, and allocation of risk and reward, but also a closer examination of how organisations can work together successfully.
- Shifting organisational boundaries require greater empowerment and re-skilling of front-line staff to handle flexible delivery of products and services.

This summary report can only hint at the depth of research conducted by the AIM Innovation fellows relating to the significance of the changing boundaries of innovation, and their increasing interconnectedness, as we head further into the 21st century.

Yet, at a time when the UK economy should be looking to the future, and emerging from one of the severest economic downturns since World War II, it is essential that both policymakers and organisations understand how innovation boundaries are changing, and the possible implications of these changes, so that they can act in ways that maximise the opportunities available, while minimising the potential downside.



The Whip and the Carriage – A Tale of Two Cities

Much has been made of the demise of the buggy whip manufacturers in America in the late 1800s and early 1900s. Westfield, Massachusetts, or the ‘Whip City’, as it is still known, was at the heart of the horse and carriage whip manufacturing world, with 42 companies, over 30 factories, and 85% of the town’s population devoted to producing whips for buggy owners.

The invention of the horseless carriage – the motor car – put paid to the Whip City’s success story. By the end of the Second World War, only two whip making firms remained there.

But, while the buggy whip industry has become synonymous with a market sector doomed to extinction by industry-changing innovation, for today’s executives and policymakers there is perhaps a more relevant lesson to be had by examining the fortunes of another city that played a central role in the horse and carriage industry – the city of Flint, just northwest of Detroit, Michigan.

As the 20th century motored into life, Flint was the biggest producer of carriages and horse-drawn carriages in America. In the pre-automobile age Flint was already known as Vehicle City. At the time, industrial life in Flint was dominated by three carriage companies the Durant-Dort Carriage Co., Flint Wagon Works and W.A. Paterson Co.

Yet Flint’s executives were all too aware of the shifting boundaries of innovation that threatened the economic prosperity of their city. And, through an acute sensitivity to how and why those boundaries were changing, much of the carriage industry in Flint was able to adapt, survive and even prosper in the era of the automobile.

So, for example, the directors of Flint Wagon Works, a leading manufacturer of horseless carriages, were responsible for bringing auto firm Buick to the city in 1903. Similarly, W.A. Paterson started making cars in 1908, and did so until 1923. And William C Durant, a partner in Durant-Dort Carriage, founded General Motors.

Flint is just one example of the challenge that faces firms, cities, regions, nations, even continents, as they battle to remain relevant and prosperous in a fast changing world. History is littered with examples of organisations that failed to sense the shifting boundaries of innovation.

The boundaries of innovation: a moving picture

Polaroid, long associated with innovations in instant photography technology filed for Chapter 11 bankruptcy in 2001. Despite attempts to resurrect it, Polaroid film is all but extinct. Eastman Kodak, the once dominant camera film company, has also suffered a dramatic decline – it is not clear whether it will survive. Both companies have been criticised for failing to adapt to the shifting boundaries of technological innovation that have made digital photography such a success.

Other organisations have sensed and reacted better to the changing world. Finnish firm Nokia is famous for its association with the mobile phone business, but in a previous guise was in the timber business, and ran a rubber works, making Wellington boots among other items. More recently, in anticipation of the continued growth in importance of the internet as a means of communication, Nokia switched direction to become an organisation that provides and facilitates consumer experiences.

Nokia’s change in strategy involves offering new services and applications such as multimedia, navigation, and location-based services, pushing its own operating system, buying up application outfits in areas like social networking, and partnering with organisations for R&D work, like its networking collaboration with Siemens.

Acknowledging the fundamental importance of changing innovation boundaries – whether geographical; technological; or organisational – AIM has, through its innovation cohort, been conducting a range of research projects that explore this vital imperative for the UK economy.

While this report is not intended to be an exhaustive account of our work in this area, it provides an insight into a number of our innovation research projects. How they relate to innovation boundaries, and why it is important for both practitioners and policymakers to understand how innovation boundaries are shifting, and the implications of these changes.

1 The Globalisation of Innovation

Originally markets were a local phenomenon. But, as transportation improved, so trade routes expanded from the regional, to national, then international, until finally, in the late 20th and early 21st century we have a truly global economy.

In a similar way, as the territorial limitations of markets have changed so the geographical boundaries of innovation have both expanded and broken down, to reshape our thinking about where innovation happens and where the people involved in the innovation value chain are located.

These changes are particularly important in the context of international knowledge flows, and developing economies like China and India that are making significant investments in boosting their knowledge base.

Research and development (R&D) and innovation were traditionally considered relatively immobile activities and tended to be carried out locally, whether that was regionally or nationally.

However, a decrease in communication and travel costs, along with changes to the world economy, such as EU economic integration and the growing importance of the emerging economies, mean that the incentives that firms face when choosing the level and the location of their investments in innovative activity have changed markedly in recent years. As a result, firms are increasingly moving these activities abroad.

There are numerous government policies aimed at encouraging and facilitating the ability of firms to innovate and to exploit the innovation of others. These policies are largely formed in the context of a national innovation system. But our research shows that firms operate globally – undertaking research and producing and selling products and services in many locations. Productivity and growth in a home country depends not only on what firms do within the national boundaries, but also on what they do abroad.

AIM researchers are working together in order to gain a better understanding of the decisions that govern where to locate innovative activity; how the benefits from innovative activities vary when these activities are carried out in different geographical locations; and what the implications of increasing globalisation are for UK and EU innovation policymakers.

The global trade in innovation

So how has globalisation impacted on innovation and R&D? AIM innovation researchers looked at the global dispersal of innovation activities over a range of measures to assess who are the winners and losers in the international innovation trade.

In particular, we looked at:

- The proportion of all innovation activity based at home and abroad, and the percentage of offshore R&D centres by country of the parent firm;
- The proportion of firms operating at home, abroad or both;
- The proportion of all innovative activity in a country conducted by domestic and foreign firms;
- The innovation ‘trade balance’.

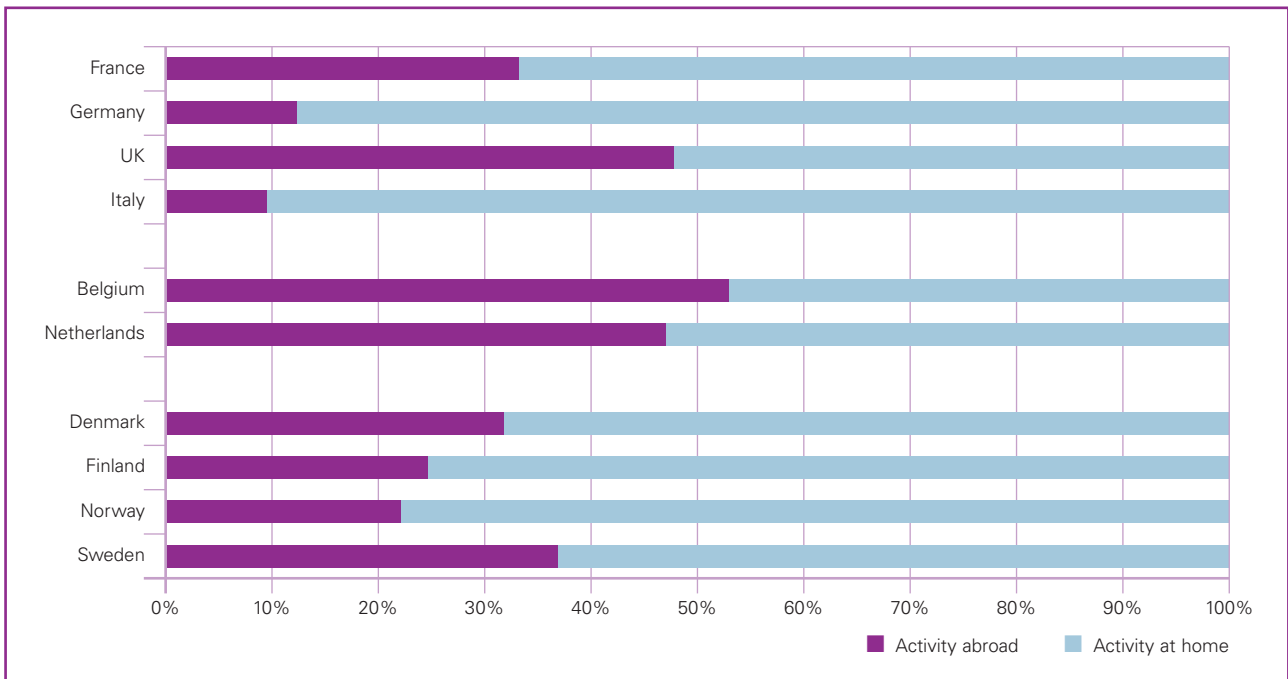
Innovation research data

As measures of innovative activity and geographical spread we looked at both data regarding the inventors listed on patents filed to the European Patent Office (EPO) for ten European countries during the period 2000/2004, as well as where Fortune 500 companies had decided to locate their R&D centres as of 2008.

Offshoring innovation activity

To monitor the extent to which firms move innovation activity offshore we counted the country where a firm’s headquarters was located as its home country, and then identified where the inventors associated with innovation being conducted by firms in a particular country were based, or where the R&D centres associated with various firms were located.

The patent inventor data reveals that firms in some countries were happy to outsource innovation, notably UK, Belgian and Dutch firms, while firms from other countries – Germany and Italy – far less so (Figure 1).

Figure 1: The proportion of all innovative activity based at home and abroad (by country of the parent firm), 2000/2004

The Fortune 500 data reinforces a picture of significant and widespread globalisation of innovation in developed economies – firms headquartered in developed economies have 50% or more of their R&D centres located offshore

(Table 1). On the contrary, firms headquartered in China have around 25% of their R&D centres located offshore, and Indian firms have all their R&D centres based at home.

Table 1: The percentage of offshore R&D centres by country of the parent firm, 2008

Country of parent firm	% offshore R&D Centres	Number of offshore R&D Centres	Number Fortune 500 Firms	% Fortune 500 Firms
France	68	104	38	7.6
Germany	53	78	37	7.4
UK	57	46	33	6.6
Netherlands	71	42	24	2.8
U.S.	49	253	162	32.4
Canada	59	22	16	3.2
Japan	52	113	67	13.4
South Korea	59	24	14	2.8
China	26	8	24	4.8
India	0	0	6	1.2

Differences in numbers in Figure 1 and Table 1 for the same countries are probably due to factors such as differences in the set of firms covered, the activities considered, and the time frame.

How firms approach innovation offshoring

The data in Figure 1 and Table 1 describes aggregate differences in offshoring across countries.

Despite aggregate national trends, however, not all firms within these countries adopt the same approach to offshoring innovation. Firms show significant differences relating to whether they offshore some, all, or none of their innovation activities (Table 2).

While many firms have no innovative activity offshore, a few firms operate entirely outside of their national borders – possibly a trend we will see more of in the future.

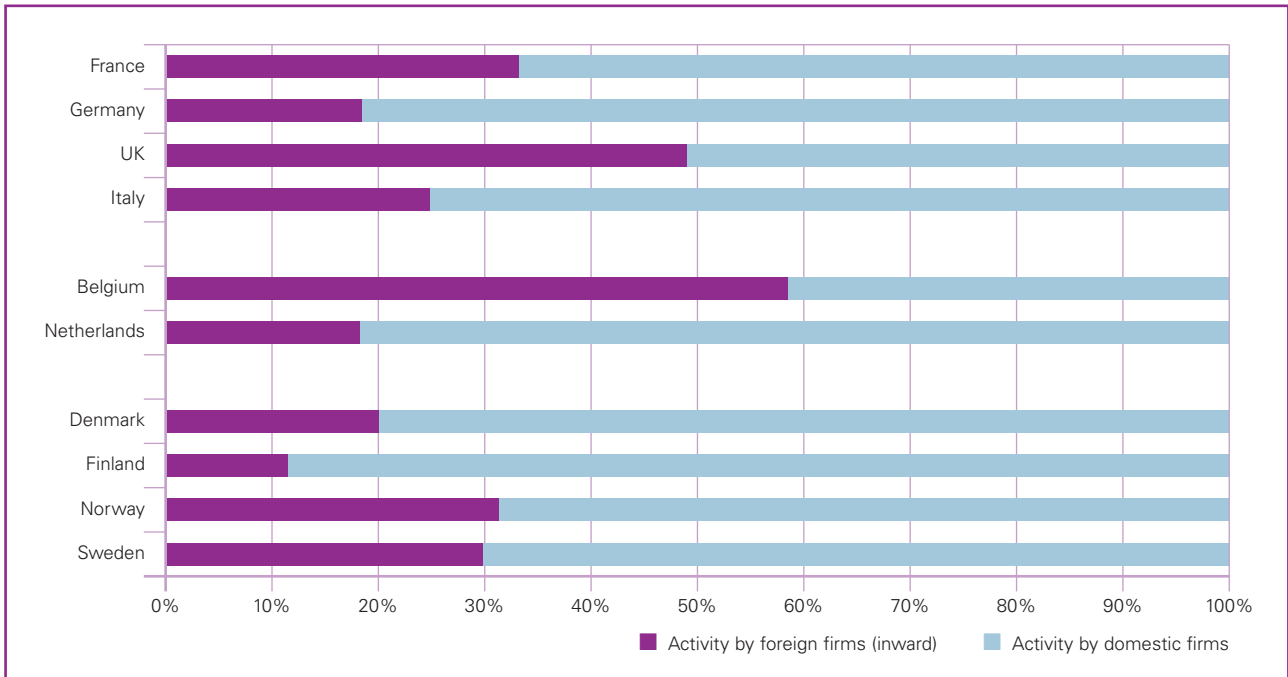
Table 2: The proportion of firms operating at Home, Abroad or both, 2000/2004

Country	Home only	Home and Abroad	Abroad only	Total
France	83.84	13.15	3	100
Germany	82.55	15.3	2.15	100
UK	80.98	13.09	5.93	100
Italy	91.27	6.21	2.52	100
Belgium	63.46	23.29	13.25	100
Netherlands	67.79	13.79	18.42	100
Denmark	76.36	18.22	5.42	100
Finland	81.42	14.87	3.72	100
Norway	80.24	14.15	5.61	100
Sweden	77.71	17	5.29	100
Total	82.12	13.25	4.64	100

The evidence from the Fortune 500 data also suggests that the larger the firm, the greater the proportion of innovation located offshore, and the more diversely spread between countries that innovation is.

Hosting global innovation

As well as locating innovation activities abroad, many countries play host to the innovation activities of foreign firms. For example, while the majority of innovation activity in European countries tends to be carried out by domestic firms there are some exceptions, with foreign firms accounting for around a half of activity carried out in Belgium and the UK.

Figure 2: The proportion of all innovative activity in a country conducted by domestic and foreign firms, 2000/2004

Similarly, the Fortune 500 data reveals that the UK, China and India all have a high proportion of R&D centres owned by foreign firms.

Table 3: Proportion of Fortune 500 firms' R&D centres owned by foreign firms, 2008

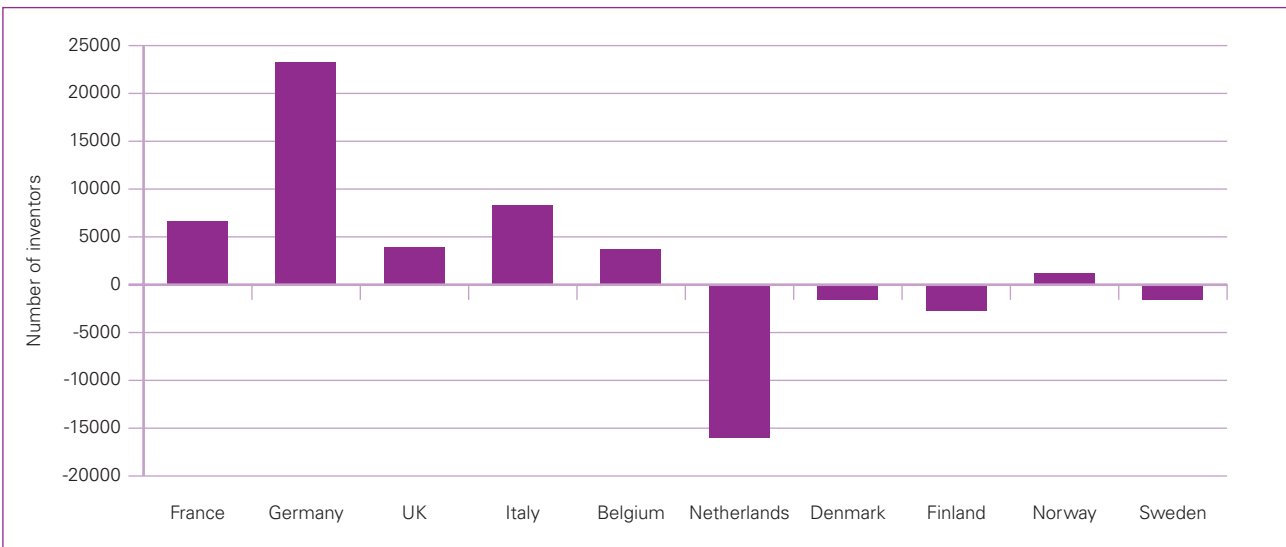
Host country	Total number of R&D centres in country owned by Fortune 500 firms	Of which owned by <i>foreign firms</i>	
		Number	%
France	84	35	42
Germany	152	79	52
UK	109	75	69
Netherlands	35	18	51
U.S.	488	223	46
Canada	52	37	71
Japan	148	43	29
South Korea	27	10	37
China	98	74	76
India	63	58	92

The innovation ‘trade balance’

Finally, by assessing the innovative activity associated with a country in terms of both the activities conducted at home by foreign firms (inward innovation), and those that domestic firms conduct offshore (outward innovation), it is possible to arrive at a net ‘innovation trade balance’ (see Figure 3).

Thus countries are shown to have a surplus or deficit in innovative activity; Germany has a large surplus while the Netherlands has a large deficit. The UK is marginally in positive territory.

Figure 3: Innovation ‘trade balance’, 2000/2004



Conducting a similar exercise with the Fortune 500 R&D centre data shows that the largest net recipients in absolute terms are China and India. The UK is doing better than many other developed economic nation countries in terms of

maintaining a positive balance. This is a welcome finding, given the emphasis on innovation as a pillar of future economic prosperity for the UK.

Table 4: Which countries have a net positive balance of R&D centres?

Country	Number of R&D centres owned by foreign firms (in)	Number of offshored R&D centres (out)	Net balance
France	35	104	-69
Germany	79	78	1
UK	75	46	29
Netherlands	18	42	-24
U.S.	223	253	-30
Canada	37	22	15
Japan	43	113	-70
South Korea	10	24	-14
China	74	8	66
India	58	0	58

Globalisation of innovation: Tesco plc

Most multinational firms are well placed to internationalise innovation activities to their best advantage, with the whole organisation benefiting from innovative practices via structured knowledge sharing, wherever those practices may occur in the firm.

AIM research suggests that multinational retailers rarely take an active decision to internationalise R&D – other than certain specialised functions, such as site/store location research, and own-label product development. Despite this, retail multinationals can derive significant competitive advantage from successful promotion, capture and management of innovation across international structures.

One company that has dealt with the internationalisation of innovation successfully, is Tesco plc, the UK's largest retailer. Over the past 15 years Tesco has emerged as a major multinational corporation, with 65% of its operating space expected to lie outside of the UK by 2009/10, and with its future growth prospects likely to be driven by its network of international subsidiaries. During that rapid international expansion Tesco has successfully captured and benefited from the innovation which has emerged from its international subsidiaries.

As Tesco has learned to operate in, and adapt to, the host economies it has entered, it has continuously transformed its organisational structures and operating skills. As well as transferring knowledge outwards from the UK to its international operations, via intra-firm telecom networks and face-to-face communication of best practices, the retailer has also captured innovatory practices emerging within its international subsidiaries via bottom up processes of organisational learning. Essentially, it has learned to manage the challenges involved in nurturing, protecting and capturing the tacit knowledge and innovation arising in its international subsidiaries and has encouraged that know-how to flow around its other operations, and also back to its home market.

Tesco's development of strong hypermarket-format retail skills is an example of the retailer capturing and exploiting innovatory practices originating from its subsidiaries. These skills were originally developed and refined in its Central European operations and were then transferred into both the UK home market operations (in the form of Tesco 'Extra' stores) and into its East Asian subsidiaries.

Similarly, multi-floor store design and operating skills, low-build-cost store development techniques, and food hall merchandising techniques, all developed in Tesco's East Asian subsidiaries, have been transferred to different parts of its operations in Europe.

More recently, Tesco has confronted several new challenges during its expansion into the USA. In response, there has been a top-down transfer of several innovatory and experimental practices including: stores that have predominately self-scanning checkout operations; high front-end-cost integrated distribution and food manufacturing/preparation centres; and strategic dependence on a dense network-structured market coverage of smaller format stores.

At the same time, the firm has demonstrated a strategic commitment to rapidly embracing bottom-up produced tacit knowledge in order to adapt to local consumer cultures. In the tech savvy west coast US markets that has involved embracing a more 'wired' and on-line consumer culture, and has seen Tesco, via its subsidiary's Chief Marketing Officer, experimenting with digital viral marketing techniques and attempting to engage on-line 'communities of consumption' via blogging and Twitter.

Global innovation, global challenges

As we head into the 21st century, a series of major challenges – climate change, the credit crunch, terrorism, and global pandemics – has emerged.

A closer examination of the relationship between these challenges and the globalisation of innovation offers an important insight into the dynamics of shifting geographical boundaries of innovation.

Initially, the logical temptation is to think that global challenges such as climate change, support current trends towards a greater global integration of innovative activity. It might reasonably be argued, for example, that global connectivity maximises the impact of innovation capacities, and that no individual country has the resources to be able to meet these huge global challenges alone.

AIM research suggests, however, that the effects of these challenges on the globalisation of innovation are far more complex than first appears. Rather than creating further global integration of innovation, with the breaking down of geographical boundaries, in the face of these global problems it is more likely that boundaries will shift and not dissolve, becoming stronger in some instances and weaker in others.

Global problems like climate change have social and political dimensions and repercussions, and while their effects may be ubiquitous, they are not uniform. The varied impact means that the incentives, interests, and capabilities of different parties regarding an innovative response to these problems will be commensurately diverse.

Thus these major global challenges have the contradictory effect of stimulating a growing concern for shared global challenges, but strengthening governance structures for defence of a particular national and regional policy against them.

Equally, factors such as the novelty and complexity of these global challenges also favour a move towards greater global connectivity in order to maximise the impact of innovation initiatives and knowledge of the problems, yet at the same time encourage stronger local governance of innovation, in order to regulate and contain the associated uncertainty and risks.

Low-carbon innovation in China

As part of our research we examined the dynamics of international collaboration between the UK and China on low-carbon technology in three areas of crucial importance: energy, mobility and agriculture.

Focusing on this particular issue addresses several crucial elements relating to the global geography of innovation, notably: the rise of new powers, both in geopolitical terms, and also in terms of science, technology and innovation (STI); and the contradictory effects of global challenges on these relationships, transforming the global innovation landscape by changing the qualitative nature of international connections, according to the global and local concerns elicited by a particular challenge.

The result is a detailed geography of innovation reflecting the strategic advantages presented by the specific strengths and weaknesses, opportunities and costs, of particular partners in various locations and socio-political contexts.

The sector and stage of the innovation process are both significant issues. Research, development, deployment and distribution may all favour different international partners. And, of course, international collaboration may take many different forms, offering different distributions of benefits.

The fundamental interactions between global problems and local context in the ongoing shifts of the geography of innovation are illustrated by looking at the Chinese side of the equation, and considering the opportunities for, and barriers to, international collaboration on low-carbon innovation in China.

Global warming demands international collaboration, with all parties reducing emissions of greenhouse gases (GHGs). The cooperative sharing of innovation and technological capacity in order to maximise global efforts towards the decarbonisation of economic activity benefits everyone. Also, given that no country has demonstrated a successful low-carbon shift yet, it is likely that collaborative efforts would improve innovation capacity, to the benefit of all.

China is now the largest absolute emitter of GHGs (though still comparatively small per capita), and its current low-carbon innovation capacity, while improving, is unlikely to enable the country to reach a global target of a 2°C limit on global warming. The inability to meet these challenges alone leaves China weighing the factors that gravitate towards international collaboration against those that suggest otherwise, in the same way that other nations and firms will evaluate the merits of collaboration for a range of issues.

Towards global ties

On one side there are a number of forces that favour China deepening its global innovation ties.

- Shifting China's growth (and developed countries such as the UK) onto a low-carbon path is an issue of global importance, making international collaboration in low-carbon innovation imperative. There is a clear case for providing significant policy support to deepen the globalisation of innovation.
- China's rapidly increasing innovation capacity (Table 5) – at the cutting edge in areas such as solar PV, coal combustion technology, and nanotechnology – underlines its attractiveness as a node for global innovation networks. Plus weaknesses in development and deployment present opportunities for international collaboration to fill any gaps.
- Strengths in disruptive low-cost innovation producing existing technologies – amongst low-carbon technologies, solar PV, solar thermal and wind power, for example – more cheaply and in a greater variety of specifications, provide opportunities for collaboration with Western businesses.
- Finally, for low-carbon innovation in particular, China provides opportunities for innovation collaboration for a number of context specific reasons: the exceptional rate of growth; the relative lack of lock-in to existing high-carbon socio-technical systems; and the growing recognition in Chinese government policy of the importance of tackling climate change.

Table 5: China's Recent S&T Indicators

	1997	2001	2005
General Expenditure on R&D (GERD) (US\$ billion)	6.1	12.5	30.1
GERD/GDP (%)	0.64	0.95	1.34
Government S&T appropriation (US\$ billion)	4.9	8.4	16.4
Government S&T appropriation/ Total government expenditure (%)	4.4	3.7	3.9
Scientists and Engineers (1000 Full Time Employees)	588.7	742.7	1119
R&D Personnel (1000 FTEs)	443	957	1365
S&T Personnel (1000 FTEs)	1474	3141	3815
Graduates in Science, Engineering, Agriculture and Medicine from HEI Undergraduate Courses (1000)	496	556	1528
S&T papers catalogued by SCI, ISTP and EI	35,311	64,526	153,374
Share of total global OSI publications (%)	2.5	3.7	6.0
Share of world citations (%)	0.92 (1995)		3.78 (2004)
Domestic patents granted	742	2468	14761
Exports of high-tech products (US\$ billion)	16.3	46.5	218.3
High-tech products/total exports (%)	8.9	17.5	28.6

“China is now the largest absolute emitter of GHGs (though still comparatively small per capita), and its current low-carbon innovation capacity, while improving, is unlikely to enable the country to reach a global target of a 2°C limit on global warming.”

Towards isolation

At the same time as some factors favour international collaboration on low-carbon innovation, other factors such as the socio-political nature of the global challenges also tend against collaboration.

- The Chinese government's priority is to maintain the country's rapid pace of economic development, favouring growth over low-carbon policies where the two clash. This compromises the whole-hearted pursuit of low-carbon innovation and policies to support it, especially at the local level, where policies must be implemented.
- In the geopolitical negotiations for a post-Kyoto deal on climate change, the Chinese (understandably) refuse to take on low-carbon measures that penalise the national economy until the developed economies, who historically are the major GHG polluters, show leadership on the issue.
- In particular, China is pressing for developed economies to fund the transfer of existing, possibly proprietary, low-carbon technologies to stimulate a low-carbon shift in developing countries that would not otherwise be able to afford or access them. Developed countries retrench national boundaries arguing that they cannot compel private businesses to hand over technology and that China can afford to pay for those technologies.
- The pre-eminence of the national economic development project in China sets a political economic context in which government intervention may prevent certain collaboration from occurring, or limit access to research results. The political culture also means collaboration requires strong personal contacts of *guanxi*, so that the political decisions behind the success or failure of a project may often be opaque, discouraging potential collaborators.
- Some policies aimed at developing globally competitive domestic industries may also undermine moves to expedite the improvement of low-carbon innovation capacity through international collaboration.

In the automotive sector, for example, low-carbon innovation is very expensive and innovation capacity is concentrated within the non-Chinese dominant global original equipment manufacturers (OEMs). Yet reluctance in China to set high emissions targets for fear of the domestic producers failing led to policies that did little to stimulate domestic innovation, further entrenching their innovative weaknesses. Meanwhile the dominant OEMs in the global car industry have faced little pressure to transfer their leading low-carbon technologies to China.

- Similarly, reluctance to reduce subsidies on gasoline for cars, or coal for energy and electricity, due to concerns about the broader social and economic impacts of such steps, creates significant disincentives for low-carbon innovation. International collaboration in these fields is also thereby discouraged.
- Finally, although significant efforts have been invested in transforming intellectual property law and practice in China, with the legislation fully WTO compliant and equivalent to that of Western countries (whether or not this is in the economic interests of China as a whole), implementation and enforcement of intellectual property law, remains an issue that concerns many potential and existing international collaborators.



2 Changing Technological Boundaries

Towards a more interconnected world

Just as the geographical boundaries of innovation are shifting, so are the boundaries of technological innovation. The structure of the UK economy, and the ways that UK citizens live, work, learn, play and communicate is being transformed, as organisations and consumers discover new ways of producing and using very many different kinds of technology.

Changes in the upstream production of technology – combining and re-combining tacit knowledge and techniques from different scientific and engineering communities, for example – and the downstream use of technologies – producing and allocating value arising from new connections, such as outsourcing problem-solving online to user communities or consumer groups, for example – suggest a number of opportunities and challenges for UK organisations and citizens.

These shifts in technological boundaries, point to significant changes in the ways business and social activities will be conducted in the future. One of the most important issues for businesses and policymakers highlighted by AIM's research in this area is how technological innovation is facilitating new forms of collaboration, which in turn is contributing to greater technological innovation.

So, for example, as the consumption of technology-intensive products and services, becomes more pervasive, increasingly sophisticated consumers have more demanding expectations about functionality and service quality relative to price. Capability gaps mean organisations are finding ways of developing technology-rich products or services with suppliers and consumers, highlighting the importance of collaborating within and along the value chain, but without compromising intellectual property rights or damaging revenue streams.

And new technologies such as Web 2.0 and social network sites, are enabling new modes of production and collaboration, creating opportunities for businesses and consumers to interact in ways that were impossible in the past.

These new methods of interaction can be seen as either a threat to established business models or a new development opportunity. Our research shows that those organisations that embrace these opportunities tend to be innovative and successful.

However, managing the challenges associated with shifting technological boundaries, raises some critical questions: How can the technological developments be initiated, fostered, managed and carried-through to enable value to be captured by and for all collaborating partners?; How can we support collaboration in communities of practice that unifies teams or individuals within scientific or technology field, but which may cross organisational and national boundaries?; How can we most effectively manage the boundaries between the users and producers, and the developers of technology, enabling effective collaborative endeavour that provides better service but without losing ownership or control?

These questions were explored in a number of research projects carried out by members of the AIM Innovation cohort, that focused on areas where changing technological boundaries and new trends in collaboration are having a profound impact.

“Universities and companies based in the UK are leading the development of substrates, functional materials, organic semiconductors and new device architectures related to this new platform of technologies.”

Is plastic fantastic? The challenges of collaborating across technological boundaries

Plastic electronics is a good example of an area where the UK has the potential to be a global leader – it has been identified as one of six priority areas for technology investment by the UK Government's Council for Science and Technology. For the UK to succeed, however, the organisations involved in the development of plastic electronics will need to overcome a number of challenges, not the least the need to collaborate effectively across technological boundaries.

Universities and companies based in the UK are leading the development of substrates, functional materials, organic semiconductors and new device architectures related to this new platform of technologies.

With electronic components, often based on organic materials, deposited onto a flexible surface, plastic electronics promises new portable and wireless applications such as electronic paper and roll-up displays, or biocompatible dressings and flexible sensors in healthcare, leading some observers to predict a 'plastic fantastic' future. However, few devices have reached full production in significant numbers. Most research activity is focused on producing prototypes demonstrating the principle of plastic electronics, but with large-scale production still a long way off.

Crossing technological boundaries

Leading the development of plastic electronics presents a profound challenge for the UK in terms of collaboration across technological boundaries. Innovation in plastic electronics cuts across scientific fields, involving the convergence of many industries, scientific disciplines and sectors that do not conventionally choose to work together.

Developments in printed electronics are relevant to the chemicals, healthcare, printing, paper, plastics, and packaging industries as well as to the electronics industry. These players must align around complex scientific and technical challenges, which span the disciplines of chemistry; physics; and electronic, systems and process engineering.

For example, creating inks that can conduct electricity requires chemicals companies to partner with firms that have expertise in materials engineering, in order to ensure that the functionality of the materials is maintained when deposited in the thin layers necessary for electronic components. Such collaboration must balance the risk of developing tailored solutions for one potential customer, against the returns from developing a generic product.

Another challenge is developing printing equipment that can be used to deposit conductive inks in precise quantities minimising errors and waste. This requires collaboration between plastic electronics innovators and equipment manufacturers to develop printing machines that can work with the correct precision under the right conditions.

Other collaborative relationships that are required include collaboration along the value chain, from the university based material development research, through the development of components, to the final assembly of devices and their integration within applications. Collaboration is needed right along the value chain to identify new markets. Collaboration across university-industry boundaries is also important as much of the expertise in basic research is within universities – various models can be adopted to licence or spin-out technologies for commercialisation.

UK versus Germany

Our research looked at how successful the UK has been in overcoming the challenges outlined above compared with one of the UK's main global competitors – Germany. The research reveals that, while some of the findings are encouraging, the UK still needs to improve in a number of areas if it is to sustain its leading position in the development of plastic electronics.

We found that typical business models adopted by companies and universities in the UK involve the licensing of early stage intellectual property (IP), whereby new innovations and discoveries are demonstrated at the proof-of-concept stage. However, capturing value from early stage IP depends on being able to push beyond proof-of-concept to what we refer to as 'proof-of-product', convincing potential licensees of the viability of the invention once it has been scaled up to the level of complete systems and application prototypes. There is a danger that, because they lack the resources to develop their technology through to the proof-of-product stage, UK innovators in plastic electronics will limit their potential access to future revenue streams. Moreover, as rival technologies with proof-of-product validation become available to product integrators, UK inventors risk losing out to innovators in other countries whose core IP has already been licensed.

There are also particular risks for UK universities, where many of the basic innovations are developed. Our comparisons with Germany suggested that lower government investment in capital expenditure will limit UK universities' access to additional revenue streams from the manufacture and supply

of finished plastic electronic components. There is a danger that innovators in the UK, especially universities, will not be able to fully develop the process and device know-how necessary to support and add value to their IP where they pursue licensing models.

UK hotel industry: A surprisingly rich environment for innovation

The hotel sector is another example of how the complex nature of shifting technological boundaries presents new challenges for industries and innovators, not least in the areas of change management and competitiveness, is.

The hotel industry is increasingly dependent on new technologies, with technological innovations numerous throughout the industry, such as: integrated booking and yield management software; human resource management systems; in-room entertainment technologies; energy control systems; and e-marketing tools.

AIM innovation researchers have looked at key international and national hotel companies to explore how these companies have had to embrace new models of innovation, most notably co-production networks, collaborating with a wide range of stakeholders in a variety of ways.

Collaborative relationships include:

Direct co-production between a hotel company and an IT provider – In-room technology for guests has become an important service, for example, with hotels initiating direct links with major IT companies to develop competitive products.

The provision of IT software for a variety of hotel management functions – Often overlooked, these collaborations play a vital role in the creation and survival of numerous high technology SMEs.

Value creation networks associated with e-business, (especially e-marketing) – The importance of e-business innovations to the competitiveness of hotels has led to new value chains and networks involving major players, such as Google, plus a variety of firms that provide e-marketing software for the hotel industry.

Collaboration and co-creation between hotels and their customers – Social network sites such as TripAdvisor have increased the power of consumer opinions. Hotels become increasingly responsive to knowledge gained through ratings and discussion sites as a result of consumer interaction online.

Third party integration with social networks sites, however, is widely rejected by hotels due to problems of quality control. Several large scale multi-national hotel corporations have incorporated edited social networks sites into their proprietary websites, in an attempt to manage collaboration and drive consumers to book through lower cost distribution networks.

The research reveals that the UK hotel industry is a surprisingly rich environment for innovation, and a good example of how the shifting boundaries of technology innovation are promoting new forms of co-production, and co-creation.

As with many industries, however, there are two distinct groups; those firms that are at the cutting-edge of innovation, and those that are following or some way behind. It is those hotels that are moving with and setting innovation trends that are more likely to succeed in the long term. Yet, some hotels still view the bare essentials of having qualified IT personnel available to make the best use of new technology as an additional cost, rather than a benefit.

The types of collaboration outlined here are key drivers of change across the hotel industry, and integral to hotels remaining competitive. Hoteliers need to ensure they have the necessary expertise and attitude to take advantage of new technological approaches in the industry – as do organisations in many other industries where collaboration and co production will become increasingly integral to long-term success.

Knowledge Transfer Networks as a means to assist collaboration across boundaries

Another challenge of collaborating across boundaries in order to bring radical innovations to market is finding the right partners. Technologies may change, but one thing stays the same – the human element of the relationship is key; even partnerships that become major corporate alliances begin with human interaction.

Academic research shows that when identifying collaborators, it is necessary to invest time in evaluating the expertise of potential partners, carefully assessing their likely value, and understanding whether the chemistry is right for interaction. Because there are search and opportunity costs associated with this evaluation process, the tendency is to remain with existing partners, to limit searches within narrow horizons, or even avoid collaboration altogether.

Recognising this dilemma, the UK government has taken steps to improve the UK's innovation performance by increasing the breadth and depth of the knowledge transfer of technology into UK-based businesses, through investment in Knowledge Transfer Networks (KTNs). KTNs are responsible for organising communications and events that allow people to meet and exchange ideas and information, and appraise the value of collaborating with each other.

But how effective are these activities and what value is there in them for organisations? AIM innovation research looked at some of these issues with respect to one particular KTN.

For any firms or other parties involved with KTNs, or other knowledge sharing networks, there were a number of important findings. Participating in these networks can generate benefits through two different mechanisms. First, organised networks provide the opportunity to interact with other members at events, and although going to events is time-consuming this can be a way to find others who have relevant expertise. Second, participation in KTNs – and especially contributing as a speaker or in a governance role – can help individuals and their organisations become known, boosting their reputation amongst the wider community, not just those they meet at events.

“There is no substitute for going to events, and hearing people speak...”

Our research findings showed that interaction is necessary for potential collaborators to become aware of each others' expertise. There is no substitute for going to events, and hearing people speak, to really understand what someone knows. So those people who speak, or who are contemplating speaking, at a KTN event – or a similar networking and knowledge sharing event – should understand that presenting at events such as these only increases awareness of a person's expertise for those people who hear them speak.

The same is not true for reputation, however. The enhancement of reputation that comes from speaking at events spreads through the network without needing direct interaction with others. So speaking at events makes KTN members more likely to be valued as collaboration partners, including by those who have not heard them speak.

Of course there are other reasons why people are valuable partners, including their prior involvement in government-funded collaborative R&D alliances, and especially their organisation's central position in a network of such alliances. However, our research showed that these factors were less important than actions by, and interactions between, individuals in the KTN for establishing attractiveness as a collaboration partner. In the search for collaborators, and especially partners who can span technological boundaries, participating in knowledge sharing networks can be a valuable starting point.

User innovation in the video games industry

Crossing the traditional boundary lines for technological innovation is not always easy for organisations. This is particularly true in a world where intellectual property is usually jealously guarded and enforced through the courts if necessary. Evidence suggests, however, that there is considerable benefit to be obtained for showing a degree of constraint when conventional boundaries are breached.

Computer video games is one area where there has been a rich tradition of collaboration between consumers and producers, and of innovative collaboration between consumers themselves.

And, although platform owners used to try and discourage the modification and innovation of video games products by users, viewing it as illegal hacking and infringement of their proprietary technology, today most platform owners, publishers and developers, see user innovation as a positive phenomenon and in some cases release tools and technologies to encourage this interaction.

Collaboration and technological innovation – the healthcare industry

Collaboration driven by, and in connection with, technological innovation, is also important in the healthcare industry.

For example, provider-client communication is important, as it is in many service sector industries, in order to tailor service delivery. This type of collaborative communication involves both experts and clients. Experts, such as physicians and nurses, gather information from patient clients in order to communicate diagnosis and treatment options.

Much of this communication and information exchange is done face-to-face, which, although an important part of service delivery, is expensive in terms of client travel time, expert time, and scheduling problems and conflicts. Also, verbal communication can lead to misunderstanding and information overload, when compared with print and computerised media.

The physician-patient visit is a brief encounter in the daily life of someone with a chronic health condition. In many circumstances, more frequent but less intense contact with patients, through a variety of media, whether phone, letter, or the internet, is essential to monitor and assess progress, and to triage which patients require additional help.

AIM research has looked at how shifting technological boundaries impact on the interactions in the expert-patient relationship, how provider-patient practices change and adapt to improve the efficiency and effectiveness of patient-provider interaction, and has evaluated whether different means of communication are associated with different patient outcomes.

In particular, we investigated the use of web-based systems implemented in clinics in Canada and the UK, that assist with diabetes care, allowing patients to record their blood glucose levels, medication, diet, and exercise, to improve the monitoring and communication between patient and diabetes specialist nurse. The web-based system also includes e-messaging, interactive chat, discussion forums, educational materials, search capabilities, and a medication-insulin record.

Interestingly, the research findings indicate that patients using an interactive web-based system do significantly better than a face-to-face only group, and substantially better than those using only the web-based educational materials and e-messaging. Every increase in use of the web-based system results in a direct improvement in blood sugar control.

Qualitative results show increased involvement of patients in their diabetes care; an increased ability of providers to examine information and triage patient issues over the phone and through e-mail; and decreased costs in travel and visit time for both patients and providers. The research suggests that clinician interaction with patients is required, and second that this interaction is substantially enhanced using a web-based system.

It is also likely that this type of web based system has the potential to transform and improve communication and collaboration in other areas, such as engineering and accountancy, who deal with clients remotely.

“ ...the research findings indicate that patients using an interactive web-based system do significantly better than a face-to-face only group, and substantially better than those using only the web-based educational materials and e-messaging. ”

The role of demonstration projects and trials in changing the boundaries of energy innovation

Another example of multi stakeholder collaboration covered by AIM research is the EU Virtual Power Plant project managed by German heating company, Vaillant. Here the research investigates the role of demonstration projects and trials in the acceleration, development, and adoption of new energy technologies – how the technological boundaries that define the way energy is supplied are changing.

The project, which ran during 2001-2005, involved placing fuel cell ‘combined heat and power’ (CHP) systems in 24 multi-family residences in Germany, Netherlands, Spain and Portugal, and connecting these to the central electricity grid. Any energy that was surplus to requirements was exported back to the grid by the families for others to use – effectively acting as a small power station.

Generating electricity in the home will become increasingly common using fuel cells, solar panels, and other energy-generating sources. In this distributed generation system, the consumer also becomes a producer, breaking down the technological boundaries between the large-scale generator operating megawatt power stations and those it supplies. In the UK from 2011, the decision to proceed with a national rollout of smart meters potentially allows all consumers to become active producers.

This shift in boundaries has enormous implications for the utility companies, for National Grid, and for the energy service companies that bring electricity on its final stage into the home, businesses and public buildings.

The EU project was an early trial of the system, managed by Vaillant, with partners across the whole energy chain. Energy service companies recruited households to participate; the heating contractor managed the installation of the energy management system to control the interface with the electricity supply (the grid); fuel cell manufacturers and gas suppliers provided the products for test; and the electricity utilities managed the grid connection.

The trial involved setting up the fuel cell CHP units and operating them according to a defined load profile for heat and power, based on weather data, etc., which could then be adjusted. The energy management system collected data automatically on consumer usage.

The technical and market data gained from this experiment, including performance data in the public domain, produced valuable learning right along the value chain – from the fuel cell manufacturers and gas companies developing CHP products, to the service companies, grid and energy utilities. Such knowledge also helps governments with respect to the pricing of electricity and gas, and contributes to the debate on the future shape of the industry.

New technologies such as, fuel cell CHP and solar panels may ultimately lead to major structural changes in the energy industry away from the current centralised generation business model. However, these technologies also help the management of the present system by taking pressure off capacity during periods of peak usage and ameliorating the impending capacity gap in UK electricity generation, thereby assisting security of supply and generators’ financial returns.

Collaborative endeavours of this type between producers and producer/consumers are not without challenges, though. A central issue, for example, is who appropriates learning and knowledge, and who controls the system – specifically, ‘who hosts the energy management system that feeds data on household consumption patterns back to the grid and to households so they can control their use of electricity?’

The utilities are keen to retain control of such data and its use, because they have most to lose from distributed generation. Fuel cell CHP systems suppliers may have to cede control of their energy management systems to the utilities they are partnering with in order to gain their cooperation. For small new firms seeking to break into a market with a novel technology, it makes sense to partner with existing incumbents who control the system and from a systems point of view it can be more economic and facilitate change.

“New technologies such as, fuel cell CHP and solar panels may ultimately lead to major structural changes in the energy industry away from the current centralised generation business model.”

3 The Changing Nature of Organisational Innovation

It is not just the geography and technology of innovation that are changing. AIM research has also explored the issue of shifting organisational boundaries for innovation. Open innovation has become increasingly common; with innovation involving multiple organisations acting together, whilst within organisations innovation is less likely to be confined to the R&D or innovation department, and more likely to be a shared responsibility involving several departments.

There are several forces driving these changes. The globalisation of markets, of production, and of sources of knowledge, leads firms to think and act globally, rather than focusing only on regional markets. The opening up of Russia and China, allows access to important talent pools and capabilities, and companies have tried to take advantage of these.

Take the new 787 airplane produced by Boeing. Boeing is a US company, but the 787 incorporates components from around the world: the passenger doors and landing gear are made in France; the cargo doors and crew escape doors in Sweden. Japanese production partners are responsible for more than a third of the work, much involving the innovative use of carbon fibre. Indian and Italian companies are also involved.

This global sourcing is only possible through the use of advanced information technologies which enable participants from around the world to co-design the aircraft. Global production also often needs to be sensitive to local market variations, which is another reason for local partnerships oriented to adapting innovations to local conditions.

In addition, some very large organisations have realised that old innovation methods, through classic invention or discovery, doesn't have the muscle to deliver the growth these large companies require.

If Procter and Gamble (P&G has an organic growth target of 4-6% per annum, with turnover at \$70bn this would leave it requiring \$4bn (and growing) annually in revenues from the sale of new products. This kind of growth target is fine as a \$25bn turnover company, but as a \$70bn business the internal R&D engine is likely to struggle to supply this volume of innovation.

As a result P&G is increasingly seeking to leverage externally developed ideas, tapping into an external talent pool of scientists, and sourcing half the firm's new product ideas from outside its own R&D labs.

Other companies have taken advantage of the internet to reach out beyond their organisational boundaries and broker solutions between firms that need solutions and individuals and organisations that can provide answers. YourEncore, is an internet based network of retired and veteran scientists and engineers providing clients with proven experience to help accelerate their pace of innovation.

Another reason for the increasing dismantling of organisational innovation boundaries, concerns the declining productivity of traditional, internal R&D. Arguably, R&D has become more difficult over time – and much of the 'low hanging fruit' has been picked, leaving more difficult problems to be tackled. Not only are these problems more difficult, but in-house R&D itself is becoming increasingly expensive. Specialist equipment is expensive, and because R&D is labour intensive its costs tend to grow faster than inflation. Rising costs, coupled with ever more difficult problems has led to declining productivity in many traditional R&D labs.



One area of great opportunity is at the intersection of previously separate knowledge domains: technology convergence or fusion. Firms often find it difficult to cope with multiple streams of technology, instead preferring to bridge between technologies by relying on partners who specialise in the complementary technology, rather than build that competence in-house. Together, they advance the new converged technology through alliances or joint ventures rather than conventional arms-length transactions.

Finally, it is important to emphasise that the shifting organisational boundaries of innovation are not confined to product innovation but also affect other aspects of innovation such as service innovation and process innovation.

Services account for about 80% of the UK's gross domestic product and employment. There is increasing evidence and recognition that because many services are inherently relational, where a service is provided by one economic entity to another at a particular time and place, that innovation in services is well suited to, and many instances requires, the participation of multiple stakeholders.

A good example of what multiple stakeholders are able to achieve is demonstrated by the long standing debate about increasing runway capacity at Heathrow airport. A similar debate to the recent discussion over whether or not to build a new runway at Heathrow took place some twenty years ago. On that occasion, no new runway was built. Instead, runway capacity at Heathrow was extended year on year over the last two decades through increasingly close co-operation between the airport owner, air traffic control, the airlines and their pilots, and by finding small ways to incrementally increase the efficiency of the system.

There are many similar stories of innovation in services, including the introduction of service innovations and product-service-solutions by manufacturers: the key point is that these innovations often depend crucially on close cooperation not only between departments within the providing organisation, but also between these departments and clients.

The changing nature of organisational boundaries for innovation

It is one thing acknowledging that the organisational boundaries for innovation are changing, but it is important to know in what ways they are changing. Our research has explored the changing nature of organisational boundaries for innovation in a number of areas.

The growing trend for firms to move into the provision of higher value-added combinations of products and services is a key driver behind recent organisational changes. Services wrap around and add value to the physical product in order to solve an individual customer's specific problem or operational needs. If firms are unable to change their offerings or change the way they create and deliver those services in combination with products, their survival and growth may be threatened.

These product-service combinations range from one-off and bespoke solutions to fully standardised offerings. In low-volume markets, Rolls-Royce competes by providing individual airlines with highly customised 'power-by-the-hour' solutions. This involves selling or leasing jet engines, operating a global IT network to monitor each engine's in-flight performance, and providing services to maintain, repair, and upgrade them.

In high-volume markets, products are combined with standardised after-sales services, such as consumer credit, maintenance contracts and short-term warranties purchased along with a new car, fridge or household boiler.

Depending on their needs, each consumer selects one or more services from a standardised menu of options. For example, SKF, the Swedish manufacturer of industrial bearings (devices to reduce friction in mechanical movement), competes in highly competitive commodity markets by offering technical and service solutions based on five platforms – bearing products, lubricants, seals, electronics and service-related technologies – which can be tailored to the needs of each customer.

As firms reposition and reorganise to provide these solutions, our research suggests that a new type of organisation called a 'systems integrator' is becoming increasingly prominent. In contrast to traditional forms of vertical integration based on internal economies of scale and scope, the systems integrator model of industrial organisation emphasises the advantages of specialisation and the division of labour.

These firms are specialised integrators of components and services supplied by a large network of external manufacturers, consultancies, SMEs and universities.

So although Boeing continues to design and manufacture core airframe components, it is primarily a systems integrator for airframe assembly, contracting out up to 80% of component production to specialist manufacturers around the world.

Making innovation dependable: opportunities and challenges for 21st century manufacturing

When organisational boundaries shift, they inevitably present new challenges for management. The world of manufacturing, for example, is changing quickly, as rapid innovation, high technological complexity, and increasingly globalised and dispersed supply chains, facilitate a switch from tightly and vertically integrated corporations to horizontal, loosely-coupled modular organisations. AIM research shows that such a fundamental change has significant consequences for the dependability of organisational processes and their outcomes.

When the design, production and maintenance of products, processes and services, are distributed across extended organisational networks, how can their properties be verified to ensure that they are at the same time, innovative and dependable?

The research reveals that the changing and extending boundaries of the firm have a critical influence over the organisation's ability to create products that are both innovative and dependable. More specifically, ongoing changes in *organisational structure* (i.e. the shift towards increasing specialisation, de-verticalisation and outsourcing) and *organisational culture* (i.e. the increasing fragmentation of knowledge and work across diverse and dispersed organisational communities holding different worldviews and knowledge bases), fundamentally influence a firm's ability to test and validate products, processes and services.

The combination of loose organisational boundaries, rapid innovation and high technological complexity and specialisation, for example, means that firms are finding it increasingly difficult to verify complex arrays of data dispersed across heterogeneous organisational networks, such as producer, customer, or supplier networks, and product life-cycles, such as the design, production and maintenance life-cycles.

The verification challenge in this context entails more than simply integrating information and data flows: it involves coordinating and controlling knowledge and processes across a very diverse range of organisational functional, cultural and geographical boundaries. This also raises questions of governance, including how to identify responsibility and accountability in distributed, high-innovation contexts, where knowledgeable suppliers can become key stakeholders in the quality assurance and reliability verification processes.

The research reminds us that, in embracing the now dominant, and undoubtedly relevant, 'open innovation' model, global enterprises are exposed to many challenges and risks, not least potential instances of undependability, as well as the possibility of new opportunities. In particular, managing open, distributed, modular innovation means managing conflicting criteria and rationales, including conflicts between innovation and dependability, flexibility and efficiency, and flexibility and reliability. Our research shows that firms that deal best with the trade-offs are those that pay great attention at the process level, for example in the context of design, testing and manufacturing processes, which is where some of the strongest clashes between contradictory requirements typically arise.

A methodology developed to support a process-oriented analysis and facilitate the resolution of trade-offs, involves following the course of a routine in practice, to see where it breaks down. Breakdown points can be where the exchange of information between firms fails, for example, or where the absence of knowledge and competences overlap between firms generates uncertainties about process integrity or a product's behaviour.

Following the routines methodology, and through a close analysis of manufacturing operations at leading electronics, automotive and software firms, the research has thus identified the practices that leading manufacturing firms develop to support error avoidance and increase organisational resilience, while at the same time remaining innovative, and producing reliable products of a high-quality.

In industries characterised by outsourcing and open innovation, a systems integrator is uniquely positioned to link or couple upstream developments in technologies and products with downstream service requirements and expectations of customers and rapidly changing markets. The service dimension of the solutions on offer depends on an ability to identify, create and deliver innovation to meet a customer's expectations and needs. Systems integrators have moved beyond the traditional technology and product domain in the value stream to providing complex and high value services including offering strategic consultancy advice and financial support to help a customer develop its business in existing and new markets.

Receptiveness from customer messages may be even more important than technology in triggering and shaping how innovation occurs in solutions. An in-depth knowledge of a user's needs, an ability to identify and solve individual client problems, and a capacity to co-create solutions with customers are some of the capabilities that are essential for the successful development of customer or 'market-facing innovations'.

As well as continuous streams of revenue and higher margins than physical products, the provision of high-value services build long-term relationships with customers and end-users of an installed base of products. This creates opportunities for customer lock-in by creating long-term loyalty and a source of innovation over an extended period of time.

For systems integrators, a key challenge is to understand how to strike a balance between customisation and standardisation of components and the final product or system. When should a product or service module be standardised and reused, instead of employing a custom-engineered piece of knowledge, to serve a customer need?

Standardised components cost less to develop, as they have already been created (and are therefore codified). They are also easily scaled to higher volumes of activity. Customised knowledge is more closely connected to the context of the customer's problem (and will therefore involve substantial tacit knowledge). But this closeness has the drawback of limiting scalability, as important contextual aspects will vary from one instance to another.

The implications of change

The increasing specialisation and division of innovative labour means that the boundaries between the various teams, functions, departments and organisations that make up a network – including producers, suppliers and customers – are becoming increasingly diverse, with more and different kinds of players involved, and distributed, with players operating at a further distance from each other.

This has important implications for organisations, such as systems integrators, influencing their ability to integrate, control and coordinate these networks, including the knowledge and processes contained within them.

A first key implication is the need to integrate productive knowledge and activities that once resided in-house, but have now become distributed across highly fragmented and diverse boundaries, including those between the producer and customer, and the producer and supplier. This challenge involves more than integrating diverse data and information sources, a tough challenge in its own right; it is also about integrating different worldviews and interpretations, corresponding to 'local' pockets of understanding and idiosyncratic meanings that reside in the groups, functions, departments and organisations that make up a network.

The challenge also involves establishing which skills and capabilities must be retained in-house versus those that need to be acquired from, and relinquished to, firms resting outside the integrator organisation. This task is complicated by the fact that integrators need to develop competences and skills that span beyond those strictly required to design, test and produce a fully-assembled system.

A second key implication is the need to coordinate and control knowledge and activities across different organisational structures, including different labour structures, and cultures, including different approaches to and requirements for regulation and standardisation across different firms, sectors and countries. However this highlights a dilemma: whilst in principle diversity is desirable, so as to provide potential sources of innovation, it can also provide obstacles to coordination.

More recent research points out how such a dilemma can be resolved through firms learning to develop shared meanings and cultures which might facilitate the convergence of meanings and thus the integration of both data and process. The challenge here is how to preserve a unified culture or consistent structure in the context of continually shifting boundaries, such as switching suppliers or evolving customer bases.

Connecting ideas, resources and value creation

Organisations and individuals make and commercialise new discoveries in many different contexts, and the changing nature of organisational boundaries and technological boundaries influences how firms reconfigure their business models to create and capture value. But, if you have to reconfigure your business model a number of challenges then arise, for example, how do you collaborate and increase the benefits of collaboration while at the same time reducing the costs of coordination between partners? How do you ensure you collaborate in a way that will increase rather than decrease total value?

In a series of related studies AIM research looked at some underlying processes associated with the shifting boundaries of organisational innovation, when technology-intensive firms acquired and leveraged knowledge resources to create superior performance and increase market value.

In the biotech industry we analysed data from 128 biotechnology firms over a twenty year period. Our research shows that the successful growth of a firm is partly dependent on how it structures its knowledge. If we think of knowledge as a metaphorical liquid a start up or early stage firm may have buckets of knowledge in a single technical domain or spread across multiple technical domains.

If the firm's knowledge is structured so that it has a single deep bucket of knowledge in a particular technical niche and then the firm enters a technically insular domain – a technical domain that relies heavily on prior inventions within the same domain for subsequent inventions – then that often turns into a negative experience for that firm in terms of innovation. It can be like heading down an innovation cul-de-sac.

For a firm that has greater breadth of technological capability with knowledge structured across multiple domains the growth prospects are more encouraging as the firm is more able to recombine its knowledge in different domains in an innovative way. Thus this suggests that while depth of technological capability is required for high impact innovation, it is not enough on its own, and organisations should also give some thought to how they structure their knowledge and expertise to ensure that the new technical area that they explore is not a dead-end for them.

Another issue touches on the search for innovation partners and the value obtained through such organisational relationships. In the UK, there has been some concern expressed that the major UK pharmaceutical companies are not partnering enough with British biotech companies despite the UK biotech sectors undoubted expertise, but instead signing agreements with firms from elsewhere in the world.

The research suggests that the benefits to tying up with large pharmaceutical firms only exist early on in a biotech firm's life cycle – in terms of co innovating and developing together, the earlier they tie up, the better off they are. So taking the valuation of biotech firms as a proxy for how a firm's value increases, the benefits of collaboration are manifest, but timing dependent; positive in the first two years, while for firms tying up after the fifth and sixth years the values become negative.

A third research project examines how, while joint production between scientists influences innovation, the costs of coordination actually decrease the benefits that are likely to accrue. So, in the case of stem cell research, for example, as with many other areas of research, universities are encouraged to collaborate with each other on the basis that recombining knowledge in this way increases the chances of producing innovative results. However, the research suggests that beyond a certain number of partners, the costs of coordination outweigh the benefits of collaboration. In fact there are decreasing returns in terms of scientific impact when there are more than three partners.

A third key consequence of shifting organisational boundaries, and one which is often neglected, is that it holds important implications for governance. The progressive loosening up of organisational boundaries means that not only information and knowledge become distributed, but also responsibility – and accountability – for the design, production and, increasingly, the life-cycle maintenance, of products, processes and services.

In a context where knowledge and processes are highly distributed, for example, who is to be held responsible when a product, process or service fails? Failure in this context can range greatly, from a product, process or service that does not perform to specification, to accidents that involve human fatalities.

The key implication for integrators here is the need to weight the benefits derived from a clear division of labour and responsibility, against the potential risks involved in losing control of aspects of their products, processes or services' operation and maintenance (ibid, see Dependable Innovation exhibit).

Challenges of organisational collaboration and coordination

The porosity of organisational boundaries creates tangible challenges and opens up new opportunities. The first real challenge comes from how organisations access, integrate, and use knowledge to create new products or manage service delivery using many different partners. If relevant knowledge is dispersed across firms, that collaboration is likely to lead to faster innovation and have a greater impact. However, the need to bring these organisations together to create something new raises issues of coordination.

The challenge then is for companies to ensure that the benefits of collaboration outweigh the challenges of coordination. These challenges are not trivial, including the fragmentation of intellectual property across multiple partners, and the managerial difficulty in sustaining multiple organisational relationships, among others.

Second, working with multiple partners creates challenges in how the value that is created is then appropriated for the firm's shareholders – requiring new business models. For instance, open innovation has become a buzzword for ways in which firms can open up their R&D or product development to the public. This benefits the firm by getting a broader array of ideas as well. However, the traditional business model of using patents or copyright to protect the technology is lost. Instead, firms need new business models to create and appropriate value from such open innovation models.

In the software sector, we find that business models focused on short-term value creation with mechanisms to exercise direct control such as dual licensing, or cost and risk reduction, are viewed by investors and the capital market as more legitimate and hence create greater value than long-term, indirect models, such as sale of complementary products or services or business transformation.

Third, a reliance on partnerships implies a greater need for clarity in the performance aspects of the relationship, as well as the allocation of risks and rewards. Partnerships to deliver large, complex projects such as Terminal 5 at Heathrow, or development of eco-cities in different parts of the world, require a clear understanding of what each organisation will be responsible for and how they interface with others to bear risk, share economic rewards, while keeping adequate flexibility in the system to innovate.

This is a significant challenge where we continue to learn how to do things together – for instance, the failure of large NHS projects is attributed to inflexible contracts that did not allow for changes in customer needs or innovation in healthcare delivery.

In addition, the contracts were so structured that there was little incentive for partnering firms to accommodate changes in user needs.

Finally, shifting organisational boundaries also imply a greater need to empower and continuously re-skill front line staff to handle the flexible delivery of products and services. The benefit of such re-skilling is the clear value-added that comes from keeping high skilled jobs in the economy. The challenge of such shifts is the need to introduce both flexibility in the workforce, and a change in employee mentality, away from the expectation of stability regarding what a specific job would entail; instead, as a unit of analysis for future work, the focus shifts from the individual to the skill.

Taken together, shifting organisational boundaries challenge conventional wisdom of how organisations operate. Instead of firms being independent, with all work transacted within its boundaries, the emphasis is on the 'task' or 'project' where firms join and disband after the completion of each successful project. This perspective introduces tremendous benefit – the ability to leverage dispersed skills to innovate and create value. It also creates tremendous challenges of learning to collaborate and coordinate, create and upgrade workforce skills as well as identify and implement new ways to create and capture value.

Conclusion: At the Edge of Innovation

The shifting boundaries of innovation matter. They matter to organisations, both public and private sector, to multinationals and SMEs, to the NHS and NGOs. They matter to industries and industry associations, regional development agencies, intergovernmental agencies, and national governments.

Why do changing innovation boundaries matter so much? Because, at its most extreme, failure to detect, acknowledge, and respond to these changing boundaries can make the difference between organisational success and failure, between national prosperity and economic hardship. To a lesser extent, a lack of awareness of changing innovation boundaries can mean missed economic opportunities, poor competitiveness, and being consigned to the second division in the league of innovative nations, rather than competing for the championship.

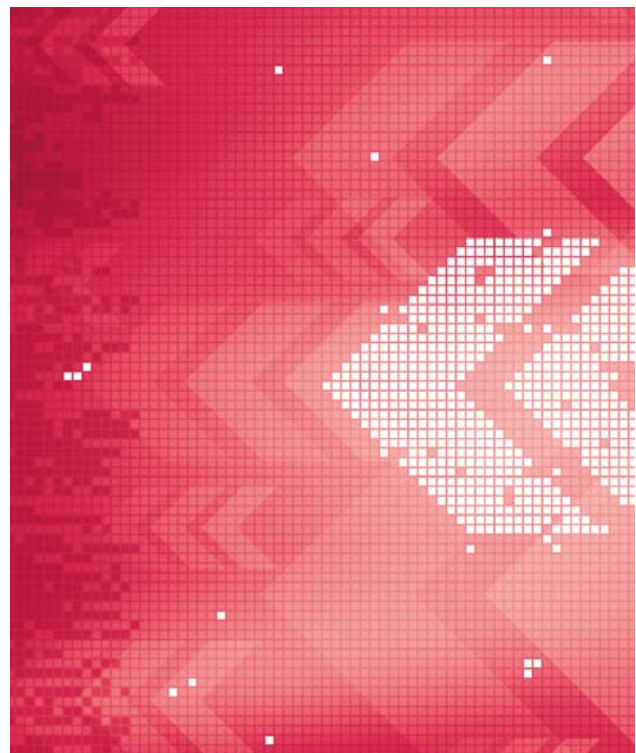
The AIM Innovation cohort has addressed multiple questions surrounding changing innovation boundaries – a complex issue that has vital importance for the UK economy. In doing so we have identified three main types of innovation boundaries undergoing significant changes: geographical, technological, and organisational. We have also identified some major challenges for practitioners and policymakers connected to these boundaries.

This report is not the place to describe all the work that AIM is doing in this field. However, it should provide an insight into some of our research, highlighting ways in which changing innovation boundaries impact on organisations and industries, and the important implications this has for practitioners and policymakers. And prompting some key questions on the issues covered.

With geographical boundaries, for example, AIM research highlights an urgent need for innovation policy that integrates both international and social issues as irreducible elements of a national innovation strategy, combined with the resources needed to appraise these issues. National innovation policy will become increasingly inseparable from international matters as global challenges strengthen both global concerns and local governance. And, given the importance of local issues, social aspects of innovation will also be increasingly central to matters of innovation policy.

For managers, this research suggests that shifting geographical boundaries of innovation are likely to change the rules of the game in their business due to a number of trends including, for example: the rise of new centres of innovation, such as India and China; and the contradictory effects of global challenges that both increase the importance of, and opportunities for, global connectivity, while heightening the importance of national contexts and regulatory structures.

With technological boundaries, one of the biggest issues concerns the integration of technology. To be the world leader in new technologies, increasingly we will need to find ways to facilitate collaboration across scientific fields, involving the convergence of many industries, scientific disciplines and sectors that do not conventionally choose to work together. The integration of technology and disciplines allows the development of new technological solutions, which in turn allows a more efficient use of time, money, and other resources.



Yet we are entering an era of the economy during which there will be considerable pressure on public and private sector spending that may stifle progress in this area.

A number of factors are behind shifting organisational innovation boundaries such as the need to leverage external talent to create sufficient value from innovation to meet growth targets, and the increased costs and decreased productivity of traditional internal R&D.

“The AIM Innovation cohort has addressed multiple questions surrounding changing innovation boundaries...”

Yet our research suggests organisations should refrain from rushing unquestioningly towards more open models of innovation, involving greater collaboration, cooperation and alliances. Open innovation presents several challenges for organisations, not least the difficulties of managing complex conflicts that may arise – between innovation and dependability, and flexibility and efficiency, for example.

Also, new types of organisations, such as systems integrators, will emerge that are likely to disrupt existing market networks. Those people involved in developing organisational strategy must consider the impact such organisations might have on their market and their business.

So even though it only represents a selection of the AIM innovation cohort’s work, the research outlined in this report is highly significant, as it draws attention to a wider issue. Increasingly, in this fast changing world there are two paths to choose from: one route leads to ‘Whip City’, an innovation evolutionary cul-de-sac; the other to ‘Vehicle City’, spearheading change at the very edge of innovation. The path that policymakers and practitioners decide to take will determine the prosperity of the UK for decades to come.



Further reading

- Abramovsky, L., Griffith, R., Macartney, G. and Miller, H. (2008) 'The location of innovative activity in Europe', IFS Working Paper, W08/10. www.ifs.org.uk/publications/4346
- Abramovsky, L., Griffith, R. and Miller, H. (2009) 'When multinational firms offshore research activity does research activity at home decline?', IFS Working Paper, W09.
- Chesbrough, H. and Davies, A. (forthcoming 2009) 'Advancing Service Innovation' in Maglio, P., Kieliszewski, C.A. and Spohrer, J., (ed.) *Handbook of Service Science*, New York: Springer.
- Coe, N.M. and Wrigley, N. (2007) 'Host economy impacts of transnational retail: the research agenda', *Journal of Economic Geography*, 7, 341-71.
- D'Adderio, L. (2009) 'Making Innovation Dependable: Key Opportunities and Challenges for 21st Century Manufacturing', ESRC Britain in 2009.
- D'Adderio, L. (2009) 'Performing Modularity: The Role of Organisational Context in Making Modularity Work', 25th EGOS Colloquium 'Passion for Creativity and Innovation', July 2-4 2009, Barcelona.
- D'Adderio, L. (2008) 'The Dependable Transfer of Routines and Capabilities: A Performative View', Paper #15238, Academy of Management (AOM) Meeting, August 8-13 2008, Anaheim (CA).
- Davies, A., Brady, T. and Hobday, M. (2006) 'Charting a path toward integrated solutions', *MIT Sloan Management Review*, Spring 2006, Vol. 47, No. 3: 39-48.
- Davies, A., Gann, D. and Douglas, T. (2009) 'Innovation in Megaprojects: Systems Integration at London Heathrow Terminal 5', *California Management Review*, Special Issue: 'Infrastructure Privatization', Vol. 51, No. 2: 101-125.
- Dennis, K. and Urry, J. (2009) 'After the Car', Cambridge: Polity.
- Flowers, S., Grantham, A., Mateos-Garcia, J., Sapsed, J., Tang, P. and Voss, G. (2008) 'The New Inventors', NESTA, London. www.nesta.org.uk/the-new-inventors-how-users-are-changing-the-rules-of-innovation/
- Hendry, C., Brown, J. and Harborne, P. (2007) 'Innovation barriers to growth in high-technology SMEs: The role of absorptive capacity', Working Paper, Cass Business School.
- Hendry, C., Harborne, P. and Brown, J. (2008) 'The lead user as a distributed role in complex systems innovation', Working Paper, Cass Business School.
- Hobday, M., Davies, A. and Prencipe, A. (2005) 'Systems integration: A core capability of the modern corporation', *Industrial and Corporate Change*, Vol. 14, No. 6: 1109-114.
- Lowe, M.S. and Wrigley, N. (forthcoming) 'Innovation in Market Entry: Tesco in the USA', *International Review of Retail, Distribution and Consumer Research*.
- Pollock, N., Williams, R.A., D'Adderio, L. and Grimm, C. (forthcoming 2009) 'Post Local Forms of Repair: The Case of Virtualised Technical Support', *Information and Organization*.
- Sapsed, J., Mateos-Garcia, J., Adams, R. and Neely, A. (2008) 'ESRC Business Engagement Project: A scoping study of contemporary and future challenges in the UK creative industries', ESRC, Swindon. www.aimresearch.org/index.php?page=BEP-Creative-Industries
- Tellis, G., Eisingerich, A., Chandy, R. and Prabhu, J. (2009) 'Competing for the Future: Patterns in the Global Location of R&D Centers by the World's Largest Firms', Working Paper.
- Tyfield, D. and Urry, J. (forthcoming 2009) 'Cosmopolitan China? Lessons from International Collaboration in Low-Carbon Innovation', *British Journal of Sociology*.
- Tyfield, D. and Wilsdon, J. (2009) 'Low-Carbon China: the Role of International Collaboration', in Yao, S., Wu, B., Sutherland, D. and Morgan, S. (ed.) *Sustainable Reform and Development in post-Olympic China*, London: Routledge.
- Tyfield, D., Zhu, Y.G. and Cao, J.H. (forthcoming 2009) 'The Importance of the 'International Collaboration Dividend' – the Case of China', *Science and Public Policy*.

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