



# Lags in the EU economy's response to change

Final report

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# Executive Summary

## Introduction

This study was commissioned to raise understanding of when and why economies are slow in their uptake of beneficial innovations. This lag in response times not only challenges efforts to deliver EU2020 policy goals, particularly those seeking to decouple EU growth from the use of resources, but may also impose greater costs on the EU economy to the detriment of its longer-term competitiveness. The work is designed to inform discussions of new policies for the promotion of resource efficiency.

One of the implied questions for the study has been the extent to which economies are responding in an 'optimal' manner to beneficial innovations, and, if some appear not to be, to understand the reasons why this might be so. Our analysis suggests that such a straight reading of the literature is too simplistic, that the patterns – and considerations – involved are more complex than this, demonstrating the value of smart policies which seek to influence consumer behaviour through differentiated, non-traditional approaches.

Although the interest of the study has been in the context of the take-up of resource efficient innovations, the content of the study itself was been steered away from this topic. Rather, the consultants were asked to examine a wider range of innovations. Similarly, the study was explicitly steered away from considering the take-up of innovations which relied upon a strong legislative or policy induced 'push'. Where such innovations were considered, they were used to illustrate how public policy may have to act to overcome asymmetries of information, or to counter deep-set tendencies of risk-aversion. Equally, although the concern of the study is the EU economy's response to change, our work draws on evidence from around the world, whilst concentrating on national economies within the EU.

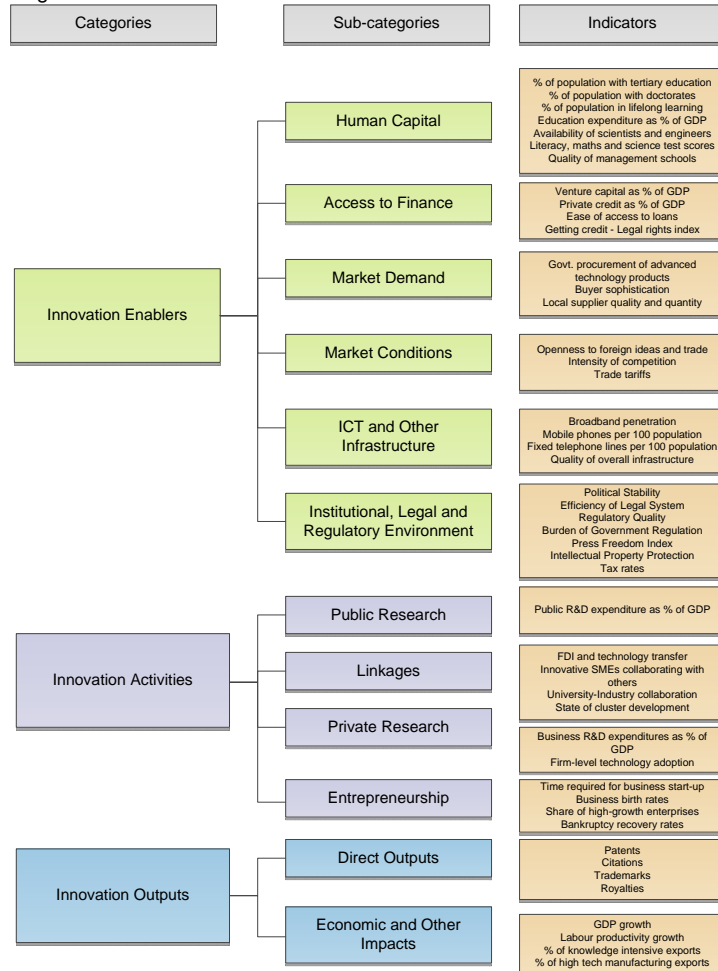
The study builds upon our existing levels of knowledge and focuses on a targeted analysis of relevant literature, academic texts and 'grey'. Our approach was based upon three principal components. Firstly, a review of measures of lags in the take-up of innovations, using published reports and a limited amount of commissioned data. Secondly, a review of the broad literature appertaining to the reasons which influence the take-up of innovations, and which might shed light on the reasons lags occur. Thirdly, the selection of a small number of cases through which to explore the reasons for lags in the take-up of particular innovations. The findings of the report were tested with other experts in the field of innovation and resource efficiency and their views incorporated.

## Measures of Innovation

A variety of innovation indicators and indexes exist to compare countries innovation performance, this study reviewed and compared 12 of the most widely used measures. We found that the measures had two common features, that: (1) their purpose is to benchmark innovation performance, i.e. to measure and compare the propensity with which firms, or economies, introduce new products or processes; and (2) policymakers are the primary target audience. In terms of data, the measures have traditionally been based upon published statistics, but more recently, bespoke survey data, through the executive opinion survey or Community Innovation Survey (CIS), has become more common.

Analysis of the innovation measures enabled us to produce a categorisation of the fields which are common across the measures, representing a common understanding of the factors in innovation, as shown in figure 1. These range from measures of framework factors that enable innovation, to direct innovation activities and measures of outputs.

Figure 1 Categorising measures of innovation



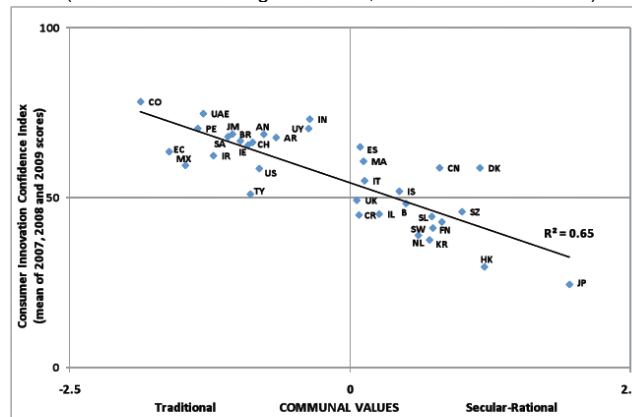
Source: Ecorys analysis

What became clear from the analysis of measures and their indicators was that they had little relevance to measuring or understanding lags in the adoption of beneficial innovations. They offered little insight into the time dimension, and less still on rates of adoption, diffusion or take-up, only measures of broadband or telephone usage and penetration offered information of this type and none of the supporting analysis used the data to explore the issue of lags in response, considering these only as enabling factors.

The area most relevant to take-up of innovations is market demand, but this was perhaps the weakest area for indicators across the 12 categories. Further investigation confirmed that this was the case, with only limited further work in producing datasets and measures of market demand relevant to detecting lags. Data from the Community Innovation Survey (CIS) and Eurobarometer survey offers some insight into the issue but the questions asked in these surveys do not directly address the issue of market demand and lags. Work being carried out by the Institute for Innovation and Information Productivity (IIIP) in preparing a Consumer Innovation Confidence (CIC) index provides more direct insight into understanding take-up, as a factor of consumer confidence. An interesting finding from this measure was a contrast in consumer attitudes between what were

termed 'secular/rational' societies, as most of the EU member states were classed, and more 'traditional' societies. This showed that secular/rational societies generally had lower innovation confidence than traditional societies, the reasoning based on the additional utility derived from innovation adoption as an expression of freedom, boosting the attractiveness of innovations in more traditional societies. The relationships are presented in figure 2.

Figure 2 Association between Consumer Innovation Confidence and national community values for 33 nations, Hong Kong and Shen Zhen (IC values are averages of 2007, 2008 and 2009 values)



Source for community values: World Values Survey latest available years (2005, 2004 or 2000)

Source: J. Levie – IIP (2010) *The IIP Innovation Confidence Indexes 2009 Report*

Overall though there was found to be a deficiency in measures that enable direct analysis of lags in innovation take-up or market demand, which is understood as the main factor in this. Work by NESTA in the UK has begun to build a theoretical framework for what such a measure could look like, setting out 4 framework conditions for measures of market demand:

1. Receptiveness to innovative products and services
2. Customers involvement in the innovation process
3. Understanding of customers needs (certainty regarding the level of demand)
4. Money spent on innovative products and services

## Evidence for lags

Analysis of specific product take-up data was carried out to test for the existence of lags. The analysis looked for trends and tested the impacts of factors such as income and price, on the take-up of innovation. The products analysed were broadband internet, mobile telephones and DVD players. The analysis charted take-up of these innovations, seeking overall patterns and trends, consistent across the countries and technologies. It found consistent patterns of take-up, based on an S curve, and did detect lags. The expectation that take-up would be closely affected by income was found to be incorrect, while in some cases a correlation existed, it was weak and not statistically significant. It also varied across products. Lags did not seem to follow clear patterns, countries that lagged in one technology could also be above average or leading in another. It was possible to draw 4 key messages from the analysis of actual figures, that:

1. Patterns of take-up follow broadly similar trajectories;
2. Lags in take-up are visible;
3. After an initial period, wealth and income effects do not appear to influence take-up rates; and
4. Common and consistent patterns are hard to identify.

It was necessary then to dig deeper to understand the causes of lags in innovation adoption and how this may affect the EU Economy's response to change.

## Reasons for lags

It was clear from the evidence that the take-up of innovations is not a smooth and seamless process. Equally, it was also apparent that differences in the rate and speed of take-up are not only due to factors such as demographics, wealth and income. Although these are undoubtedly important, they cannot explain all of the observed variations. So why do lags in the take-up of innovations occur? Why is the picture one of discontinuity and differential take-up?

A wide, if disparate, literature exists which considers different reasons that influence the speed with which innovations are taken up, both by the general population – as consumers of goods and services – and by firms, as inputs into their own production processes. We drew on this literature to highlight the principle reasons identified as to why lags can occur in the take-up of innovations that, with the benefit of hindsight, might be thought to have been beneficial.

It is of course a truism, but one reason is simply because not all places are the same. Physical geography can influence the take-up of innovations by affecting the cost-effectiveness of investments, or the ease with which knowledge can diffuse, with language being an important factor. Similarly, neighbour effects may mean that awareness of innovations is stronger in adjacent places than those which are more distant. Yet, the evidence also suggests that this is too simple an explanation.

Other explanations focus on the culture of a place, or on its historical path of economic development. Work by writers such as Geels and Schot<sup>1</sup> for example highlighted the role of socio-technical regimes where existing regulations and standards; prevailing cognitive routines; lifestyles which centre around prevalent technical systems, and sunk investments in the infrastructure and competencies relating to those systems all combine to limit the speed with which innovations from outside of prevailing practice can be taken up. Such explanations though do not fully explain why some places may prove slower than others in beginning to take-up innovations which emerge, or why some firms and consumers are swifter than others to adopt innovations within such regimes.

Our examination of the literature, for a full exposition see chapter 4 of the main report, suggested the following 7 themes as central to illuminating any attempt to understand lags in the take-up of innovations. These reasons were then explored in the context of 6 case studies<sup>2</sup> of significant innovations across various industries where lags were evident or expected, the findings from theory and practice, are presented for each of the 7 reasons.

### 1. Existing infrastructure and practices influence future choices

Firms, and by extension economies, are not entirely free to choose their future development paths. They are, to a certain extent, locked-in to paths determined by past investment decisions, existing economic structures and prevailing institutions (Kaldor 1934<sup>3</sup>, Martin and

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<sup>1</sup> Geels, F. W. and Schot, J. (2007) Typology of Sociotechnical Transition Pathways in *Research Policy* 36 p.399-417

<sup>2</sup> 6 case studies: Automotives – alternative vehicle and fuel technologies, broadband and internet technologies, mobile telephone technologies, energy efficiency technologies, audio and visual technologies, process innovations.

<sup>3</sup> Kaldor, N. (1934) 'A Classificatory Note on the Determinateness of Equilibrium' *Review of Economic Studies* Vol 1 1 pp 122-36 Reprinted in Targetti, F. and Thirlwall, A. P. (eds) (1989) *The Essential Kaldor* New York Holmes and Meier

Sunley 2006<sup>4</sup>). These can constrain the ability of firms to adopt new innovations, and may influence their availability to the consumer market. This can play an important role in introducing lags into the observed pattern of innovation adoption over time. The evidence of this is all around us in the case of our physical infrastructures, the past investment decisions by firms – their sunk costs – and embedded institutions and routines of decision-making.

This was evident as a highly significant barrier across almost all of the case studies, with lock-ins that spanned the socio-technological range, mostly the lock-in acted against innovation take-up, but not always. In the automotive sector there was evidence of a very strong lock-in to the current petrol engine vehicle and associated infrastructure, the way this is now established as the norm in peoples perceptions and the cost and risk in developing alternatives deterring both new entrants and also innovation within the industry. Alternative vehicles and fuels struggle to gain traction in this situation, only in certain special circumstances and with strong regulatory support, such as for biofuels in Brazil, had it been possible to significantly move away from petrol vehicles.

For broadband technologies infrastructure played a vital role in take-up, in the developing world a lack of infrastructure proved a significant hindrance, contributing to lags in take-up. In some countries, such as Sweden and the Netherlands, the lock-in of strong existing infrastructure enabled much faster take-up of broadband. In the context of energy efficient innovations it became clear that in the case of light-bulbs there was significant lock-in to inefficient incandescent bulbs, based on existing habits and also the lighting infrastructure (fittings) with which the new more efficient compact fluorescent lightbulbs (CFL) were not compatible. CFLs have since had to be adapted to be consistent with the existing infrastructure, to work with this lock-in.

In looking at process industries it was evident that historical choices by firms, represented in sunk costs, are also a significant factor in affecting innovation adoption choices. Firms need to balance their investment decisions and it is also important to recognise the intangible factors in lock-in, such as the learning and optimisation of current infrastructure and the associated knowledge and human capital (training and skills) that could be lost through adoption of a new innovation.

A final element of relevance was the nature of infrastructure change itself. By definition infrastructure is intended to be long-lasting, to underpin and support other activities, therefore replacement cycles are often measured in decades rather than years and the costs involved are high. This builds in lags related to the sunk costs, but also the process for infrastructure change itself can cause lags, with the decision making and planning process also in many cases lengthy due to the range of stakeholders effected and the serious impacts. The case of wind farm applications was highlighted, where this process takes between 23 months average in one member state (Belgium), to more than 76 months average in another (Spain), taking nearly three times as long<sup>5</sup>.

## **2. Our expectations of the future influence what we choose to do now**

Our propensity to adopt innovations is heavily influenced by how we see the future, but not necessarily in any consistent manner. Old habits die hard and in deciding on the future we often

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<sup>4</sup> Martin, R. and Sunley, P. (2006) 'Path Dependence and Regional Economic Evolution' Journal of Economic Geography Vol 6 4 pp. 395-438

<sup>5</sup> EWEA (2010) Wind Barriers: Administrative and grid access barriers to wind power

fall back on the familiar; that is what we know now. More significantly perhaps, we also tend to value present returns more highly than potential future returns and act in a highly risk averse manner. This tendency towards short-term prioritisation can be accentuated by the demands of others and our perceived need to satisfy their requirements.

In general the case studies showed a preference for consumers and firms to keep their options open where possible, this was a factor of both risk aversion and uncertainty of the future. For energy efficient products this was related to uncertainty about price movements, given significant swings in the past such as the oil crises of the 1970's and price spikes in 2008. It may be expected for this effect to erode as a more constrained world shifts expectations towards upwards trends – this could be particularly relevant to resource efficiency and the more tangible idea of finite resources.

In the broadband and mobile telephone sectors the role of uncertainty was proven to be an important factor in lags. In situations of competing standards or market fragmentation, the uncertainty over which would emerge as the dominant technology contributed to firms and consumers adopting a 'wait and see' approach to avoid being left with a redundant innovation.

The strength of this effect was tested empirically in some circumstances, notably in the case of energy efficient heating systems for greenhouses in the Netherlands<sup>6</sup>. This found that farmers required benefits of between 25%-300% greater than the costs of an innovation to overcome their aversion and adopt a beneficial innovation. This obviously represents a significant barrier to adoption and cause of lags.

### **3. Our consumption habits and choices are shaped by those around us**

In deciding whether to take-up an innovative product, service or process – whether in business or as a consumer – we are affected by those around us and our surrounding cultures (both socially and organisationally). Our decisions are informed by what our friends, our colleagues and our neighbours do, and what we feel are their expectations of us. We rarely make an independent choice. We exhibit the propensity to make our product choices on a selfish basis, consuming for private benefit in most cases, valuing the use we will derive from consumption over any benefit to society. In doing so we base our decisions primarily on price, quality and performance rather than other factors.

Differences in culture, in expectations and rates of surrounding adoption affect the speed with which we adopt innovations, which in turn affects others propensity to adopt. Culture, whether institutional, governmental or social, has the potential to greatly hinder or boost attempts to initiate change. Where current culture conflicts with innovation, many case studies show that such reforms can be met with intense resistance as individuals seek to protect the present way. A shift in culture, however, can greatly boost capacity for change.

In the case of broadband technology it was shown that habits could be an important factor in innovation adoption. The role of the consumption habits of young people, in quickly adopting internet use, then communicated through family and other networks to become a factor in opening up internet use and broadband adoption for the mass market. These type of network effects were also observed in the mobile telephone industry, with the market reaching a critical

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6 Diederer, P., Van Tongeren, F., & Van der Veen, H. (2003). Returns on Investments in Energy-saving Technologies Under Energy Price Uncertainty in Dutch Greenhouse Horticulture. *Environmental and Resource Economics*, 24, 379–394

mass that reinforced the value of the innovation to consumers and also the further development of the technology.

In the automotive sector the habit for petrol vehicles is long established, over more than a century, this forms a type of behavioural lock-in that shapes our choices. There is, as yet, only a small market for alternative vehicles, with Hybrid Electric Vehicles (HEVs) now gaining some traction. This helps move towards a critical mass for the technology and expands the potential choices in peoples perceptions. A link was drawn to celebrity ownership of HEVs and the connection to status symbols as a driver of innovation adoption.

#### 4. Knowledge diffusion and awareness can shape decisions

Whilst it is a truism that to adopt an innovation you must be aware of it, not all knowledge is available in all places at the same time. Differential rates of diffusion of knowledge can, and do, lead to lags in the take-up of innovations. This diffusion and adoption of an innovation has a lifecycle that depends on types of people adopting at different times. We don't all purchase a new type of good, or service, at the same time. Some of us are more cautious than others, others are attracted by the 'new'. Various models of this behaviour have been produced since Frank Bass was among the first to write in this area in 1969<sup>7</sup>, an example from Ryan and Gross<sup>8</sup> is shown in Figure 3 developed a simple model of five categories of people according to their ability and willingness to adopt an innovation. This shows that in general, consumers are conservative and tend to wait until benefits of a product switch are assured, that the technology is ready.

There is also good evidence as to how marketing agencies seek to influence these patterns, and our perceptions, of the take-up and 'acceptability' of particular goods and services in order to increase the speed of take-up and sales. Negative first experiences with innovative products have been shown to be especially important in shaping knowledge about an innovation and its diffusion and adoption. The role of entrepreneurship in ensuring knowledge diffusion, by matching technical and business/marketing skills to get positive initial feedback, is also important.

Figure 3 Categorisation of adopters according to "innovativeness"

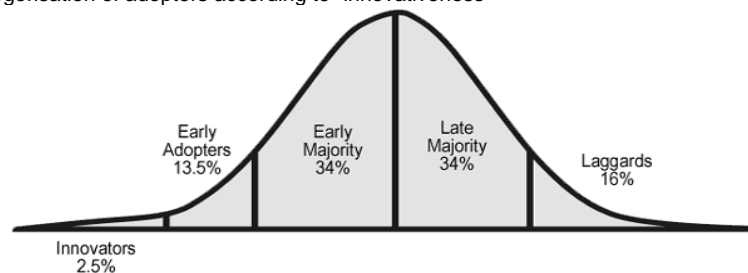


Diagram adapted from Rogers, E.M. (2003). Diffusion of innovations. New York: Free Press. p281

Negative first experiences were shown to be critical factors in innovation lags and slow adoption in relation to electric cars and energy efficient lightbulbs (CFLs). It is necessary for a product to compete on performance, price and quality characteristics, and beyond this to provide a compelling story of the advantages over the existing products. In the case of environmental or resource efficient technologies this was shown to be a problem, due to the double externality,

<sup>7</sup> Bass, F. (1969) A new product growth model for consumer durables. *Management Science* 15 (5): p215–227.

<sup>8</sup> Ryan, B. and Gross, N. (1943), "The Diffusion of Hybrid Seed Corn in Two Iowa Communities," *Rural Sociology* 8 (March): 15 – based on Rogers, E. M. (1983), *Diffusion of innovations* (3rd Ed). New York: Free Press

whereby the environmental benefits are usually marginal for the consumer, and other technologies do not have their negative externalities internalised in their prices.

The energy efficiency example highlighted a further important knowledge and awareness aspect, in the ability to understand and perceive the beneficial effects of innovation. The way in which energy is used and then also measured and billed does not allow for the impact of more efficient innovations to be easily understood. This inability to perceive what the actual benefits may be provides significant uncertainty to consumer adoption decisions.

## 5. The important role played by skills, education and educational systems

Technological change, the taking up of innovations, is skills-biased, early adopters of new innovations are more likely to have high education levels<sup>9</sup>. Education, skills and qualifications are all therefore important contributors to the swift take-up of innovations. Where education systems are less well-developed then lags in innovation may occur. This requirement for knowledge and capabilities is often referred to as 'absorptive capacity'.

Without absorptive capacity, companies are unable to actually absorb and use available information to take-up prevalent innovations<sup>10</sup>. This capacity rests on basic skills and prior knowledge, as well as a shared language and knowledge on the most up to date issues in the field. Importantly, ongoing internal R&D activity also helps to underpin absorptive capacity, allowing companies to 'assimilate and exploit new knowledge'<sup>11</sup>, enabling them to respond quickly-become a fast second-when competitors come up with a major advance<sup>12</sup>.

The case studies showed the importance of education as a diffusion tool itself, it was a powerful factor in the diffusion of internet and broadband technologies.

## 6. The role of market and organisational structures in influencing decisions

There is an ongoing debate as to the role that structures – be they of organisations or markets – play, in influencing the take-up of innovations. Whilst much of this is couched in the language of the development of new or improved products and processes, it applies equally to the adoption of these developments. Crucial to this aspect is the role of the market to provide enabling conditions for entrepreneurs and innovators, access to finance, venture capital and a system that does not over-punish risk takers in the case of failure. The role of universities within the innovation process is also important – not for themselves so much but in their role as 'pipelines of knowledge'<sup>13</sup>, channelling and brokering the potential to take-up innovations into the local economy.

An organisation's structure has a significant effect on the capacity for innovation to be taken forward or potentially rejected. Much of the literature agrees that where organisations show inability to change, their structure or practices are at least partly to blame. In fact, innovation

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9 Berman, Eli, John Bound and Zvi Griliches, "Changes in the Demand for Skilled Labor within U.S. Manufacturing Industries: Evidence from the Annual Survey of Manufactures," Quarterly Journal of Economics, May (1994)

10 Wesley M. Cohen, W. M. and Levinthal, D. A. (1990), Absorptive Capacity: A New Perspective on Learning and Innovation. Administrative Science Quarterly, Vol. 35, No. 1, Special Issue: Technology, Organizations, and Innovation. (Mar., 1990), pp. 128-152.  
<http://links.jstor.org/sici?sici=0001-8392%28199003%2935%3A1%3C128%3AACANPO%3E2.0.CO%3B2-5>

11 Ibid. P148

12 Ibid. p148

13 Bennenorth, P. and Hospers, G-J. (2007) 'The New Economic Geography of Old Industrial Regions: Universities as global-local pipelines' Environment and Planning C: Government and Policy Vol. 25 pp. 779-802

sometimes needs to occur outside existing organisational structures in order to ensure that unsuitable organisational environments don't stifle its effective utilisation.

The case studies often returned to nature of the markets and how they rewarded innovation activity and adoption, particularly the role of competition and first movers. In the automotive sector first movers in HEVs and electric vehicles were studied, the evidence showed that Toyota and Honda, as first movers for HEVs, were able to establish dominant positions that other firms are only now responding to. This has been beneficial to their success but notably required them to work on the product as a loss-maker to start with, only becoming profitable to the firm after 2-3 years. A similar expectation is found for Nissan and its new Leaf electric vehicle. This evidences a potential barrier to innovation by firms, where industry competition works to the detriment of innovation, and also the natural lags that occur between innovation leaders and followers.

Competition was found in the context of broadband and mobile telephones to also be able to have a significant positive effect on innovation adoption. Countries with more open-access to providers and competition between them experienced faster rates of take-up of these technologies in comparison to countries with markets controlled by a single operator and only limited competition.

Access to finance was also highlighted as an important supplementary issue to market structure, relevant to both consumers and firms. For firms finance is necessary for entrepreneurs and firms to be able to develop an innovation, to get it to market, obviously if it is not possible to get a product from development to market then this will form a major lag in its adoption. Similarly access to finance is necessary for firms and consumers for them to be able to purchase the innovation in question, this is particularly relevant to the high value innovations. Access to finance in the context of environmental improvement and resource efficiency has always been something of a hard sell to financiers, due to the double externality problem, in that not all investment benefits accrue to the innovator/adopter and competing investments do not have the same issue.

## **7. Policymakers can hinder as well as assist the take-up of innovations**

Regulation and Standards play a crucial, but ambiguous, part in the take-up of innovations. On the one hand they can slow the adoption and take-up of innovations, on the other they can enhance it. What is clear though is that differential standards of regulation can play a clear role in affecting the speed at which innovations are adopted across economies and territories.

The automotive sector case studies provided instructive examples of the power of policy in innovation adoption. For alternative fuels the two leading nations, Brazil and the US, both embarked on significant policy programmes in support of biofuels much earlier than other countries. The support in Brazil was more wide ranging and deeper than in the US and, supported by highly suited natural conditions, was able to induce mass adoption of biofuels. The EU has lagged on the adoption of biofuels, with a much later policy response, though this may also be the appropriate response to the EU circumstances.

Vehicle emissions controls also provided an important example of the role of policy. It highlighted the success of clean air regulation in the US leading to the development and widespread adoption of catalytic converters. At the same time though it also contrasted the relative failure of US CAFE regulation to improve vehicle fuel efficiency against much more

successful vehicle efficiency gains in Europe, attributed to tax instruments (on fuel) and subsequent price effects on consumer choice and demand.

In broadband technology the role of intellectual property rights (IPR) and their protection was raised. The contrasting broadband penetration trajectories of the Baltic States and Russia are, at least partially, attributed to the weakness of Russian IPR protection and enforcement.

In the mobile telephone example the role of policy in helping to define standards was important, the relative speed at which EU member states adopted mobile phone technologies, compared to the US was attributed, in part, to the early establishment of European technology and communication standards, whereas in the US two competing standards led to a fragmented market and divergent technologies.

In energy efficiency the role of policy was viewed as a crucial and highly necessary driver for the adoption of efficient and innovative technologies. In the cases of both boilers and CFLs there was a clear difference in performance between countries with regulatory standards on this issue, with those without regulation significantly lagging in their take-up of energy efficient technologies.

## **8. Other factors – technology readiness and principal-agent**

In the course of the case studies other factors in lags also became evident. The need for the innovative technology to be 'ready' was identified as a key factor in automotive and lightbulb technologies. The first examples of innovative alternatives did not provide a substitute for the existing technologies, this led to negative perception from consumers, in essence - why should they adopt the innovative technology if it does not offer performance characteristics or other benefits over and above existing technologies? Innovations need to be close to a perfect substitute, and bring other benefits, if they intend to displace an existing technology.

The principal-agent problem was found as an issue in certain areas, particularly in affecting the decision for energy efficiency innovations. Where there is a separation between those that make a decision and bear its costs and those that will then receive the benefits of the decision then sub-optimal efficiency decisions are likely. This is most evident in the construction sector, with choices and the cost of building design and fit-out being made by those within the trade, rather than the building occupiers. The evidence showed that choices become skewed towards choices that are cheaper and easier for the decision maker, rather than those for more innovative and efficient technologies.

## **Policy implications**

Understanding the main causes of lags in innovation take-up is important in understanding how and why economies respond to change, but what does this understanding mean for policymakers?

### *Understanding interactions of causes*

One of the most important aspects to recognise is that all of the causes are interrelated and affect each other. Changes or policy action to affect one cause can have knock-on effects on other causes, some expected effects, others unexpected. One of the more interesting interactions is the balance between consumers and producers in innovation adoption, with the bulk of consumers waiting for a critical mass to reduce the risk of their purchase, and producers waiting on consumer signals before developing and releasing innovations – the potential for impasse is clear.

The causes work as part of a complex system. It is impossible to analyse and understand every aspect of the system but lessons can be drawn from work on the subject. These lessons return to the need for policy to work with the existing strengths and limitations of the system, to harness the market mechanisms that exist. Drawing on the general economics work in this area and the emerging literature on resilient regions it is clear that the objectives for greater responsiveness should be a more flexible and adaptable economy that encourages innovation and its adoption.

#### *In the context of structural change – resource efficiency*

Encouraging responsiveness to change is crucial to ensure structural change in resource efficiency and successful sustainable development. The current system has successfully encouraged incremental innovations and their adoption, but the scale of the resource efficiency challenge suggests that more radical change is necessary. This is more problematic from a policy point of view given the behavioural factors affecting consumers and producers, which work against risk, particularly in uncertain circumstances and when the benefits are societal not private. This creates an important role for policy to ensure that societal benefits are promoted, in addition to private.

The literature suggests that policy response in this context can be based around taking advantage of windows of opportunity. Where an opportunity for change emerges then policy should look to enhance and support the market and consumers in doing this. Where the technologies or demand is less certain then policy can work through information and traditional innovation support mechanisms to prepare and create future windows of opportunity. Suggestions for specific policy responses in this area include promoting shared R&D between firms, continuing to level the playing field between resource efficient and non resource efficient technologies and improving access to finance for producers and consumers of resource efficient innovations.

#### *Lags inherent to policy*

In taking these actions it is important to recognise that policy also has its own inherent lags, from idea, to decision, to implementation takes time. At EU level this is evident in the time it can take for directives to be transposed into national legislation. The reasons for this are natural to political and administrative systems.

Decisions are subject to political choice which has to take account the electoral cycles and views of the people. A drawback of this is that it can encourage short term thinking and planning. Where a long-term issue of structural change, such as resource efficiency, is being considered it can take time to develop support for the types of policies that are necessary to deliver the long term change. A further aspect of this short-term aspect is the role of initiatives, which are often beneficial and bring important learning, but are sometimes detrimental, and bring uncertainty dependent on the funding and time over which they are committed. Administrative aspects, to follow the correct process and ensure that stakeholders are all represented are necessary but also take time, the example of the planning process for wind farms taking 2-6 years on average is enlightening in this regard.

A final point made in this respect is that despite these lags to the process, policy can also be visionary, it can lead thinking. It can provide structure to the future direction of change, reducing uncertainty. It is important for policymakers to grasp this visionary role.

## Conclusions

This study set out to explore when and why economies are slow in their take-up of beneficial innovations. It has drawn on existing evidence as to where lags can be discerned and the reasons typically given for this.

The focus of the work has been on the take-up of innovations, that is the act of adoption and consumption. This proves to be a relatively novel approach, despite on first sight to be a matter of commonsense. One of the most significant findings is the lack of exploration of this matter. There is a limited literature which deals with lags in innovation take-up explicitly, and data sources are equally sparse. Current attempts to measure innovation are dominated by indicators relating to the production of new goods and services, with considerations of consumption and take-up much more limited. Some useful approaches are beginning to emerge however, which do seem to suggest that there are differences in the readiness of European consumers to embrace innovative products and services, both between EU economies and in comparison with non-EU economies.

From the prevailing measures, it would appear that there is something of an assumption that if a 'beneficial' innovation should be available, then it will be automatically taken up. An assumption that our review of the literature suggests, is dangerously misplaced. Yet, this fallacy continues. The recent Communication on a Resource Efficient Europe<sup>14</sup>, seems to maintain the belief that simply through the provision of better information, consumers will take-up resource efficient goods and services (p.7) and that empowering consumers will lead to more resource-efficient consumption patterns. A reading of the literature suggests that this may not be the case unless other factors are also present.

The available evidence from literature and cases, suggests that lags do exist in the take-up and adoption of innovations. These are visible at two levels. Firstly, between countries, or economies, over time and, secondly, between the availability of an innovation and its widespread adoption. Both types of lags were clearly present in the data, however, it is also clear from the evidence that these lags do not conform to consistent patterns. It is not necessarily the case that some economies are consistently slower to adopt innovations than others. Even in associated technology fields patterns of adoption and take-up between economies can vary quite strongly. Swift adoption of one innovation may occur at the same time as another is being taken up relatively slowly.

A simple analysis of the data quickly dispels the notion that lags in the take-up of innovations is due to wealth and income effects. This can undoubtedly play a role, particularly at an early stage in the introduction of an innovative good or service when prices may be high, as the literature indicates for mobile phones, but is rarely the defining reason. Our analysis of the literature suggests that the reasons behind lags in take-up are complex, variable and often inter-related.

Analysis of the theoretical understanding of why lags in the take-up of innovations occur suggests seven broad reasons, which each include a number of subsidiary themes. This is reinforced by an examination of the take-up of particular cases of innovation, with some additional reasons also suggested from this work.

The role of existing infrastructure and practices in influencing future choices has emerged as a major factor in why some economies lag behind in the adoption and take-up of particular innovations. The evidence of this is all around us in the case of our physical infrastructures, the past investment decisions by firms – their sunk costs – and embedded institutions and routines of decision-making.

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<sup>14</sup> European Commission (2011) A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy COM(2011) 21 final Brussels, 26.1.2011

Our expectations of the future also influence what we choose to do now. On the whole, we are naturally risk averse and we value ownership of a good now more highly than our ability to pay for it in the future. Whether such cultural markers vary significantly between economies within Europe is not clear from the literature, but there is some evidence that cross-cultural differences do exist when comparing the European economy as a whole to other economies.

We have also been found to be selfish in our consumption patterns rather than altruistic. Lags in the take-up of innovations seem to occur when we, as consumers or producers, fail to see a benefit to ourselves. To be taken-up an innovation needs to display benefits over other products, being better, cheaper, or more exciting, for example, it needs to be both be this and have a story to convince potential buyers. That benefits might accrue to others, who we do not know, does not appear to be a powerful influence on our consumption choices, except where conscious efforts are made to influence our behaviour – such as in the case of the Fairtrade movement as one example.

Significantly, our consumption habits and choices are shaped by those around us. There is now extensive evidence that the take-up of innovative goods and services is dependent upon the extent to which our peers, neighbours, families and friends take-up these goods and services. Lags in take-up occur, where this process is slow to occur for any reason. The stress placed on Quarterly Financial Reporting by the investment community is increasingly held up as one example of how decisions are influenced by the expectations of others.

The spread of knowledge and awareness can also shape decisions, both in terms of consumers being aware of the availability of a particular innovation, but also in terms of the information cascade referred to in the previous paragraph. Knowledge is not ubiquitous and this lack of awareness can impede the take-up of particular innovations. The means by which knowledge and awareness spreads can also influence patterns of take-up and lead to lags in some economies compared to others. There is also good evidence as to how marketing agencies seek to influence these patterns, and our perceptions, of the take-up and 'acceptability' of particular goods and services in order to increase the speed of take-up and sales. The role of entrepreneurship in ensuring knowledge diffusion, by matching technical and business/marketing skills to get positive initial feedback, is also important.

Consumers have also proven to be very conservative, only adopting new products once they are assured that they are at least as good as the alternatives available. Poor initial performance can also bias consumption decisions for a long period. This notion of technical 'readiness' has proven important across several diverse sectors. As consumers tend to act within discrete markets, their decisions can be based on local perceptions of the 'readiness' of particular alternative options.

Available skills, education and educational systems have all been found to play a role in the speed with which particular innovations are adopted. This can be due to inertia in the skills set, the use of some educational systems to promote familiarity with particular technologies or the fact that levels of education appear to have a bearing on the willingness of consumers to take-up new goods and services.

Both market and organisational structures have emerged as powerful reasons for lags in the take-up of innovations. Organisational structures can both encourage and inhibit the take-up of innovations, and organizational cultures also act in similar ways. Overall, open competitive markets appear to be more conducive to the take-up of innovations. Where competition is limited delays in the introduction of innovations, such as in the case of vehicle technologies, can occur, or can account lags in take-up between economies – such as has been found in broadband technologies.

However, the picture is complicated where there are significant costs related to the introduction, and so take-up, of particular innovations.

There are challenges here for policy makers, but also opportunities. Some of the reasons identified are extremely hard to influence, particularly in the short-term. However, recognizing their influence is the first stage in developing smarter policy approaches, policy approaches which work with prevailing trends rather than against, whilst trying to break out of the constraints of past investment decisions and the shackles of future expectations.

The review of the literature demonstrates that the choices of policy makers – whether they are deliberate or not - can hinder as well as assist the take-up of innovations. Regulations, standards and incentives have all acted to speed up the take-up of some innovations and slow down others. Policy should be targeted where possible at reducing the double externalities of resource efficiency improvements, supporting new products and ensuring that externalities of inefficient products are increasingly internalised. In summary, where policy making is slow to recognize new opportunities, or conflicts in objectives, so lags in innovation can occur.

#### *Some final thoughts on lags and resource efficiency*

The principle is whether lags affect the take up of resource efficiency innovations more than other innovations. Also should we perhaps differentiate between lags in the take-up of particular innovations in general and lags in the take-up of those innovations in one country compared to another.

1. Raising awareness is not enough. Even with strong levels of awareness behaviour may not change. Regulation seems to be an important driver for eco-innovation!
2. One approach will not fit all cases. It is not the case that some countries/economies lag behind others consistently. Policies need to be smarter than this and consider how the various parts of the system apply in each area. Core principles to encourage are economic flexibility and adaptability.
3. Infrastructure constraints are real and make some lags unavoidable. This means that alternative solutions to common goals are needed. There is strength in diversity.
4. Market structures, skills and education are important but are longer terms issues. Actions here are unlikely to have an impact on Europe 2020 goals - but our understanding of their effect might (back to smarter policies).
5. Developing a stronger understanding of consumers' willingness to adopt innovative goods and services is valuable and deserves more attention - particularly in particular fields of resource efficiency (again aggregate measures are likely to be too coarse).
6. Generating consumption momentum seems to be the key. Consumers react to the behaviour of others (their friends, family and neighbours). Techniques for generating such snowball effects may be underutilised (including the ways messages are framed).
7. Opportunities should be taken to build consumer momentum – through preparing, creating and utilising windows of opportunity for beneficial and resource efficient innovations. This needs to include ensuring consumer certainty as to future value/returns/benefits, the reliability and utility of the products on offer (compared to alternatives).

8. Short-term thinking and risk aversion is unlikely to change - but a better understanding of this may assist in the design of more effective policies. In the case of businesses is there scope for changing accounting standards/practices? For policy an increasing focus on material flow innovation?

9. If producers are to take up new innovations then they need knowledge (awareness and capability), capacity, access to finance and confidence in the future savings/return. Evidence suggests that when all this is in place many do react, but when any single element is missing then lags in take up occur.

10. Be realistic about the time taken for change – some lags are in-built and the policy process itself has lags – but use the experience of swift adopters to generate momentum for change in economies which are lagging.



# 1 Introduction

## 1.1 Context

Since 1980, the global use of abiotic (fossil fuels, minerals) and biotic (agriculture, forestry, fishing) resources has grown from 40 to 58 billion tonnes in 2005. In order to sustain global economic growth, total natural resource extraction would have to be as high as 80 billion tonnes (200% of the 1980-value) by 2020 (Bleischwitz et al 2010). As world-wide competition for these resources increases pressure is rising for a significant reduction of global resource use, either through a more efficient use of resources or through reductions in the consumption of particular products. Achieving higher levels of resource-efficiency presupposes substantial levels of innovation across a range of sectors.

Over past decades, technological changes have enabled increasing levels of resource efficiency throughout the global economy, yet the adoption of more efficient production and consumption patterns have often lagged behind the technological frontier. The reasons for such lags in innovation have been subject to much scrutiny and a wide and comprehensive academic literature has emerged, particularly as higher levels of innovation have been associated with stronger levels of economic growth and the creation of employment and prosperity.

To date, much of the focus on innovation has been on the level of innovation outputs; that is, the production and introduction of new or improved products, processes and services. Explanations for differences in levels of innovation performance have been explored through studies of individual firms, examining how managerial decisions and organizational structures influence decision-making, through studies of different economic sectors, illustrating the role of systemic relationships in the innovation processes, and through studies of individual regions, demonstrating the role the political and socio-economic context can play in supporting or hindering levels of innovation. More recently, an emergent behavioural literature has been providing new insights into our understanding of innovation, and the introduction and take-up of new products and processes.

This behavioural literature highlights a serious gap in our understanding of the innovation process. To date, very little attention has been given to the reasons why consumers – be they firms or individuals – chose to adopt certain innovations and not others, and why some people, and it seems places, appear to be swifter in their take-up of new products, processes and services than others. In a world where policy makers and firms are seeking to change patterns of consumption behaviour this ‘blind spot’ in our knowledge base is unfortunate.

Despite the wide academic literature, the introduction and take-up of new or improved products and processes remains a slippery and ill-defined area. As we shall see, accepted measures of innovation performance are only just beginning to emerge, following many years of reliance on proxy measures, and our understanding that innovation is as much a social process as a technological process is only now beginning to lead to insights into how to catalyse the introduction of new socially-desirable products and production techniques, which are in turn can inform the development of new policy initiatives.

## 1.2 Aims and approach

This study was commissioned to raise understanding of when and why economies are slow in their uptake of beneficial innovations. This lag in response times not only challenges efforts to deliver EU2020 policy goals, particularly those seeking to decouple EU growth from the use of resources, but may also impose greater costs on the EU economy to the detriment of its longer-term competitiveness. The work is designed to inform discussions of new policies for the promotion of resource efficiency.

One of the implied questions for the study has been the extent to which economies are responding in an 'optimal' manner to beneficial innovations, and, if some appear not to be, to understand the reasons why this might be so. Our analysis suggests that such a reading of the literature is too simplistic. The pattern of response to different innovations examined in the study was not consistent across countries and it is difficult to say that some economies respond in a more 'optimal' manner than others. The patterns – and considerations – are more complex than this, demonstrating the value of smart policies which seek to influence consumer behaviour through differentiated, non-traditional approaches.

Although the interest of the study is the context of the take-up of resource efficient innovations, the content of the study itself has been steered away from this topic. Rather, the consultants have been asked to examine a wider range of innovations. Similarly, the study was explicitly steered away from considering the take-up of innovations which relied upon a strong legislative or policy induced 'push'. Where such innovations are considered here, they tend to illustrate how public policy may have to act to overcome asymmetries of information, or to counter deep-set tendencies of risk-aversion. Equally, although the concern of the study is the EU economy's response to change, our work draws on evidence from around the world, whilst concentrating on national economies within the EU.

The study builds upon our existing levels of knowledge and focuses on a targeted analysis of relevant literature. The literature is predominantly English-language based and covers academic texts and 'grey' literature. Our approach is based upon three principal components. Firstly, a review of measures of lags in the take-up of innovations, using published reports and a limited amount of commissioned data. Secondly, a review of the broad literature appertaining to the reasons which influence the take-up of innovations, and which might shed light on the reasons lags occur. Thirdly, the selection of a small number of cases through which to explore the reasons for lags in the take-up of particular innovations.

The cases were selected on the basis of a review of the published material available for a short list of 12 significant innovations. Those selected met a number of criteria. Most importantly, there was a range of material available that could shed light on lags in their take-up. They also complemented each other in that way, that they illustrated the strength of different factors which influenced rates of take-up. In each case, the innovation selected had to mark a significant break with previous technologies, had to be distinctively different in order to show up in the literature (or data sets), had to be widely available (in order to be discernable) and needed to be rapidly introduced over a relatively short period of years (10-15) in order that distinctive lag patterns might be visible. Although this latter criteria means that lags of the order of 2-3 years are the norm (and so may be felt to be negligible) we echo the argument of Christensen in his landmark study of the Hard Drive industry – that such fast moving markets are the technical equivalent of the Fruit Fly in biological studies. Robust results can be identified within a short time-series, which reduces the impact of significant changes in other external variables which would otherwise 'muddy the waters'.

In finalising the report experts in innovation and eco-innovation were consulted and their insight and comments were used to enhance and further develop the findings.

Our starting point was a review of how the responsiveness of economies to change is measured, and what these measures can tell us about differential response times. As Chapter 2 illustrates, these measures do not typically take great account of the take-up of innovations, focusing rather on the outputs of the innovation process. Their value for any assessment in the innovation responsiveness is therefore limited. There is a small but, for the purposes of this study, significant emerging literature which is beginning to focus on the question of innovation take-up and we report on the findings of this.

Owing to the limitations of available aggregate measures of innovation take-up, we have examined data on the market penetration of the innovations we selected as particular cases for analysis. The results of this are set out in Chapter 3, which draws on especially commissioned data runs as well as publicly available data sets. This indicates that lags do occur in the take-up of innovations between countries, but that the patterns of take-up are complex and inconsistent. Simple analysis of the data suggests that variables such as differences in income are insufficient to explain the lags identified.

Chapter 4 of the study explores the variety of factors which are increasingly seen to influence patterns of take-up of innovations. These draw upon a wide ranging literature and the important role played by perceptions, expectations of the future and the influence of those around us loom large. Other explanations highlight the contingent nature of innovation take-up and role that public sector actions can have to constrain, as well as to facilitate, take-up.

In Chapter 5, we examine a number of particular innovation cases to explore the factors which have influenced patterns of take-up in each case. We highlight the factors which are identified in the literature which have caused variations in the take-up of the innovation in question across different economies. Through these varied cases we are able to illustrate that a number of common reasons can be discerned for lags in take-up, but that in each case individually specific causes can also be identified.

Chapter 6 takes the findings from the previous sections and synthesises what this then means for policymakers. We look at how can policy best be applied to addressing the lags, taking into account how they are interconnected. We propose how policy could best be applied in the context of resource efficiency, but close by highlighting that the policy process itself is prone to lags.

In chapter 7 we bring together the results of the study, summarizing the main findings and drawing out potential policy conclusions which merit further consideration.



## 2 Measuring the uptake of innovations

### 2.1 Existing measures of Innovation

Measuring levels of innovation has been a burgeoning industry over recent years, fuelled by the significance attached to innovation as a driver of economic growth. A review of literature (primarily economic and innovation) was carried out to assess what measures of responses to changes in external conditions might be useful guides to policy discussions. The review has focused on the various published sources of measuring innovation, including specifically the 12 following measures of innovation:

1. European Innovation Scoreboard (EIS)
2. EU Performance Scoreboard for Research and Innovation
3. NESTA Innovation Index
4. INSEAD Global Innovation Index
5. World Economic Forum – Global Competitiveness Forum (Innovation)
6. Lopez-Claros Innovation Capacity Index
7. OECD - Measuring Innovation: A New Perspective
8. IBM Innovation Index of Australian Industry
9. Index of the Massachusetts Innovation Economy
10. Nordic Innovation Monitor
11. The Economist - EIU Innovation Ranking
12. The World Bank - Knowledge Economy Index

Two common features emerge across almost all measures, that: (1) their purpose is to benchmark innovation performance, i.e. to measure and compare the propensity with which firms, or economies, introduce new products or processes; and (2) policymakers are the primary target audience. Traditionally, measures have been based upon published statistics, although more recently bespoke survey data has become a more common addition to the measurement arsenal.

Most measures are based on a composite index, utilizing a number of indicators to provide an overall score. Table 2.1 presents average innovation rankings for the EU-27 and major competitors using the 5 measures that provide single index rankings. The results show that across the 5 rankings, Sweden is ranked as the no.1 country for innovation. Finland, the USA, the Netherlands, Denmark and Japan represent the next 5 countries. By these measures the main competitors of the EU (the US and Japan) outperform all but a handful of member states. This finding is perhaps in keeping with the fact that the US and Japan invest a higher proportion of GDP in research and development than the EU as a whole.

At the bottom of the rankings are found the BRIC economies, interrupted only by Greece and Romania from the EU. This illustrates a perceived notion that most EU economies are more innovative than the nations that are continuing to develop into major economic players.

Table 2.1 Average Innovation Ranking Scores (data are in most cases for 2009 and 2010)

| Country | INSEAD - GI | WEF – GCF | Lopez-<br>Claros - ICI | Economist<br>EIU | World Bank<br>KEI | Average<br>Ranking |
|---------|-------------|-----------|------------------------|------------------|-------------------|--------------------|
| SE      | 2           | 2         | 1                      | 5                | 2                 | <b>2,4</b>         |
| FI      | 6           | 7         | 2                      | 3                | 3                 | <b>4,2</b>         |
| USA     | 11          | 4         | 3                      | 4                | 6                 | <b>5,6</b>         |
| NL      | 8           | 8         | 5                      | 8                | 7                 | <b>7,2</b>         |
| DK      | 5           | 9         | 11                     | 10               | 5                 | <b>8,0</b>         |
| Japan   | 13          | 6         | 15                     | 1                | 12                | <b>9,4</b>         |
| UK      | 14          | 12        | 8                      | 18               | 11                | <b>12,6</b>        |
| DE      | 16          | 5         | 20                     | 6                | 18                | <b>13,0</b>        |
| LU      | 15          | 20        | 11                     | -                | 17                | <b>15,8</b>        |
| AT      | 21          | 18        | 23                     | 12               | 16                | <b>18,0</b>        |
| BE      | 17          | 19        | 22                     | 15               | 19                | <b>18,4</b>        |
| FR      | 22          | 15        | 24                     | 13               | 22                | <b>19,2</b>        |
| IE      | 19          | 29        | 18                     | 19               | 13                | <b>19,6</b>        |
| SI      | 26          | 45        | 31                     | 24               | 24                | <b>30,0</b>        |
| ES      | 30          | 42        | 28                     | 26               | 26                | <b>30,4</b>        |
| EE      | 29          | 33        | 25                     | 30               | 36                | <b>30,6</b>        |
| CZ      | 27          | 36        | 32                     | 28               | 31                | <b>30,8</b>        |
| IT      | 38          | 48        | 30                     | 22               | 28                | <b>33,2</b>        |
| CY      | 32          | 40        | 53                     | 25               | 30                | <b>36,0</b>        |
| HU      | 36          | 52        | 41                     | 27               | 25                | <b>36,2</b>        |
| PT      | 34          | 46        | 35                     | 33               | 37                | <b>37,0</b>        |
| LT      | 39          | 47        | 26                     | 38               | 45                | <b>39,0</b>        |
| MT      | 31          | 50        | 52                     | -                | 29                | <b>40,5</b>        |
| PL      | 47          | 39        | 40                     | 44               | 38                | <b>41,6</b>        |
| SK      | 37          | 60        | 39                     | 36               | 40                | <b>42,4</b>        |
| LV      | 44          | 70        | 27                     | 43               | 47                | <b>46,2</b>        |
| BG      | 49          | 71        | 33                     | 47               | 49                | <b>49,8</b>        |
| China   | 43          | 27        | 65                     | 54               | 63                | <b>50,4</b>        |
| Russia  | 64          | 63        | 49                     | 39               | 41                | <b>51,2</b>        |
| EL      | 46          | 83        | 62                     | 32               | 35                | <b>51,6</b>        |
| RO      | 52          | 67        | 47                     | 57               | 60                | <b>56,6</b>        |
| Brazil  | 68          | 58        | 87                     | 49               | 52                | <b>62,8</b>        |
| India   | 56          | 51        | 85                     | 56               | 82                | <b>66,0</b>        |

Source: Data from latest reporting year of each innovation index – in most cases 2009 or 2010

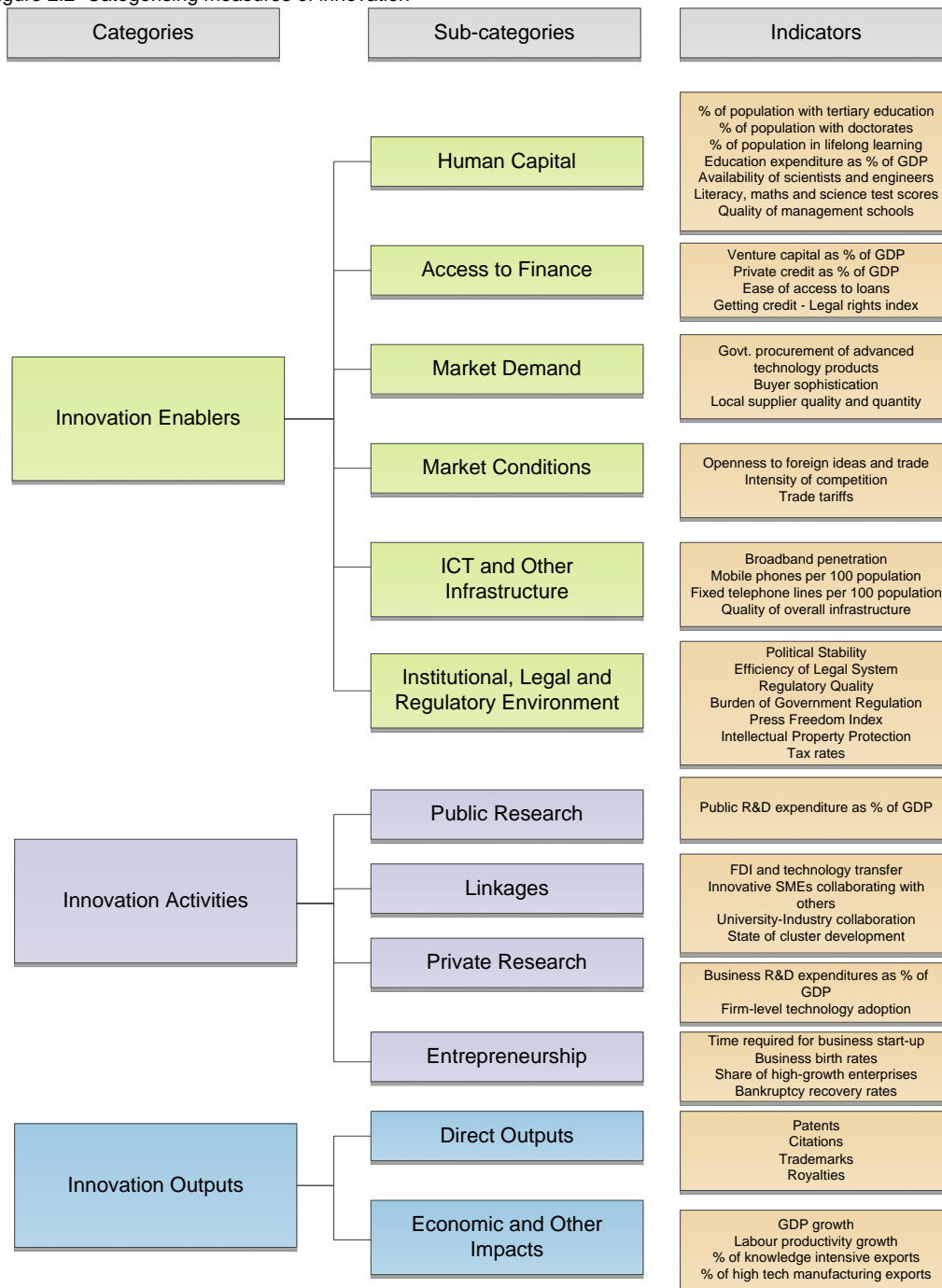
The results presented in this way are as notable for what they don't tell us. From an overall perspective, the relative changes in these rankings over time may be of interest and to varying extents it would be possible to calculate these changes, though most of these indices go back only a few years. More importantly for this study, the rankings tell us little about how innovation performance may translate into economic performance and then if poor performance may lead to lags or not. The analysis needs to delve deeper into these measures to understand what they measure, how and why, and then beyond that, how useful this is for measuring economic lags.

## 2.2 Components of current innovation measures – what do they measure?

Of the 12 measures reviewed, 7 are composite measures such as those used in table 2.1. These are constituted from a range of indicators which are then combined through various weightings and calculations to a single index score. The other 5 measures are presented as indicator sets where



Figure 2.2 Categorising measures of innovation



Source: Ecorys analysis

### 2.3 Existing measures don't allow for analysis of lags in take-up

Considering the factors and indicators identified illustrates the strong focus on measures of the level of innovation in an economy but with a focus on measuring direct innovation output and innovation activity, and of factors which promote an environment conducive to innovation (with a small number of indicators associated with each).

Only a handful of the measures have indicators that are expressed in the metrics of time to aid in explicit measurement of lags and these are related to business registration, time to start a business, property registration, administrative burdens and time to file taxes. While these specific indicators

provide some insight into lags arising from regulatory constraints they do not offer much wider insight into innovation take-up as a measure of economic change.

Despite the volume of work carried out on measures of innovation there is little in the literature which addresses differences in the rate at which different places, or groups, adopt, or take-up, innovations. Perhaps only the measures of ICT penetration offer an insight into this, though tellingly this is not the purpose for which these indicators are used, they are understood as part of the enabling infrastructure rather than as a measure of innovation outcomes.

The most relevant category for the analysis of innovation take-up in this way could be market demand, as a measure of the extent to which innovations are actually consumed. Market demand is considered as an enabling factor for innovation, indicating a known market opportunity, reducing the apparent commercial risks and this acts to stimulate innovation in the first place. But it can also be a measure of innovation uptake, and changes in uptake, yet the indicators in this area are only indirectly focussed on this through spend on innovative products and services. Market demand for innovation has not received the same attention as supply side factors. To fully make the link between innovation and economic outcomes, to consider the existence of lags or not requires closer examination of market demand.

## 2.4 Measuring innovation take-up

Among the earliest work in this area is a study carried out in the US by IBM in 2004<sup>16</sup>, which starts from the premise of innovation as an outcome of both technology push and market pull (demand). It focuses on customer value as fundamental to innovation, which is the value customers expect when they acquire a product or service. As Levitt surmised 'People do not buy products; they buy expectations of future benefits'<sup>17</sup>. Demand is created by applications that deliver this customer value. Consequently, the receptiveness of customers to innovation is the critical factor in rates of diffusion and adoption which determine the overall impact of a particular innovation.

The IBM work noted that innovation measures are stronger in measuring inputs and intermediate outputs, such as patents, than customer value and demand, and while this gives some general indications of innovation performance it leaves an information gap for policymakers. It also highlighted how some intermediate output indicators, such as market share, lag behind changes in innovation performance. Inadequate data on customer value as a driver of demand is seen as the primary reason for the input based focus of measures. Addressing this issue is challenging as demand is a matter of understanding customer value and decisions to adopt innovations, with factors such as ease of use, business adjustment costs, observability, quality, convenience, testing, training and technical support all being relevant, on top of the usual financial considerations.

### 2.4.1 Establishing a conceptual framework for measures of demand

In the UK, NESTA, the government-backed National Endowment for Science, Technology and the Arts, has carried out a range of work on innovation in recent years and reported in 2009 on the issue of data for market demand for innovation<sup>18</sup>. It highlighted that while the important role of demand in innovation is increasingly understood, data relevant to tracking it remains very limited. While there is some data on mass consumer demand for innovations from business, there is very

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<sup>16</sup> IBM (2004) Measuring Innovation for National Prosperity, Innovation Framework Report

<sup>17</sup> Levitt, Theodore (1969). The Marketing Mode: Pathways to Corporate Growth.

<sup>18</sup> NESTA (2009) Innovation Index Working Paper, Measuring the nature of demand for innovation in the UK: The challenges of an indicator approach

little data on other innovation demand such as business to business (B2B) or government. It proposed a framework to be used to structure an improvement in measurement, of four indicators of innovation demand addressing each key component of demand:

5. Receptiveness to innovative products and services
6. Customers involvement in the innovation process
7. Understanding of customers needs (certainty regarding the level of demand)
8. Money spent on innovative products and services

This again highlights receptiveness to innovation as a key factor. It also draws in customer involvement and understanding and the final element attempting to measure the economic value of innovation demand. Across these 4 framework categories the distinction was made between 3 groups, consumers, business and government, and 4 types of innovation demand, consumer-business, consumer-government, government-business and business-business are defined. In all but consumer-business demand, significant information gaps were identified.

#### 2.4.2 *Current Measures of market demand for innovation – the CIS and Eurobarometer*

The background work all points to consumer receptiveness to innovation being a key factor in the diffusion and adoption of innovation, yet actual measures in this area are limited. Among the innovation measures reviewed previously, there are few indicators of market demand, in total only 20 (3%) of the 700 indicators could be classed as indicators of market demand, and only half of the reviewed measures have any indicators of this type. Among the 20 individual measures less than half are quantitative measures of demand and those are of general market size and sectoral investment. The qualitative indicators also tend to have a general focus such as consumer confidence or corporate sales.

Indicators more directly relevant to innovation uptake include 'buyer sophistication', 'government procurement of advanced technology products' and 'uncertainty of demand as an obstacle to innovation'. These indicators are drawn from two primary sources, the EC Community Innovation Survey (CIS) and the Executive Opinion Survey carried out by the World Economic Forum (WEF), which ask the following questions of relevance:

##### *Community Innovation Survey*

- How important (High / Medium / Low / N/A) to this business's innovation related activities was information from: clients or customers?
- Did your business co-operate on any innovation activities with any of the following: clients or customers? Answer - regional / national / Other Europe / All other countries
- During the three-year period 20XX-20XX, how important (High / Medium / Low / N/A) were the following factors as constraints to your innovation activities or influencing a decision not to innovate? Uncertain demand for innovative goods or services
- A range of factors may inhibit your ability to innovate. Please grade the importance (High / Medium / Low / N/A) of the following constraints during the period 20XX-20XX: Lack of customer responsiveness to new goods or services.

### *Executive Opinion Survey*

- How well do companies in your country treat customers? [1 = generally treat their customers badly; 7 = are highly responsive to customers and customer retention]
- In your country, how do buyers make purchasing decisions? [1 = based solely on the lowest price; 7 = based on a sophisticated analysis of performance attributes]
- Do government procurement decisions foster technological innovation in your country? [1 = no, not at all; 7 = yes, extremely effectively]
- To what extent do businesses in your country absorb new technology? [1 = not at all; 7 = aggressively absorb]

The CIS questions are directed towards firms and are more focused on internal business process and the perception of consumer demand as a factor in the decision to innovate, this makes them perhaps more useful as measures of market demand as an enabling factor and then indirectly as a measure of uptake of innovation. The questions in the Executive Opinion Survey are more clearly focused on the perceptions of a wider audience, not just consumers as customers but also government and other businesses as customers and important actors in demand for innovation. Questions 7 and 8, in particular are directly relevant to measuring innovation uptake from government and business, though the questions are subjective and perception based. The questions also fit quite closely to the four point framework proposed by NESTA.

In a slightly different approach, the European Commission carried out a special survey in 2005 on 'Population Innovation Readiness' as part of Eurobarometer<sup>19</sup>. This asked a sample population a range of questions directly relevant to measuring their receptiveness to innovation, including:

- In general, to what extent are you attracted towards innovative products or services, in other words new or improved products or services? (Very attracted / Fairly attracted / Not very attracted / Not at all attracted / Don't Know)
- Compared to your friends and family, would you say that you tend to be...? (More inclined to purchase innovative products or services / Less inclined to purchase innovative products or services / As inclined to purchase innovative products or services as they are (SPONTANEOUS) / Don't Know)
- What does "innovation" mean for you? The creation of new products or services or the improvement of existing products or services? (The creation of new products or services / The improvement of existing products or services / Don't Know)
- In general, when an innovative product or service is put on the market and can replace a product or service that you already trust and regularly buy, do...? (You prefer to continue purchasing a product or service that you already trust and do not try the innovative one / You quickly try the innovative product or service at least once / Don't Know)

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<sup>19</sup> Eurobarometer (2005) Population Innovation Readiness. Special Eurobarometer 236 / Wave 63.4.

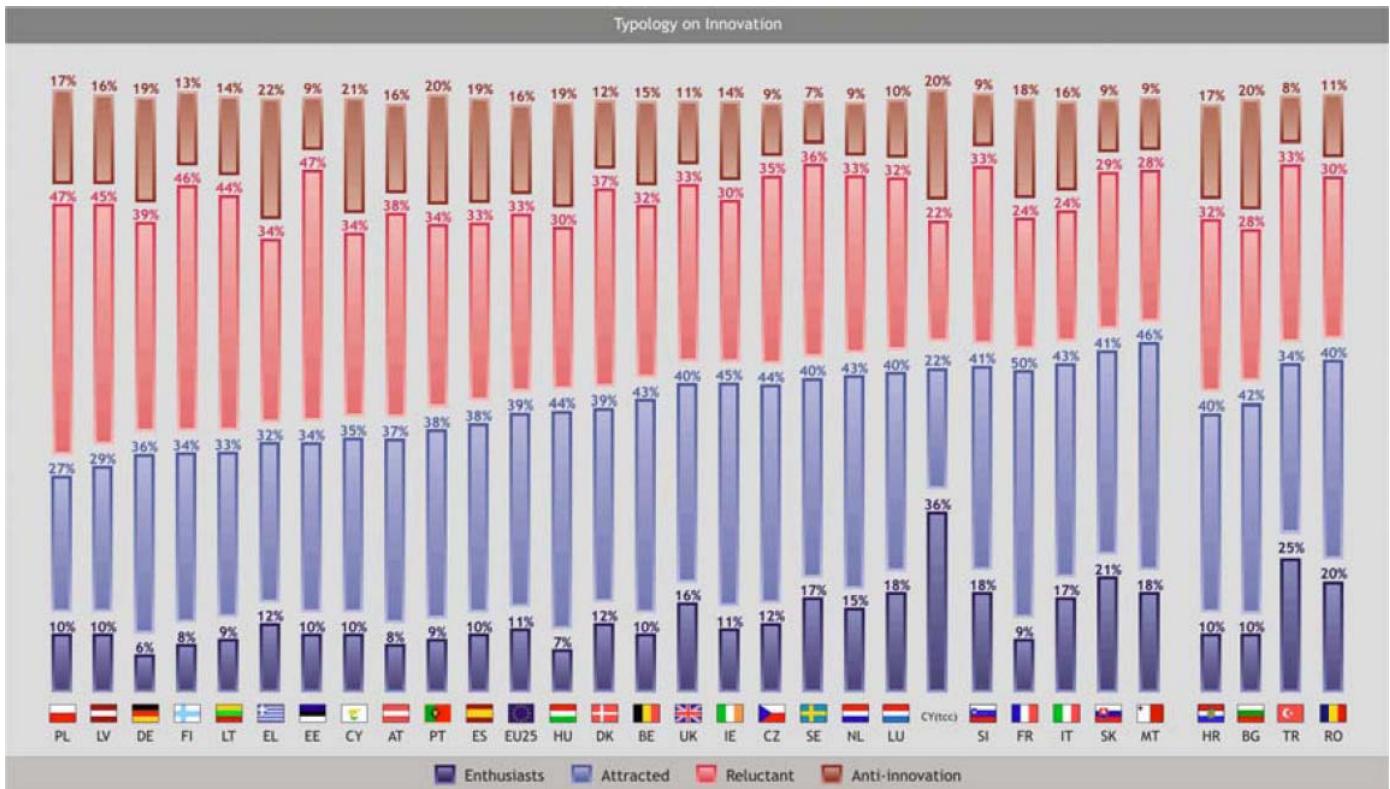
- You would be willing to replace a product or a service that you already use by an innovative one... (Even if this is significantly more expensive / Only if this is a little more expensive / Only if this would cost the same / I would never be willing to purchase an innovative product or service (SPONTANEOUS) / Don't Know)
- With which of the following statements do you agree?
  - Innovative products or services are most of the time gadgets
  - Innovative products or services are a matter of fashion
  - Innovative products or services often simplify everyday life
  - A company that sells an innovative product or service improves the image of all its products or services
  - A company which does not innovate is a company that will not survive
  - Purchasing an innovative product or service is risky for the consumer
  - The advantages of innovative products or services are often exaggerated
  - Innovation is essential for improving economic growth
  - None of these (SPONTANEOUS)
  - Don't Know

The findings of the study identified 4 types of consumers:

1. **Anti-innovation** – generally opposed to innovation, primarily females and over 55's, comprised 16% of the EU population sample.
2. **Reluctant** – not yet ready to adopt innovations, mostly female and over 40's, comprising approximately 33% of the EU population sample.
3. **Attracted** – this group is somewhat attracted to new products and services, usually younger, mostly male and white collar, comprising 39% of the EU population sample.
4. **Enthusiasts** – calling out for innovation and early adopters, primarily male, with high proportions of students and senior managers, comprising 11% of the EU population sample.

Interestingly the survey returns showed a nearly 50-50 split between those with positive and negative views on innovation. As is shown below in figure 2.3, the proportions varied considerably across member states, Poland, Latvia, Germany and Finland among those with a more negative perception and a 60 / 40 split. While Malta, Slovakia, Italy and France among those with the reverse and a more positive 40 / 60 split. This is surprising to the extent that Germany and Finland are placed among the top performers by most innovation measures but perhaps illustrates that while each country has good conditions for innovation and innovative firms, that their innovative efforts find greater export markets than domestic.

Figure 2.3 Typology on Innovation - Source: Eurobarometer Population Innovation Readiness 2005



The report made only limited progress in explaining the differences in responsiveness. The question regarding the role of cost confirmed that it remains an important factor in innovation adoption decisions. It also shed some light on the role of quality / trust in purchasing a new product, 14% agreeing that the purchasing of an innovative product or service is risky for the consumer and 30% that the advantages of innovative products or services are often exaggerated. As only a one off special survey, it is not possible to track changes in these factors over time, limiting its ongoing usefulness in tracking economic responses to change.

### 2.4.3 Current Measures of market demand for innovation – the Consumer Innovation Confidence (CIC) index

In a recent development the Institute for Innovation and Information Productivity (IIIP)<sup>20</sup> has looked specifically at market demand for innovation. Innovation confidence indexes have been developed - primarily the Consumer Innovation Confidence (CIC) index and the Organisational Innovation Confidence (OIC) index – on an annual basis since 2007 and in 2009 covered 33 countries. The index measures consumer attitudes to innovation over time based on a questionnaire survey which asks questions such as:

Answer on scale: Strongly Agree / Somewhat Agree / Neither Agree or Disagree / Disagree  
Somewhat / Strongly Disagree / Don't Know / Refused

- In the next 6 months, you are likely to buy products or services that are new to the market

<sup>20</sup> J. Levie – IIIP (2010) The IIIP Innovation Confidence Indexes 2009 Report

- In the next 6 months, you are likely to try products or services that use new technologies for the first time
- In the next 6 months, new products and services will improve your life

The CIC finds that while age, gender and income play important roles in innovation receptiveness, community values are also crucial. Their results (see table 2.2) show that more 'traditional' societies display generally much higher levels of innovation confidence than secular/rational societies<sup>21</sup>.

Table 2.2 Innovation Confidence Index – Consumer Innovation Confidence (Higher values indicate higher consumer innovation confidence)

| Nation         | 2007-2009 mean | 2007 | 2008 | 2009 |
|----------------|----------------|------|------|------|
| Colombia       | 78             |      | 78   |      |
| UAE            | 75             | 76   |      | 73   |
| India          | 73             | 73   |      |      |
| Peru           | 70             |      | 70   | 71   |
| Uruguay        | 70             |      | 75   | 66   |
| Jamaica        | 69             |      | 69   |      |
| Angola         | 69             |      | 69   |      |
| South Africa   | 68             |      | 68   |      |
| Argentina      | 68             |      | 68   |      |
| Brazil         | 67             | 68   | 68   | 64   |
| Chile          | 66             |      | 67   | 66   |
| Ireland        | 66             | 66   | 65   |      |
| Spain          | 65             |      | 66   | 64   |
| Ecuador        | 64             |      | 65   | 62   |
| Iran           | 62             |      | 62   | 63   |
| Macedonia      | 61             |      | 61   |      |
| Mexico         | 60             |      | 60   |      |
| Denmark        | 59             |      |      | 59   |
| China          | 59             |      | 60   | 57   |
| United States  | 59             | 58   | 60   | 58   |
| Italy          | 55             | 54   | 56   |      |
| Iceland        | 52             |      | 53   | 50   |
| Turkey         | 51             | 51   |      |      |
| United Kingdom | 49             | 55   | 50   | 43   |
| Belgium        | 48             |      |      | 48   |
| Israel         | 45             |      | 45   |      |
| Croatia        | 45             |      | 55   | 35   |
| Slovenia       | 44             | 48   | 47   | 38   |
| Finland        | 43             | 44   | 42   |      |
| Switzerland    | 41             |      |      | 41   |
| Korea Republic | 39             |      | 44   | 34   |
| Netherlands    | 38             | 38   |      |      |

<sup>21</sup> In this context traditional societies are defined from the scores of 5 indicators from the World Values Survey relating to communal values including, religiosity, patriotism, need to respect authority, teaching goals (obedience v independence) and family values. Countries classed as traditional in this way include United Arab Emirates, India, Colombia, Peru, Jamaica, Uruguay, Angola, South Africa, Argentina, Ireland, Brazil, Ecuador, Mexico, Turkey, the US and Iran. Secular / rational societies include the UK, Estonia, Malta, Japan, China, the Netherlands, Denmark, Spain, Israel, Hong Kong, Switzerland, Slovenia, Korea, Finland, Belgium, Italy, Iceland, Macedonia.

| Nation        | 2007-2009 mean | 2007 | 2008 | 2009 |
|---------------|----------------|------|------|------|
| Honk Kong SAR | 30             |      |      | 30   |
| Japan         | 24             |      | 24   |      |

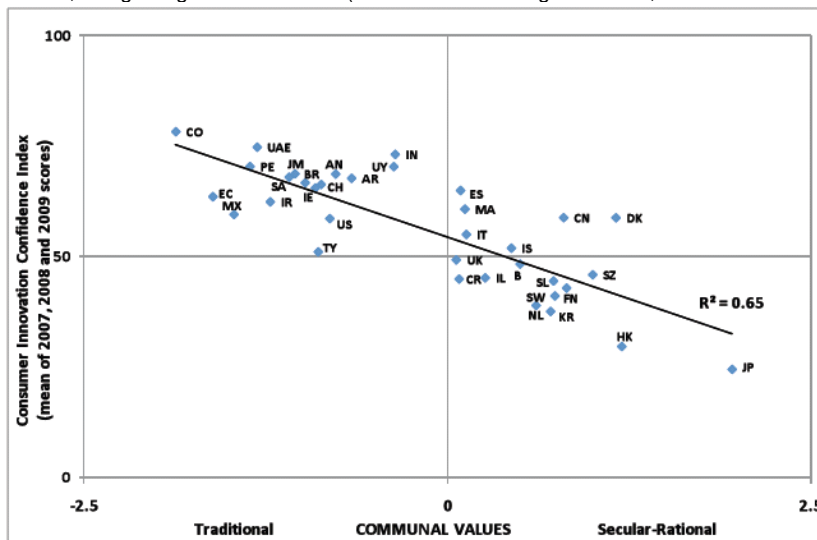
Source: J. Levie – IIIP (2010) The IIIP Innovation Confidence Indexes 2009 Report

Testing this correlation showed that this classification could account for over 60% of the variation in the CIC between countries. The explanation proffered is that innovation offers an acceptable release for consumers in these societies where other areas of their lives are restricted, this offers a benefit / utility of innovative products that is not as relevant in less traditional societies.

The results of the CIC (figure 2.4) show that the EU countries, the majority of which are classed as secular-rational, generally fall in the bottom half of the CIC, with the highest scores recorded by Ireland (defined as traditional), Spain and Denmark and the lowest from the Netherlands, Finland and Slovenia. Competitors such as the US (traditional) and China (secular-rational) are around halfway, with each having contradictory elements within their community values – it is suggested - may explain this, e.g. religiosity and patriotism in the US and authoritarianism in China.

Whilst the classification of individual countries as traditional or secular-rational might be contentious, it is nonetheless instructive to illustrate the apparent differences amongst different economies to adopt new products and services.

Figure 2.4 Association between Consumer Innovation Confidence and national community values for 33 nations, Hong Kong and Shen Zhen (IC values are averages of 2007, 2008 and 2009 values)



Source for community values: World Values Survey latest available years (2005, 2004 or 2000)

Source: J. Levie – IIIP (2010) The IIIP Innovation Confidence Indexes 2009 Report

The IIIP has also begun to compile an Organisational Innovation Confidence (OIC) Index asking very similar questions as the CIC but to firms regarding their purchasing and innovation use expectations. This could fill one of the key information gaps identified by NESTA in their conceptual framework for innovation demand indicators.



## 3 Evidence for lags in the take-up of innovations

### 3.1 Introduction

One of the challenges for this study has been identifying evidence for the central proposition regarding the occurrence of lags in the take-up of innovations. Quantitative and anecdotal evidence for the slow take-up of innovations abounds, but evidence as to the differential level of take-up of particular innovations across economies is much more difficult to identify.

Our review of the literature demonstrates that this is an area where studies are relatively limited, echoing the limited focus on this topic identified in the previous Chapter. In order to assess the extent to which lags might be identified in the take-up of innovations we have identified three innovations where distinctive products have been introduced, robust annual datasets are available and the speed of take-up is sufficient for patterns to be visible over a relatively short timeframe. These are:

- Broadband internet
- Mobile telephones
- DVD player

Through this data we are seeking to identify whether common patterns can be identified in the take-up of these innovations and what this might signify in terms of the existence of differences in the speed and rate of adoption. From the data we draw 4 key messages that:

5. Patterns of take-up follow broadly similar trajectories;
6. Lags in take-up are visible;
7. After an initial period, wealth and income effects do not appear to influence take-up rates; and
8. Common and consistent patterns are hard to identify.

### 3.2 Patterns of take-up follow a broadly similar trajectory

Measured in terms of per capita possession, both DVD players and mobile telephones, demonstrate similar trajectories of market penetration. From slow beginnings, where less than 10% of the population have a mobile phone subscription (Table 3.1) or own a DVD player (Figure 3.1) there is a rapid take-up, with ownership levels rapidly rising over a period of 3-4 years. Broadband figures show a similar pattern, although with a more pronounced profile, which may be the consequence of providers connecting areas with higher concentrations of population in the early phase of the roll-out (Figure 3.2).

What is instructive is that the trajectories are broadly similar although the date of take-off may differ (Figure 3.2). The speed of take off is more gradual in those countries where adoption appears to have begun earlier, with more rapid rises visible in those countries where adoption began later. Although the trajectories are similar though, it is equally apparent that some places began to adopt these particular innovations later than others, a point which is explored further in the following section.

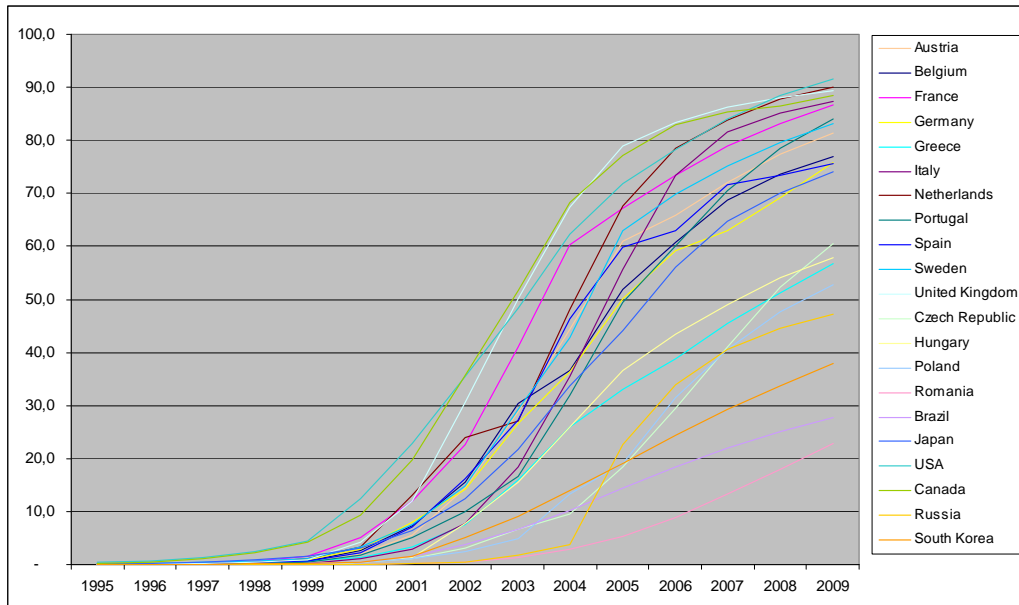


Table 3.1 Number of mobile phone subscriptions per 100 people.

|                 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002  | 2003  | 2004  | 2005  | 2006  | 2007  | 2008  | 2009  |
|-----------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|
| Austria         | 0.0  | 0.1  | 0.3  | 0.3  | 0.5  | 0.7  | 1.0  | 1.5  | 2.2  | 2.8  | 3.5  | 4.8  | 7.5  | 14.5 | 28.7 | 53.2 | 76.4 | 81.4 | 83.3  | 89.4  | 97.6  | 105.3 | 112.2 | 119.3 | 129.7 | 136.7 |
| Belgium         | 0.0  | 0.0  | 0.0  | 0.1  | 0.2  | 0.3  | 0.4  | 0.5  | 0.6  | 0.7  | 1.3  | 2.3  | 4.7  | 9.6  | 17.3 | 31.3 | 55.2 | 75.3 | 78.9  | 83.4  | 88.1  | 92.2  | 94.0  | 102.0 | 111.6 | 117.5 |
| Czech Republic  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.1  | 0.3  | 0.5  | 1.9  | 5.1  | 9.4  | 19.0 | 42.5 | 68.1 | 84.5  | 95.4  | 105.9 | 115.5 | 121.3 | 128.8 | 133.5 | 137.5 |
| Denmark         | 0.6  | 0.9  | 1.1  | 1.5  | 2.0  | 2.4  | 2.9  | 3.4  | 4.1  | 6.9  | 9.7  | 15.7 | 25.1 | 27.4 | 36.5 | 49.5 | 63.0 | 74.0 | 83.4  | 88.5  | 95.6  | 100.6 | 107.3 | 115.8 | 120.1 | 125.0 |
| Finland         | 1.1  | 1.4  | 1.7  | 2.1  | 2.8  | 3.8  | 5.2  | 6.4  | 7.7  | 9.7  | 13.3 | 20.3 | 29.3 | 42.1 | 55.3 | 63.4 | 72.1 | 80.5 | 86.9  | 91.1  | 95.4  | 100.5 | 107.7 | 115.1 | 128.8 | 144.6 |
| France          | 0.0  | 0.0  | 0.0  | 0.1  | 0.2  | 0.3  | 0.5  | 0.7  | 0.8  | 1.0  | 1.5  | 2.2  | 4.2  | 10.0 | 19.1 | 36.4 | 49.1 | 62.2 | 64.5  | 69.2  | 73.5  | 78.8  | 84.2  | 89.7  | 93.4  | 95.5  |
| Germany         | 0.0  | 0.0  | 0.0  | 0.1  | 0.1  | 0.2  | 0.3  | 0.7  | 1.2  | 2.2  | 3.1  | 4.6  | 6.7  | 10.1 | 17.0 | 28.6 | 58.7 | 68.3 | 71.9  | 78.7  | 86.6  | 96.2  | 104.0 | 116.9 | 128.3 | 127.8 |
| Greece          | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.5  | 1.4  | 2.6  | 4.9  | 8.7  | 18.8 | 35.8 | 54.2 | 72.6 | 84.7  | 81.1  | 84.4  | 92.7  | 99.0  | 110.6 | 123.9 | 119.1 |
| Hungary         | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.1  | 0.2  | 0.4  | 1.4  | 2.6  | 4.6  | 6.9  | 10.4 | 15.9 | 30.1 | 48.8 | 67.8  | 78.4  | 86.4  | 92.5  | 99.1  | 109.9 | 122.1 | 118.0 |
| Iceland         | 0.0  | 0.0  | 1.1  | 2.0  | 2.6  | 3.1  | 3.9  | 5.0  | 5.9  | 6.6  | 8.2  | 11.5 | 17.3 | 23.9 | 37.8 | 62.0 | 76.5 | 87.5 | 91.2  | 97.1  | 99.6  | 95.7  | 100.2 | 105.8 | 106.8 | 105.3 |
| Ireland         | 0.0  | 0.0  | 0.0  | 0.1  | 0.2  | 0.4  | 0.7  | 0.9  | 1.2  | 1.7  | 2.5  | 4.4  | 7.9  | 14.9 | 25.5 | 44.7 | 64.7 | 76.8 | 76.1  | 87.1  | 94.1  | 102.0 | 109.8 | 114.1 | 113.8 | 107.9 |
| Italy           | 0.0  | 0.0  | 0.0  | 0.0  | 0.1  | 0.1  | 0.5  | 1.0  | 1.4  | 2.1  | 3.9  | 6.9  | 11.2 | 20.6 | 35.9 | 53.1 | 74.0 | 89.4 | 94.1  | 98.0  | 107.7 | 121.9 | 136.3 | 151.4 | 151.6 | 147.0 |
| Luxembourg      | 0.0  | 0.0  | 0.1  | 0.1  | 0.1  | 0.2  | 0.2  | 0.3  | 0.3  | 1.3  | 3.2  | 6.6  | 10.9 | 16.0 | 30.7 | 48.5 | 69.4 | 92.5 | 105.6 | 118.9 | 102.5 | 109.9 | 151.9 | 144.1 | 147.1 | 148.1 |
| Netherlands     |      | 0.0  | 0.1  | 0.2  | 0.2  | 0.4  | 0.5  | 0.8  | 1.1  | 1.4  | 2.1  | 3.5  | 6.5  | 11.0 | 21.3 | 42.6 | 67.6 | 76.2 | 75.2  | 81.7  | 91.1  | 97.0  | 105.5 | 117.2 | 124.8 | 127.7 |
| Norway          | 0.9  | 1.5  | 2.1  | 2.9  | 3.6  | 4.0  | 4.6  | 5.5  | 6.6  | 8.6  | 13.6 | 22.5 | 28.8 | 38.0 | 46.7 | 59.8 | 71.9 | 79.7 | 83.5  | 88.9  | 98.4  | 102.6 | 104.1 | 106.7 | 109.3 | 111.4 |
| Portugal        | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.1  | 0.1  | 0.4  | 1.0  | 1.7  | 3.4  | 6.6  | 14.9 | 30.3 | 45.9 | 65.2 | 77.6 | 83.8  | 96.0  | 100.8 | 108.5 | 115.4 | 126.7 | 140.1 | 148.8 |
| Slovak Republic | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.1  | 0.1  | 0.2  | 0.5  | 3.7  | 8.7  | 12.4 | 23.1 | 39.9 | 54.3  | 68.4  | 79.4  | 84.3  | 90.8  | 112.5 | 102.2 | 101.7 |
| Spain           |      |      | 0.0  | 0.0  | 0.0  | 0.1  | 0.1  | 0.3  | 0.5  | 0.7  | 1.0  | 2.4  | 7.6  | 11.0 | 16.2 | 37.6 | 60.3 | 72.8 | 81.3  | 88.9  | 90.9  | 99.1  | 104.9 | 109.9 | 111.5 | 113.8 |
| Sweden          | 0.7  | 0.9  | 1.3  | 2.1  | 2.9  | 4.1  | 5.4  | 6.6  | 7.6  | 8.9  | 15.7 | 22.7 | 28.2 | 35.8 | 46.4 | 57.9 | 71.9 | 80.8 | 89.1  | 98.1  | 97.4  | 100.4 | 105.4 | 110.5 | 118.3 | 125.9 |
| Switzerland     | 0.0  | 0.0  | 0.0  | 0.1  | 0.5  | 1.1  | 1.9  | 2.6  | 3.1  | 3.7  | 4.8  | 6.4  | 9.4  | 14.7 | 23.8 | 42.8 | 64.6 | 73.0 | 78.8  | 84.3  | 84.9  | 91.8  | 99.4  | 109.3 | 118.0 | 122.3 |
| United Kingdom  | 0.0  | 0.1  | 0.2  | 0.5  | 1.0  | 1.7  | 1.9  | 2.2  | 2.6  | 3.9  | 6.8  | 9.9  | 12.5 | 15.1 | 25.4 | 46.3 | 73.8 | 78.3 | 82.9  | 90.9  | 99.5  | 108.6 | 115.7 | 121.2 | 126.3 | 130.6 |
| Latvia          | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.1  | 0.3  | 0.6  | 1.2  | 3.2  | 6.9  | 11.5 | 16.9 | 27.9 | 39.2  | 52.6  | 66.7  | 81.7  | 95.8  | 97.7  | 98.9  | 105.4 |
| Lithuania       | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.1  | 0.4  | 1.4  | 4.6  | 7.5  | 9.4  | 15.0 | 29.2 | 47.5  | 60.9  | 88.8  | 127.4 | 139.2 | 146.4 | 151.2 | 151.0 |
| Poland          | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.1  | 0.2  | 0.6  | 2.1  | 5.0  | 10.3 | 17.6 | 26.1 | 36.3  | 45.5  | 60.4  | 76.4  | 96.3  | 108.5 | 115.3 | 117.7 |
| Romania         | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.1  | 0.9  | 2.9  | 6.1  | 11.3 | 17.5 | 23.3  | 32.3  | 47.0  | 61.7  | 74.2  | 95.1  | 114.7 | 119.4 |
| Slovenia        | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.2  | 0.3  | 0.8  | 1.4  | 2.1  | 4.7  | 8.2  | 31.9 | 61.2 | 73.9 | 83.7  | 87.2  | 92.5  | 87.9  | 90.7  | 95.9  | 102.0 | 104.0 |
| Estonia         | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.2  | 0.5  | 0.9  | 2.1  | 4.9  | 10.3 | 17.8 | 28.1 | 40.6 | 47.8 | 64.9  | 77.6  | 93.1  | 107.3 | 123.4 | 147.6 | 188.2 | 203.0 |
| Cyprus          | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.2  | 0.5  | 0.7  | 1.4  | 2.2  | 3.2  | 6.1  | 9.5  | 12.2 | 15.2 | 19.5 | 27.8 | 39.4 | 51.8  | 67.5  | 79.6  | 93.6  | 102.7 | 115.8 | 117.9 | 122.0 |

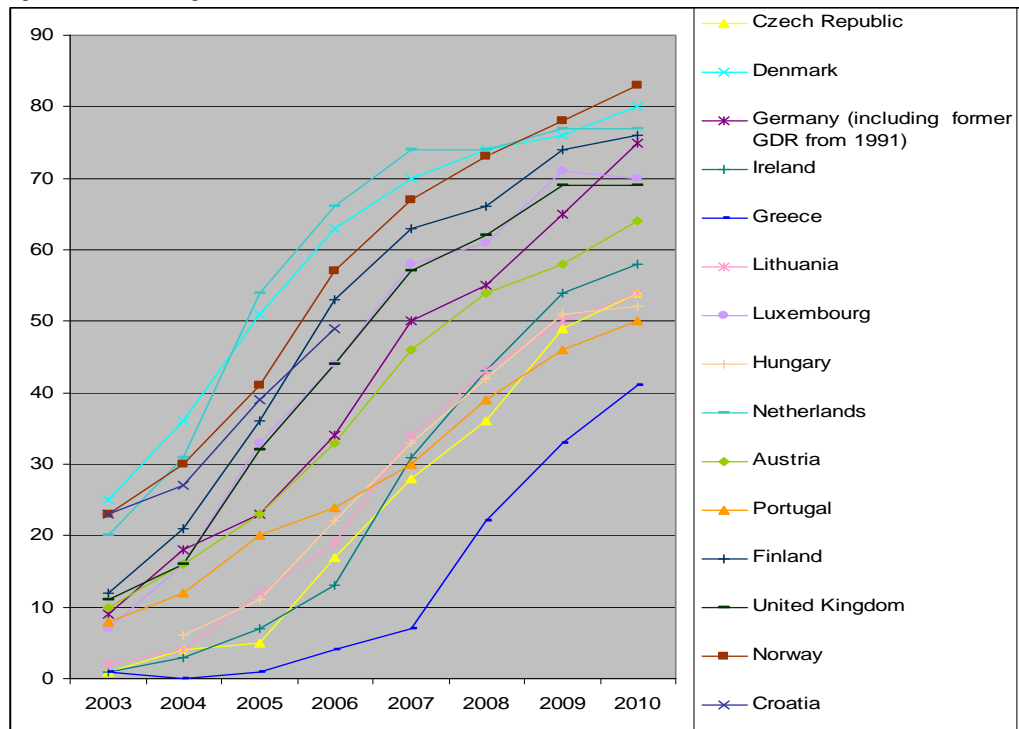
Source: ITU World Telecommunication/ICT Indicators Database 2010 (14th Edition)

Figure 3.1 Possession of DVD players per 100 people



Source: Euromonitor Passport: Consumer Electronics 2010 – extracted Jan 2011

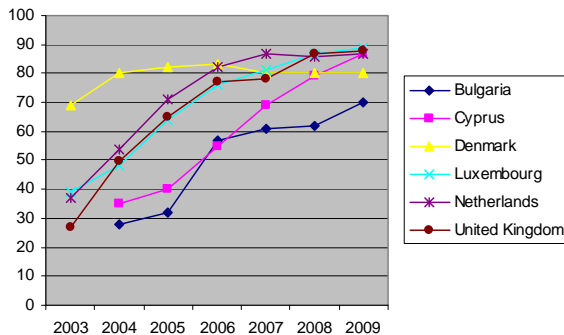
Figure 3.2 Percentage of households with broadband access



Source: Eurostat, 2011. *Households having access to the internet, by type of connection – broadband [online]*. Available from: <http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=1&language=en&ocode=tin00073> [Accessed 1 February 2011].

However, the picture is less clear when we turn to data about particular sections of the economy. Figure 3.3 illustrates the differential proportion of enterprises with access to broadband across six EU Member States. The lags in take-up here are not constant but vary over time, with clear phases of catching up but also some step phases visible.

Figure 3.3 Enterprises with broadband access by selected Member State

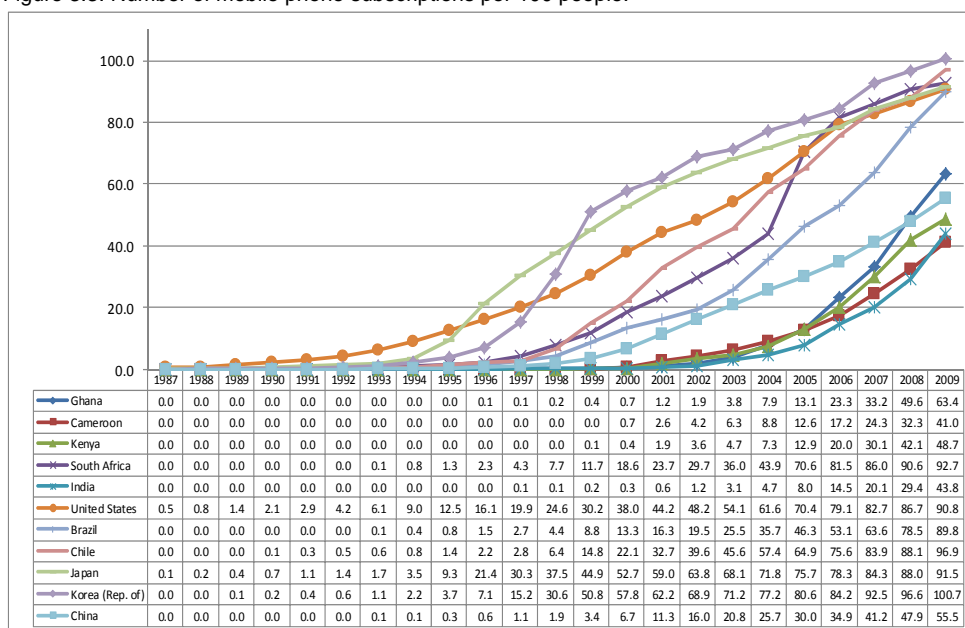


Source: Eurostat, 2011. *Enterprises having a broadband connection* [tin00063]. [Accessed 27 January 2011].

Examination of ownership data for mobile phone subscriptions across international comparisons (Figure 3.4) illustrates a similar picture, where trajectories are again a little more diverse in their overall shape. What is apparent is that the temptation of some analysts to group together particular countries might be too simplistic when considering lags in the take-up of innovation. Intuitively, one might expect countries that are developing at a faster rate – such as the BRIC countries – to see greater uptake of mobile telephony. However, figure 3.4 shows this to be false. Chile, for example, has a greater penetration of mobile phone subscriptions than Brazil and China as well as the United States and Japan. In fact, in this dataset, only South Korea has a higher rate of penetration.

This data set also illustrates that in the case of mobile phones the US has been slower to adopt this innovation than most European member states, with the proportion of the population with mobile phone subscriptions exceeding 50% only in 2003, at least 3 years later than most European states and on a par with Latvia and Lithuania.

Figure 3.3. Number of mobile phone subscriptions per 100 people.



Source: ITU, World Telecommunication/ICT Indicators Database 2010 (14th Edition)

### 3.3 Lags are visible

From the data available it is evident that the adoption of innovations occurs earlier in some countries than others. It is also apparent that the level of adoption varies across countries. Picking out a few patterns from the data we can see that:

The US and Canada were early adopters of DVD players (Table 3.2), soon followed by France, the Netherlands and the UK. Japan was slower in its uptake of this technology with South Korea, Romania and Brazil having the lowest levels of take-up at the end of our data series in 2009. Of other European countries, both Greece and Poland have relatively low rates of ownership.

Table 3.2. Possession of DVD players per 100 people

| Country     | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|-------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Japan       | 0,1  | 0,2  | 0,3  | 0,5  | 0,9  | 1,6  | 3,2  | 6,3  | 12,4 | 21,6 | 33,7 | 44,1 | 56,0 | 64,8 | 70,1 | 74,1 |
| S-Korea     | 0,0  | 0,0  | 0,0  | 0,1  | 0,1  | 0,2  | 0,4  | 1,6  | 5,0  | 9,1  | 13,9 | 19,1 | 24,3 | 29,2 | 33,8 | 37,9 |
| Czech R.    | 0,0  | 0,0  | 0,0  | 0,0  | 0,0  | 0,1  | 0,5  | 1,2  | 3,0  | 6,7  | 9,6  | 18,5 | 29,6 | 41,0 | 52,3 | 60,6 |
| Hungary     | 0,0  | 0,0  | 0,0  | 0,0  | 0,0  | 0,1  | 0,3  | 1,4  | 7,8  | 15,6 | 26,0 | 36,5 | 43,5 | 49,0 | 54,2 | 57,9 |
| Poland      | 0,0  | 0,0  | 0,0  | 0,0  | 0,1  | 0,2  | 0,5  | 1,1  | 2,4  | 4,8  | 13,3 | 19,1 | 31,4 | 40,6 | 47,7 | 52,9 |
| Romania     | 0,0  | 0,0  | 0,0  | 0,0  | 0,0  | 0,0  | 0,1  | 0,2  | 0,5  | 1,3  | 2,8  | 5,3  | 8,8  | 13,3 | 18,0 | 22,9 |
| Russia      | 0,0  | 0,0  | 0,0  | 0,0  | 0,0  | 0,0  | 0,1  | 0,2  | 0,4  | 1,7  | 3,8  | 22,6 | 34,0 | 40,5 | 44,6 | 47,3 |
| Brazil      | 0,0  | 0,0  | 0,0  | 0,0  | 0,1  | 0,2  | 0,5  | 1,6  | 3,7  | 6,6  | 10,3 | 14,4 | 18,3 | 21,9 | 25,1 | 27,7 |
| Canada      | 0,1  | 0,3  | 0,5  | 1,0  | 2,2  | 4,1  | 9,3  | 19,8 | 35,8 | 51,7 | 68,3 | 77,1 | 83,0 | 85,3 | 86,4 | 88,5 |
| USA         | 0,2  | 0,4  | 0,7  | 1,2  | 2,4  | 4,4  | 12,4 | 22,9 | 35,5 | 48,3 | 62,2 | 71,9 | 78,3 | 84,0 | 88,5 | 91,6 |
| Austria     | 0,0  | 0,0  | 0,1  | 0,1  | 0,3  | 0,5  | 2,1  | 5,6  | 14,4 | 28,9 | 44,3 | 60,9 | 65,8 | 72,2 | 77,4 | 81,4 |
| Belgium     | 0,0  | 0,0  | 0,1  | 0,2  | 0,3  | 0,6  | 2,6  | 7,3  | 15,4 | 30,4 | 36,6 | 51,9 | 60,7 | 68,7 | 73,7 | 77,0 |
| France      | 0,0  | 0,1  | 0,2  | 0,3  | 0,7  | 1,6  | 5,0  | 11,9 | 22,6 | 41,0 | 60,2 | 67,2 | 73,4 | 79,0 | 83,1 | 86,8 |
| Germany     | 0,0  | 0,1  | 0,1  | 0,2  | 0,4  | 0,8  | 2,9  | 8,0  | 14,1 | 26,5 | 36,4 | 50,1 | 59,3 | 62,9 | 69,1 | 75,9 |
| Greece      | 0,0  | 0,0  | 0,1  | 0,1  | 0,3  | 0,6  | 1,4  | 3,4  | 7,5  | 15,9 | 26,0 | 33,0 | 38,8 | 45,5 | 51,3 | 56,8 |
| Italy       | 0,0  | 0,0  | 0,1  | 0,1  | 0,2  | 0,3  | 1,2  | 2,9  | 7,8  | 18,5 | 35,4 | 55,7 | 73,5 | 81,7 | 85,2 | 87,3 |
| Netherlands | 0,1  | 0,1  | 0,2  | 0,3  | 0,5  | 1,0  | 3,4  | 13,0 | 24,0 | 27,0 | 48,1 | 67,6 | 78,4 | 83,8 | 87,8 | 90,0 |
| Portugal    | 0,0  | 0,0  | 0,0  | 0,1  | 0,2  | 0,4  | 1,7  | 5,0  | 10,0 | 16,6 | 31,9 | 49,3 | 60,1 | 70,6 | 78,4 | 84,0 |
| Spain       | 0,0  | 0,0  | 0,1  | 0,2  | 0,3  | 0,7  | 2,3  | 7,1  | 16,3 | 27,4 | 46,4 | 59,8 | 62,9 | 71,6 | 73,4 | 75,6 |
| Sweden      | 0,1  | 0,2  | 0,2  | 0,4  | 0,6  | 1,1  | 3,3  | 7,5  | 14,9 | 29,3 | 42,8 | 63,0 | 69,9 | 75,2 | 79,7 | 83,2 |
| UK          | 0,1  | 0,1  | 0,2  | 0,2  | 0,4  | 0,9  | 4,2  | 12,0 | 30,5 | 50,0 | 67,5 | 78,9 | 83,3 | 86,2 | 88,0 | 89,4 |

Source: Euromonitor Passport: Consumer Electronics 2010 – extracted Jan 2011

In the case of mobile telephone subscriptions (Table 3.1), it is the Nordic countries of Finland, Norway and Sweden that led the adoption of this new technology, closely shadowed by Denmark, Iceland and Italy (a lone outlier of this Nordic club). Although countries like Estonia and Lithuania were relatively slow to begin to take-up this innovation, by 2009 they had the highest levels of mobile phone subscriptions in Europe.

As with mobile telephones, some countries take longer to begin the process of adopting broadband technologies than others (Table 3.3). Here, early adopters included Belgium, Denmark, the Netherlands and Sweden. In the case of broadband though, these countries remain amongst those with the greatest number of lines per 100 population in 2009, with only Belgium falling out of the top

four. Slower adopters include new Member States such as Bulgaria and Romania, and also Greece, Poland and Slovakia.

Table 3.3 Number of broadband lines per 100 people

|  | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|--|------|------|------|------|------|------|------|------|
| European Union (27 countries)            | :    | :    | :    | :    | :    | 18.2 | 21.7 | 23.9 |
| European Union (25 countries)            | :    | :    | 6.5  | 10.6 | 14.8 | 19   | 22.4 | 24.6 |
| European Union (15 countries)            | 2.3  | 4.5  | 7.6  | 12   | 16.5 | 20.8 | 24.3 | 26.4 |
| Belgium                                  | 6.7  | 10.1 | 14   | 17.4 | 20.7 | 23.9 | 26.6 | 28.3 |
| Bulgaria                                 | :    | :    | :    | :    | :    | 5.7  | 9.5  | 11.9 |
| Czech Republic                           | :    | :    | 0.7  | 4.3  | 8.4  | 12.2 | 15.8 | 17.8 |
| Denmark                                  | 7.4  | 10.4 | 15.6 | 22   | 29.6 | 37.2 | 37.4 | 37.2 |
| Germany (including former GDR from 1991) | 3.2  | 4.8  | 6.7  | 10.2 | 15.3 | 21.1 | 26.3 | 29.4 |
| Estonia                                  | :    | :    | 7.6  | 11.1 | 16.6 | 20   | 23.6 | 26.3 |
| Ireland                                  | 0    | 0.2  | 1.7  | 4.4  | 8.8  | 15.5 | 19.5 | 21.3 |
| Greece                                   | 0    | 0    | 0.2  | 0.8  | 2.7  | 6.8  | 11.2 | 15.6 |
| Spain                                    | 2    | 4.3  | 6.7  | 10   | 13.2 | 16.8 | 19.8 | 20.7 |
| France                                   | 1.2  | 4    | 8.2  | 13.9 | 18   | 22.3 | 26.2 | 29.2 |
| Italy                                    | 1    | 2.8  | 6.1  | 9.5  | 13.1 | 15.9 | 18.1 | 19.8 |
| Cyprus                                   | :    | :    | 2    | 2.7  | 6.6  | 11.1 | 16   | 20.9 |
| Latvia                                   | :    | :    | 1.5  | 3.7  | 6.8  | 11.6 | 16.3 | 17.5 |
| Lithuania                                | :    | :    | 2.5  | 5    | 8.4  | 12.7 | 16.1 | 18.2 |
| Luxembourg                               | 0    | 2.3  | 5.7  | 11.7 | 17.4 | 24.6 | 27.3 | 31.2 |
| Hungary                                  | :    | :    | 2.2  | 4.5  | 7.5  | 11.6 | 15.7 | 17.2 |
| Malta                                    | :    | :    | 3.5  | 10.4 | 12.8 | 13.9 | 20.5 | 26.2 |
| Netherlands                              | 6.3  | 9.8  | 14.7 | 22.4 | 29   | 33.1 | 35.8 | 37.7 |
| Austria                                  | 4.7  | 6.6  | 8.7  | 11.6 | 15.8 | 18.4 | 20.8 | 21.8 |
| Poland                                   | :    | :    | 0.5  | 1.9  | 3.9  | 6.8  | 9.6  | 12.8 |
| Portugal                                 | 1.5  | 3.6  | 6.4  | 10.1 | 12.9 | 14.8 | 15.8 | 17.6 |
| Romania                                  | :    | :    | :    | :    | :    | 6.6  | 10.7 | 12.3 |
| Slovenia                                 | :    | :    | 3.8  | 7.8  | 11.4 | 15.3 | 19.1 | 22.1 |
| Slovakia                                 | :    | :    | 0.4  | 1.5  | 4    | 6.9  | 9.6  | 14.3 |
| Finland                                  | 3    | 6.6  | 11   | 18.7 | 24.9 | 28.8 | 30.7 | 30.5 |
| Sweden                                   | 4.6  | 8.6  | 12.1 | 17.1 | 22.9 | 28.3 | 32.5 | 32.5 |
| United Kingdom                           | 1.6  | 3.7  | 7.4  | 13.5 | 19.2 | 23.8 | 27.5 | 28.8 |

Source: Eurostat, 2011. Number of broadband access lines per 100 people [isoc\_si\_broad]. [Accessed 27 January 2011].

Take-up of internet via mobile telephone (Table 3.4), by way of comparison, offers a very different picture. Here, early adopters include Italy, the UK and Austria. And, by 2009, the most significant levels of take-up were to be found in Finland, Sweden and Luxembourg, followed by Austria, Spain, Portugal and Italy.

Table 3.4. Number of mobile phone subscriptions that include internet access per 100 people

|                 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|-----------------|------|------|------|------|------|------|------|
| Austria         | 0,0  | 3,9  | 11,0 | 20,2 | 29,7 | 42,7 | 53,7 |
| Belgium         | ..   | ..   | ..   | ..   | 5,4  | 7,0  | 8,4  |
| Czech Republic  | ..   | ..   | ..   | 1,2  | 6,5  | 13,1 | ..   |
| Denmark         | ..   | 2,3  | 2,2  | 6,0  | 12,3 | 22,6 | 3,6  |
| Finland         | ..   | ..   | 1,8  | 0,7  | 11,5 | 12,9 | 14,5 |
| France          | ..   | ..   | 2,2  | 6,8  | 13,8 | 2,4  | ..   |
| Germany         | ..   | ..   | 2,9  | 5,5  | 1,5  | 21,8 | 3,2  |
| Greece          | ..   | ..   | 2,1  | 7,7  | 2,2  | 25,7 | 35,1 |
| Hungary         | ..   | ..   | ..   | 3,1  | 7,9  | 15,5 | 22,9 |
| Iceland         | 0,0  | 0,0  | 0,0  | 0,0  | 0,0  | 2,7  | 0,6  |
| Ireland         | ..   | ..   | ..   | ..   | 24,9 | 32,4 | 39,7 |
| Italy           | ..   | 0,6  | 17,7 | 40,1 | 4,1  | 48,8 | 52,8 |
| Luxembourg      | ..   | 3,9  | 14,5 | 2,9  | 42,4 | 82,6 | 84,0 |
| Netherlands     | ..   | ..   | 1,6  | 4,9  | 12,6 | 15,1 | 21,5 |
| Norway          | ..   | ..   | 1,9  | 7,5  | 13,3 | 20,9 | ..   |
| Portugal        | ..   | ..   | ..   | 20,4 | 28,9 | 40,5 | 55,9 |
| Slovak Republic | ..   | ..   | ..   | ..   | 11,0 | 30,7 | 41,4 |
| Spain           | ..   | ..   | 2,2  | 8,5  | 22,8 | 38,9 | 5,1  |
| Sweden          | ..   | 3,6  | 6,8  | 1,4  | 11,0 | 11,8 | 12,6 |
| Switzerland     | ..   | ..   | 1,5  | 4,8  | 19,3 | 28,3 | 37,0 |
| United Kingdom  | ..   | 4,3  | 7,7  | 12,9 | 20,5 | 33,9 | 38,0 |
| Latvia          | ..   | ..   | ..   | ..   | 2,4  | 6,4  | 8,8  |
| Lithuania       | ..   | ..   | ..   | 1,1  | 2,0  | 3,5  | 4,9  |
| Poland          | ..   | ..   | ..   | 1,1  | 7,8  | 16,9 | 26,0 |
| Romania         | ..   | ..   | ..   | 2,7  | 7,9  | 21,5 | 26,3 |
| Slovenia        | ..   | ..   | 0,1  | 3,2  | 11,6 | 26,3 | 2,9  |
| Estonia         | ..   | ..   | ..   | 1,1  | 3,3  | 14,9 | 18,7 |
| Cyprus          | 0,0  | 0,0  | 0,0  | 0,0  | 11,3 | 2,6  | 57,2 |

Source: ITU World Telecommunication/ICT Indicators Database 2010 (14th Edition)

Globally, even greater differences can be seen (Table 3.5). In 2002, South Korea was the international leader (by quite some way) in domestic broadband adoption, with the highest rate of broadband subscribers both as a percentage of all internet subscribers and as a percentage of people. One particularly noteworthy figure is that the vast majority (93.9%) of internet subscribers used broadband, far more than any of its closest competitors. Table 3.5 shows us that at this early stage broadband had been extensively adopted earlier in South Korea, Hong Kong and Canada than the European countries, except Belgium.

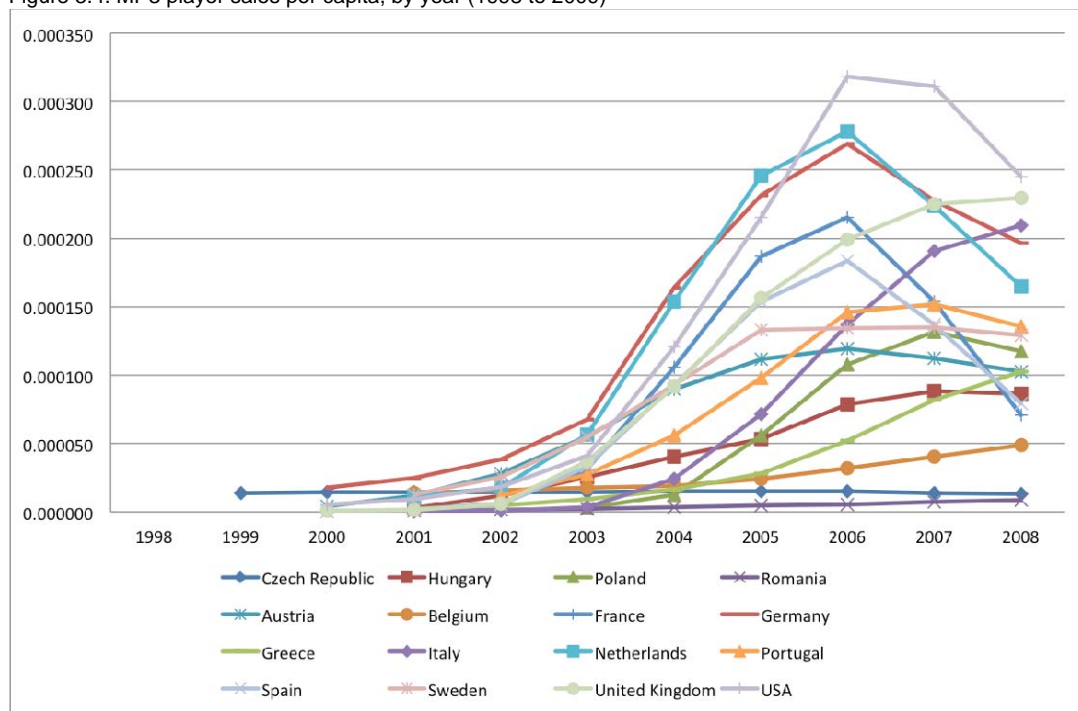
Table 3.5 Broadband subscription by country (2002)

|                  | % of all internet subscribers using broadband | Broadband subscribers per 100 people |
|------------------|---|--------------------------------------|
| South Korea      | 93.9  | 21.3                                 |
| Belgium          | 51.3  | 8.4                                  |
| Canada           | 50.4  | 11.2                                 |
| Hong Kong, China | 42.5  | 14.9                                 |
| Japan            | 30.8  | 7.1                                  |
| Taiwan, China    | 28.2  | 9.4                                  |
| Iceland          | 20.8  | 8.4                                  |
| Netherlands      | 26.0  | 7.2                                  |
| Denmark          | 18.9  | 8.6                                  |
| United States    | 18.3  | 6.9                                  |
| Sweden           | 12.5  | 7.8                                  |

Source: Lau, T.Y., Wook Kim, S. and Atkin, D., 2005. An examination of factors contributing to South Korea's global leadership in broadband adoption. *Telematics and Informatics*, 22, pp.351

Examining another source of data, number of sales of MP3 players (Figure 3.4), reinforces the suggestion that lags are visible in the rate of take-up of innovations. What this example also illustrates is that some technologies can exhibit very different consumption trajectories across different countries.

Figure 3.4. MP3 player sales per capita, by year (1998 to 2009)



Source. Ecorys from Euromonitor data

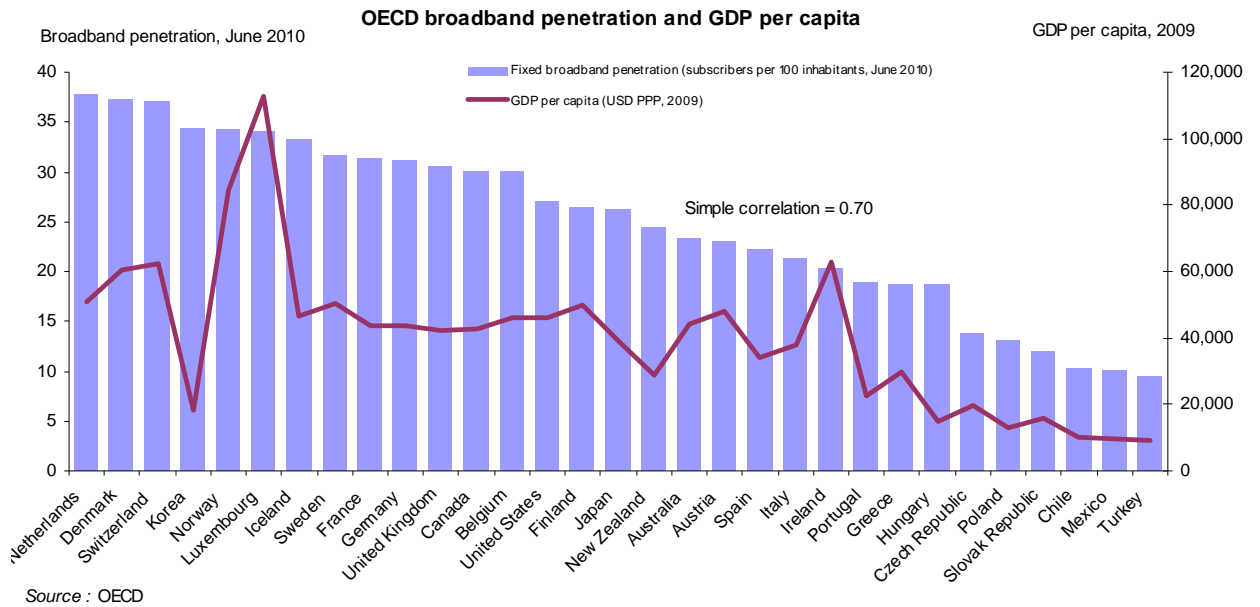
### 3.4 Wealth and income does not seem to explain the lags visible

It was not the intention of this analysis to seek to explain the reasons behind individual variations, merely to identify whether common patterns can be discerned. However, it is impossible not to wonder whether the take-up of innovations is not simply a function of their affordability across different economies. A casual glance across the evidence would seem to suggest that economies

with higher levels of wealth often appear to have a more rapid and deeper take-up of the innovations in question, although this is not always the case.

In the case of broadband technologies research by the OECD<sup>22</sup> seems to suggest that income is not the causal factor in levels of adoption (Figure 3.5). Although GDP levels are correlated to levels of broadband penetration it is not to a level that is statistically significant.

Figure 3.5 Broadband penetration and GDP



A similar analysis for both mobile telephone subscriptions and DVD ownership illustrates the same point. Although a correlation is visible in some cases this is not universal, is certainly not consistent and in many cases the association is negative (Tables 3.6 and 3.7).

<sup>22</sup> OECD Broadband statistics available at: [oecd.org/sti/ict/broadband](http://oecd.org/sti/ict/broadband)

Table 3.6. Correlation between GDP (ppp) and mobile phone subscriptions (1995 to 2009)

| Country        | Correlation |
|----------------|-------------|
| Romania        | 0,95        |
| Hungary        | 0,93        |
| Czech Republic | 0,91        |
| Italy          | 0,80        |
| Greece         | 0,79        |
| Spain          | 0,73        |
| Portugal       | 0,71        |
| Poland         | 0,65        |
| Belgium        | 0,59        |
| Netherlands    | 0,29        |
| France         | 0,24        |
| Austria        | -0,01       |
| United Kingdom | -0,61       |
| USA            | -0,72       |
| Sweden         | -0,79       |
| Germany        | -0,91       |

Source. Euromonitor with own calculations

Table 3.7 Correlation between GDP (ppp) and DVD ownership (1995 to 2009)

| Country        | Correlation |
|----------------|-------------|
| Romania        | 0,93        |
| Czech Republic | 0,88        |
| Hungary        | 0,77        |
| Italy          | 0,74        |
| Portugal       | 0,57        |
| Poland         | 0,47        |
| USA            | 0,36        |
| Greece         | 0,30        |
| United Kingdom | 0,25        |
| Spain          | 0,10        |
| Netherlands    | 0,06        |
| Belgium        | -0,14       |
| France         | -0,31       |
| Sweden         | -0,32       |
| Austria        | -0,50       |
| Germany        | -0,62       |

Source. Euromonitor with own calculations

### 3.5 No patterns across countries either

The data across these three fields also demonstrates no firm consistency as to which countries lags might be expected to be present. This is despite the fact that the three fields are all similar in that they represent rapidly developing modern technologies which are in many aspects inter-related.

Adoption of mobile telephony, and mobile internet applications, was swift in Italy, but broadband penetration has been limited. This may be one reason that adoption of mobile internet is strong within Italy – illustrating the interdependence which can occur between technologies or innovations that may substitute for each other or carry one another.

Like Italy, Sweden was one of the earliest adopters of mobile telephones, yet its take-up of DVD players is around average for the European member states considered here. In this it is matched by Portugal, where the take-up of mobile telephony is much lower, suggesting no linkages between these two markets.

### 3.6 Other consistent patterns are hard to discern

The EU, and the world, is often divided into convenient blocks. We have the EU 15, Portugal, Ireland, Greece and Spain are often considered together, there are the 12 'new' Member States of the EU. Like the example of the BRICs cited above, the temptation to consider these as homogenous groupings for the purposes of analyzing lags in the take-up of innovations appears too simplistic on the data available. The only grouping where a strong pattern appears to be valid is around the Nordic nations in the early years of mobile telephone adoption and even here Italy appears as a guest at the Nordic party.

In fact, the only pattern that we have been able to discern from the data available is the probability that there is no pattern; or at least, there is no pattern which can be readily identified on the basis of a limited number of variables.



## 4 Understanding innovation lags: evidence from the literature

### 4.1 Introduction

The evidence that the take-up of innovations is not a smooth and seamless process is clear. Equally, it is apparent that differences in the rate and speed of take-up are not only due to factors such as demographics, wealth and income. Although these are undoubtedly important, they cannot explain all of the variations observed.

So why do lags in the take-up of innovations occur? Why is the picture one of discontinuity and differential take-up? As the previous chapter highlighted, much attention has been given to the ability of different economies to innovate through the introduction of new and improved products, and processes in the markets for both goods and services. In contrast, the different rates visible in the take-up of innovations between economies, and the implications that this can have for economic change or social and environmental welfare, has received less attention.

Despite this, there is a wide, if disparate, literature which considers different reasons influencing the speed with which innovations are taken up, both by the general population – as consumers of goods and services – and by firms, as inputs into their own production processes. The following section draws on this literature to highlight the principle reasons identified as to why lags can occur in the take-up of innovations that, with the benefit of hindsight, might be thought to have been beneficial.

It is of course a truism, but one reason is simply because not all places are the same. Physical geography can influence the take-up of innovations by affecting the cost-effectiveness of investments, or the ease with which knowledge can diffuse. Similarly, neighbour effects may mean that awareness of innovations is stronger in adjacent places than those which are more distant. Yet, the emergent evidence of the previous section suggests that this is too simple an explanation.

Other explanations focus on the culture of a place, or on its historical path of economic development. Work by writers such as Geels and Schot<sup>23</sup> for example highlights the role of socio-technical regimes where existing regulations and standards; prevailing cognitive routines; lifestyles which centre around prevalent technical systems, and sunk investments in the infrastructure and competencies relating to those systems all combine to limit the speed with which innovations from outside of prevailing practice can be taken up. Such explanations though do not fully suggest why some places may prove slower than others in beginning to take-up innovations which emerge, or why some firms and consumers are swifter than others to adopt innovations within such regimes.

An examination of the literature suggests the following 7 themes as illuminating any attempt to understand lags in the take-up of innovations:

- The role of existing infrastructure and practices in influencing future choices
- How our expectations of the future influence what we choose to do now

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<sup>23</sup> Geels, F. W. and Schot, J. (2007) Typology of Sociotechnical Transition Pathways in *Research Policy* 36 p.399-417

- How our consumption habits and choices are shaped by those around us
- How knowledge diffusion and awareness can shape decisions
- The important role played by skills, education and educational systems
- The role of market and organisational structures in influencing decisions
- How policy makers can hinder as well as assist the take-up of innovations

## 4.2 Existing infrastructure and practices influence future choices

### Path dependency

Firms, and by extension economies, are not entirely free to choose their future development paths. They are, to a certain extent, locked-in to paths determined by past investment decisions, existing economic structures and prevailing institutions (Kaldor 1934<sup>24</sup>, Martin and Sunley 2006<sup>25</sup>). These can constrain the ability of firms to adopt new innovations, and may influence their availability to the consumer market. Various reasons have been postulated for this including the legacy of a dominant industrial structure, as can be witnessed in areas tied to declining industries such as mining, and the influence of past investment decisions whereby the existing capital stock influences the ability of firms to implement known innovations. This notion of path-dependency highlights the significance of existing characteristics in influencing the direction of future direction. As Cohendet and Llerena<sup>26</sup> put it "the local entity is not a passive source of competitive advantages but an active element of the overall competition process that can create and select technologies in a specific manner" (Cohendet and Llerena 1997 p.231). These factors can play an important role in introducing lags into the observed pattern of innovation adoption over time.

One of the more well-known examples of the influence of existing infrastructure on the take-up of innovations is perhaps the development of the rail infrastructure in the UK. New high-speed train sets are unable to operate on existing rail lines owing to the curvature of the tracks and other engineering constraints, which requires significant levels of investment in new lines before new services can be considered. Equally, the electrification of existing rail lines was hindered for many years by the need to raise the height of bridges crossing the existing railway lines which had been built to the standards of steam and diesel powered engines.

### Behavioural 'lock-in'

The diffusion and application of knowledge can also be influenced by prevailing norms of activity and behaviour – the 'way things are done'. New ideas are not simply picked up by firms and brought into use. Old ideas must be 'unlearnt', production processes altered and new skills acquired (Lundvall and Johnson 1994<sup>27</sup>). Inherited institutions and routines may influence the rate at which firms within an economy adapt to changing circumstances; as inertia forestalls adaptation. Habits

<sup>24</sup> Kaldor, N. (1934) 'A Classificatory Note on the Determinateness of Equilibrium' *Review of Economic Studies* Vol 1 1 pp 122-36 Reprinted in Targetti, F. and Thirlwall, A. P. (eds) (1989) *The Essential Kaldor* New York Holmes and Meier

<sup>25</sup> Martin, R. and Sunley, P. (2006) 'Path Dependence and Regional Economic Evolution' *Journal of Economic Geography* Vol 6 4 pp. 395-438

<sup>26</sup> Cohendet, P. and Llerena, P. (1997) 'Learning, Technical Change and Public Policy: How to create and exploit diversity' in Edquist, C. *Systems of Innovation* London Pinter

<sup>27</sup> Lundvall, B-Å. and Johnson, B. (1994) 'The Learning Economy' *Journal of Industry Studies* Vol 1 2 pp. 23-41

and routines tend to be slow to change and patterns of behaviour are reproduced and replicated, with new ideas having to compete with previously accepted norms of behaviour and action (Nelson and Winter 1982). Where an economy is dominated by particular industrial forms and structures this inertia may be especially prevalent (Dosi 1984<sup>28</sup>).

The role of existing knowledge, experience and structures in shaping behaviour and limiting the take-up of innovations can be seen in the case of the Swedish construction industry, as reported by Mahapatra and Gustavsson, (2008)<sup>29</sup>. As they explain, timber was prohibited as a frame material for multi-story buildings in Sweden until 1994, consequently, construction professionals' knowledge and experience has been dominated by brick/concrete construction. Existing, well-developed networks (between engineering firms, architects, commissioners etc.) were all geared towards effective construction with concrete, creating pre-determined construction paths that favour concrete production techniques. The tendency of these professionals to stick to what they already know means that timber-constructed buildings remain relatively scarce. The established patterns are beginning to be broken, in part, by niche management of the timber construction industry. Critically, the knowledge base was expanded through learning from US experiences of building with timber, which demonstrated great benefits of timber over concrete. Also, the government put funding into timber R&D, to boost the sector's relatively small knowledge base and rate of development<sup>30</sup>.

Arguably then, the ability of firms to respond to new ideas also depends on the extent to which they are open to the influx of new ideas. Firms, and – by extension – economies, that are open to ideas from outside sources will be in a better position to grow and adapt to change than ones that are closed to these ideas.

### **Role of institutions**

The institutional context of an economy also influences the ability of firms to assimilate new ideas. To the extent that innovation is a shared, interactive and collective process it will involve different organisations and be governed by accepted norms of behaviour concerning the sharing of information (Cooke 1998<sup>31</sup>, Braczyk and Heidendreich 1998<sup>32</sup>). Institutions, as social norms or regulatory structures, permit knowledge flows and synergies through encouraging co-operative behaviour, helping to produce new levels of innovation and the assimilation of knowledge on which further development can be built (Oughton et al 2002<sup>33</sup>). In this respect Amin and Cohendet<sup>34</sup>, amongst others, argue that weaker degrees of rational decision making must be considered particularly in the context of situational learning where "the respect for the social norms of the group and the practices of engagement are a more important guide to behaviour than a rational decision-making context" (2004 p.33), a point we explore later.

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<sup>28</sup> Dosi, G. (1984) *Technical Change and Industrial Transformation* London Macmillan

<sup>29</sup> Mahapatra, K. and Gustavsson, L., 2008. Multi-storey timber buildings: breaking industry path dependency. *Building Research & Information*, 36(6), pp.638-648.

<sup>30</sup> Mahapatra, K. and Gustavsson, L., 2008. Multi-storey timber buildings: breaking industry path dependency. *Building Research & Information*, 36(6), pp.638-648.

<sup>31</sup> Cooke, P. (1998) 'Introduction: Origins of the concept', in: Braczyk, H-J., Cooke, P., and Heidenreich, M. (eds) *Regional Innovation Systems; The Role of Governances in a Globalized World*, London: UCL Press Cooke and Willis 1999

<sup>32</sup> Braczyk, H-J. and Heidenreich, M. (1998) 'Regional Structures in a Globalised World' in Braczyk, H-J. et al. (Eds) *Regional Innovation Systems* London: UCL Press

<sup>33</sup> Oughton, C. et al. (2002) 'The Regional Innovation Paradox: Innovation Policy and Industrial Policy' *Journal of Technology Transfer* Vol 27 pp. 97-110

<sup>34</sup> Amin, A. and Cohendet, P. (2004) *Architectures of Knowledge: firms, capabilities, and communities* Oxford University Press

Coombs and Hull (1997) identify three areas in which path dependency can be manifested in individual organisations. First, technology and hardware 'bear the impression of previous choices and chance events'<sup>35</sup> and impact on future decisions. In this respect the sunk costs of previous investment decisions play a significant role in influencing the speed at which firms are able to incorporate new innovations. Second, the knowledge base of a company moulds its actions, firms can only act on what they know and – e paraphrasing the immortal words of Lew Platt when CEO of Hewlett-Packard – 'what they know, they know'. Third, routines undertaken, for example, linked to deploying knowledge, can inform future action not least through their ongoing repetition. Their argument is that knowledge management practices can be used to counteract path dependency by ensuring evolving knowledge bases etc.

### **Technological 'lock-in'**

Redding (2002) explores the idea of technological lock in – essentially the continued reliance and use of a technology rather than utilising or researching new innovations. The research looks at technological change and argues that if spillovers of secondary knowledge across fundamental technology is incomplete, 'an increase in the stock of secondary knowledge relating to one fundamental technology m reduces agents' incentives to engage in research directed at the discovery of fundamental technology  $m+1$ '<sup>36</sup>. So, as knowledge builds and builds, there is less incentive to push for the next innovation.

Companies involved in environmental improvement and development are susceptible to path dependent working, and therefore have often failed to take advantage of potential innovation in the past. Continuity approaches have in fact accounted for an estimated 70-90% of expenditure on environmental technology, slowing development and innovation. Organisations have been averse to discontinuous development of their structures as it may require great transformation of corporate business models, production systems, services, products and markets. When change has been embraced, it has been limited as in the case of moving to Environmental Management Systems (EMSs). These developed as an extension to the 'total quality management' paradigm that was largely adopted in the 1980's. As companies already possessed the skills and knowledge to develop this type of approach, this saved the greater costs of developing a totally new paradigm of institutional practice. By doing so however, companies and organisations developed along a limited pathway that limited the structural approach to innovation, since development was restricted to the streamlining of existing systems rather than the development of a totally new and innovative system<sup>37</sup>.

Paradoxically, strong linkages can also bring benefits by accelerating rates of change and the adoption of innovations. Fagerberg et al, (2008) highlight the example of Norway's innovation system which has succeeded by focusing on the country's historical strengths, and developing resource-based industries. Even when public policy has tried to shift away from this path dependency, the continued scope for innovation and success in historic industries has meant such efforts have failed. In this sense, path dependency can contribute to success if the onus is on exploiting strengths as opposed to rejecting change. This is a minority example of path dependency not being negative however, and is based on an understanding that 'at any point in time many new

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<sup>35</sup> Coombs, R. and Hull, R. (1997). Knowledge management poractices and path dependency in innovation. CRIC discussion paper, No 2. <http://www.cric.ac.uk/cric/Pdfs/dp2.pdf> p5

<sup>36</sup> Redding, S. (2002). Path dependence, endogenous innovation, and growth [online]. London: LSE Research Online. P2

<sup>37</sup> Konnola, T. and Unruh, G.C., 2007. Really Changing the Course: the Limitations of Environmental Management Systems for Innovation. *Business Strategy and the Environment*, 16, pp.525-537.

ideas emerge, but only those that (at the time) are well adapted to the selection environment are likely to be applied and form the basis for continuing adaptation and improvement.<sup>38</sup>

### 4.3 Our expectations of the future influence what we choose to do now

Our propensity to adopt innovations is heavily influenced by how we see the future, but not necessarily in any consistent manner. Old habits die hard and in deciding on the future we often fall back on the familiar; that is what we know now. More significantly perhaps, we also tend to value present returns more highly than potential future returns and act in a highly risk averse manner. This tendency towards short-term prioritisation can be accentuated by the demands of others and our perceived need to satisfy their requirements.

#### **Time preference – for short term benefits**

Mulgan and Albury (2003) use the higher education sector to demonstrate how a focus on achieving immediate gains or maintaining status quo fails to look to the medium and long term benefits of innovation. They show that when universities faced efficiency gain targets of 2% per year, they reacted by increasing the size of seminar groups, cutting the length of student essays, and banning the use of first-class post and peak-time phone calls. In contrast, in other universities where vice-chancellors were asked what they would have done facing 22% cuts over 10 years (the same as 2% per year), they reacted by suggesting much more radical and transformative models of change, such as new models of learning and teaching, full use of IT and a re-focussing on institutional strengths<sup>39</sup>.

This example provides a demonstration that long term thinking changes the perspective on risk and objectives, heightening the potential for innovation. Yet, we are singularly challenged when it comes to long-term thinking. This is particularly the case in the business world, where a focus on short-term results can have a significant impact on the investment choices made. Such investments are clearly fundamental to the speed of take-up of innovations. A relatively recent survey of financial executives indicated that 78% of those surveyed would give up economic value in exchange for smooth earnings and that 55% of managers would avoid initiating projects, even with a strong net present value, if it meant that reported earnings for the current quarter would fall below the consensus expectation<sup>40</sup>. Indeed, there are suggestions that firms are so risk averse that returns on investment must be perceived to be 'air-tight'<sup>41</sup> with figures of 27% suggested as being not unusual<sup>42</sup>. It is likely that in challenging economic climates, these tendencies will be reinforced rather than reduced.

That we, as humans, tend to emphasise the value of present returns against future returns (often described as short-termism) is now a matter of record. However, this can have two very different effects on our propensity to adopt innovations. In so far as we value ownership of a good now more highly than our future ability to pay for it, it may increase our propensity to purchase 'desirable'

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<sup>38</sup> Fagerberg, J. Mowery, D. C. and Verspagen, B. (2008). Innovation-systems, path-dependency and policy: The co-evolution of science, technology and innovation policy and industrial structure in a small, resource-based economy. DIME Working paper 2008.1 in the series on "Dynamics of Knowledge Accumulation, Competitiveness, Regional Cohesion and Economic Policies" (DIME Working Package 3.1) June 2008. <http://www.dime-eu.org/files/active/0/FagMowVer.pdf>

<sup>39</sup> Mulgan G. and Albury, D. (2003). Innovation in the public sector. <http://michaellittle.org/documents/Mulgan%20on%20Innovation.pdf>

<sup>40</sup> Graham, J., Harvey, C. and Rajgopal, S (2005) .Journal of Accounting and Economics 40 p3-73 <http://ideas.repec.org/p/nbr/nberwo/10550.html>

<sup>41</sup> Arthur D. Little 2008 <http://www.adl.com/reports.html?view=240>

<sup>42</sup> <http://www.bankofengland.co.uk/publications/quarterlybulletin/qb940308.pdf>

goods and services. This is particularly the case if we purchase goods using credit facilities. Set against this is where the benefits of expenditure now will only be realised in the future – then we may be less likely to make that purchase, or investment. What authors such as Dasgupta and Maskin<sup>43</sup> have shown is that we tend to act impatiently and realise short term urges rather than longer-term strategies. It is for this reason that savers use illiquid accounts to save for events such as Christmas<sup>44</sup> – removing the temptation to spend the savings earlier. But the example is also salient regarding investment decisions by firms – a small gain now may well be more attractive than a larger future benefit, particularly if immediate preferences change.

Our notion of what is short and long term can also be very different. In a survey of fund managers conducted by Watson Wyatt more than half described the long-term return on investment as being over 5 years and a quarter actually felt that it was 3 years<sup>45</sup>. Many consumers may not agree with this and other sectors may take a different perspective. However, such short-term thinking (even if respondents feel that this is the long term!) amongst the financial markets – particularly in anglo-saxon cultures – is significant given their importance in financing the investments required to introduce substantive innovations.

Of course, not all firms are driven by the same strategies, and figures such as those quoted above are averages. Some will act on lower returns on investment. Indeed, this was one of the principle findings of Clayton Christensen in his ground-breaking work examining the Hard Disk Drive Industry<sup>46</sup>. Christensen identified that it was the fact that leading firms focused on the markets with the highest returns that provided the opportunity for smaller players to operate in markets with lower returns. As technologies developed, and costs fell, these smaller firms were then better positioned to capture new market share as consumption patterns changed.

In a recent article, *The Economist*<sup>47</sup> suggests that the medical devices industry may about to be beset by a similar revolution. Medical technology companies in China and India are rapidly challenging the traditional American behemoths of the industry. Not only are new entrants able to 'leap-frog' to new technologies (as highlighted in the previous section), they are also operating in markets which are not hampered by risk averse regulators (see later section). Known as 'frugal innovation' firms that produce low margin, cheaper products, which are sufficient for the job in hand may trump those that have relied on higher margin high performance machines, particularly as consumers begin to count the cost of healthcare systems. As Cristensen identified, small value markets tend to be overlooked initially because they do not provide the returns required by a large firm (10% growth in a market worth €1m is very different from that of a market worth €100m). This can lead to lags in the adoption and production of innovations.

### **Risk aversion and uncertainty**

Our expectations of the future can have a significant impact on how we act. Humans are inherently risk averse and consumers, and producers, are unlikely to take-up innovations where they are uncertain as to their benefits. This aversion is the reluctance to accept an uncertain outcome in favour of more certain, but potentially less rewarding outcomes. Kahneman and Lovallo (1993)

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<sup>43</sup> Dasgupta, P. and Maskin, E. (2005) Uncertainty and Hyperbolic Discounting in *American Economic Review* 95 (4) 1290-1299

<sup>44</sup> Strotz, R. H. (1956) *Myopia and Inconsistency in Dynamic Utility Maximization* in *Review of Economic Studies* 23 p165-180

<sup>45</sup> Porritt, J. and Tuppen, C. (2003) Just Values: beyond the business case for sustainable development. British Telecoms PLC and Forum for the Future

<sup>46</sup> Christensen, C. (1997) *The Innovator's Dilemma: When new technologies cause great firms to fail*. Harvard Business School Press

<sup>47</sup> *The Economist* (2011) Frugal Healing January 22nd p.73-74

argue that people are proportionately risk averse, meaning that there is almost as much risk aversion when the stakes are small as when they are large<sup>48</sup>. This means that not products of all scales must take account of risk aversion. They also argued that the successful adoption of an innovation is threatened by a bias towards negativity in the evaluation of its potential impact versus cost by consumers. This is because there is a 'sharp discrepancy between the weights that are attached to sure gains and to highly probably gains in the evaluation of prospects'<sup>49</sup>. A position reinforced by Christensen who argues that firms "are willing to bet enormous amounts on technologically risky projects when it was clear that their customers needed the resulting products (but were unable to do so) if existing profitable customers didn't need the products" (p.101)<sup>50</sup>. An innovation may therefore be rejected if its benefits are not made entirely clear or if its market is not already known.

Research such as Felder et al (1981)<sup>51</sup> showed that this was the case for the rejection of innovation in agriculture. They argued that agricultural innovations were less likely to be adopted if they appeared unfamiliar, showing that the impact of risk aversion. This built on earlier research in the late 1970s that showed a lower adoption rate of innovation (new crop varieties) by Tunisian farmers where the product was unfamiliar and imported. This compared to greater adoption for similar, yet locally produced innovations. In this case, the farmers were subjectively more risk averse when they were when higher exposure to information negated their subjective risk aversion.

This level of risk aversion in farming remains as true today as it was in the 1970s. Research in 2008 found that there was a link between the readiness of farmers to adopt new technology. In this case, GPS guidance systems, and their previous readiness to adopt new innovations, particularly whether they had already adopted other precision-farming techniques and used computers for farm management<sup>52</sup>. Although the level of education was not a significant influence on the propensity to adopt factors such as age, farm size and yields were. Again, the importance of familiarity and the levels of perceived risk to the individual emerge strongly.

The link between knowledge, trust and risk, with the former two negating (to an extent) the latter was also highlighted amongst focus groups conducted in England and Wales, looking at public acceptance of the development of hydrogen technology. The research found that the amount of trust people feel towards different sources of information influences their acceptance of their new policies and strategies. One important factor in increasing trust was the provision of accurate and comprehensive information, which is necessary if people are to see the need for change and the benefits it can bring (Ricci et al., 2009).

### **Irrational choices – inconsistency and framing effects**

That we are fundamentally inconsistent though in our choices has been proven by researchers who demonstrate the importance of 'framing' effects – whereby people "consistently violate the

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48 Kahneman, D. and Lovallo, D. (1993). Timid choices and bold forecasts: a cognitive perspective on risk taking. *Management Science*, vol. 39. No. 1 (Jan 1993)

49 Ibid. p18

50 Christensen, C. (1997) *The Innovator's Dilemma: When new technologies cause great firms to fail*. Harvard Business School Press

51 Feder, G. Just, R. and Silberman, D. (1981). Adoption of Agricultural Innovations in Developing Countries: A Survey. World Bank Staff Working Paper No. 444. [http://www-wds.worldbank.org/external/default/WDSContentServer/WDS/IB/2003/08/08/000178830\\_98101903410198/Rendered/PDF/multi0page.pdf](http://www-wds.worldbank.org/external/default/WDSContentServer/WDS/IB/2003/08/08/000178830_98101903410198/Rendered/PDF/multi0page.pdf) P14

52 Banerjee, S. B., Martin, S. W., Roberts, R. K., Larkin, S. L., Larson, J. A., Paxton, K. W., English, B. C., Marra, M. C. and Reeves, J. M. (2008) A binary logit estimation of factors affecting adoption of GPS guidance systems by cotton producers in *Journal of Agricultural and Applied Economics* 40 p.345-355.

requirements of consistency and coherence<sup>53</sup> in making their choices. What they found was that people are risk averse when considering possible gains, and risk taking when seeking to avoid losses. In demonstrating this, they used the following example:

There are two treatment choices available in the context of a new fatal disease epidemic. In the first case choice one would save 200 of the 600 persons affected and choice two would provide a one-third probability of saving 600 people and a two-third probability that no-one would be saved. In case two, adopting choice one would mean that 400 people would die and choice two has a one third probability that no-one will be saved and two-thirds probability that 600 people will die. Interestingly in case one, most people (72%) chose choice one (risk averse) and in case two most people (78%) chose choice two (risk taking). Yet the two cases are identical.

Overall, it seems that the certainty of a small gain will outweigh the chance of a bigger gain, as reflected in the saying 'a bird in the hand is worth two in the bush', whilst the chance of preventing a larger loss will lead to riskier choices over the certainty of a small loss. The tendency to take-up innovations may then depend on how people see the choice on offer, or how that choice is 'framed', as we saw in our University example at the beginning of this section.

#### 4.4 Our consumption habits and choices are shaped by those around us

In deciding whether to take-up an innovative product, service or process – whether in business or as a consumer – we are affected by those around us and our surrounding cultures (both socially and organisationally). Our decisions are informed by what our friends, our colleagues and our neighbours do, and what we feel are their expectations of us. We rarely make an independent choice. Differences in culture, in expectations and rates of surrounding adoption affect the speed with which we adopt innovations, which in turn affects others propensity to adopt.

Culture, whether institutional, governmental or social, has the potential to greatly hinder or boost attempts to initiate change. Where current culture conflicts with innovation, many case studies show that such reforms can be met with intense resistance as individuals seek to protect the present way. A shift in culture, however, can greatly boost capacity for change.

##### **Cultural attitudes to innovation – role in inertia**

A 2011 survey looked at the attitudes of executives in 12 countries towards innovation<sup>54</sup>. There was a global acceptance that innovation is the main level for competitiveness, and that innovation is the way to secure jobs. There were marked differences between executives from different countries when asked about how optimistic they were on innovation changing lives however. Executives from Saudi Arabia scored 88 (weight 100 points), but executives from Japan only scored 58. The conclusion of the survey is that there are different and important cultural attitudes towards innovation. On one extreme are the optimists, from countries where a new innovation model is seen

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53 Tversky, A. and Kahneman, D. (1981) The Framing of Decisions and the Psychology of Choice in Science New Series Vol. 211 (4481) Jan. p453-458

54 GE Global Innovation Barometer 2011: An Overview on Messaging, Data and Amplification. <http://files.gereports.com/wp-content/uploads/2011/01/GIB-results.pdf>

as a key solution to shared problems. On the other extreme are the pessimists, sharing a position that focuses on big company success, relying on protection and assistance to innovate<sup>55</sup>. It seems highly likely that the most likely countries to embrace innovations in the future will come from the more optimistic end of the scale.

That culture can have practical effects on levels of innovation is illustrated by the manner in which Japanese companies failed to respond to change in the computer chip industry. In the 1990s, Japanese companies failed to respond to the shift away from semiconductors towards custom made chips and processors. Rather than shift product models and shed staff to reduce costs, firms chose to support existing norms. They honoured commitments to staff and equipment makers, when foreign competitors were rapidly changing their industrial models. Firms were unwilling and culturally unable to adapt due to long term, low risk strategies of competing in a single area (memory chips) on price and quality. Ultimately, US companies became dominant forces in chip manufacturing, whilst Japanese firms fell behind<sup>56</sup> (see also Chen, 2008<sup>57</sup> and Anchordoguy, 2005<sup>58</sup>).

Similarly, The Economist recently quoted Tadashi Yanai, founder and manager of Fast Retailing, Japan's largest clothing retailer, as saying "the *salaryman-shacho* is one of the biggest reasons why the Japanese economy went down. They don't take responsibility"<sup>59</sup>. The *salaryman-shacho* is the hired manager and represents a shift from the original founder-managers of Japan's corporate giants. These founders were able to act swiftly and decisively, as they chose, such as when Akio Morita, founder of Sony fought with his engineers and executives who argued that a tape-player without the ability to record would never be successful. He won, the Sony Walkman was born and the rest is history. The Economist argues that the *salaryman-shacho* is unable to act in this way, as he is beholden to ties of loyalty and is "implicitly expected to keep things as they are" (p.73)<sup>60</sup>. The take-up of new innovations can, in these circumstances, be severely constrained.

Corporate cultures can also inhibit (as well as promote) the take-up of innovations. Contrary to perceived wisdom, Christensen suggests that one of the reasons that leading firms fail to introduce certain new ideas (that he terms disruptive technologies), is because they do all the right things: listen to their customers, invest in high return areas and focus on large markets<sup>61</sup>. By responding to their existing customers and their investors, companies can miss the development of new technologies which tend to be "cheaper, simpler, smaller and, frequently, more convenient to use" (Christensen 1997, p.xv). Crucially though they tend to give lower levels of performance in their early years. However, the speed with which technologies develop mean that by the time they become widespread once leading firms have lost their commanding positions. The recent statements by Nokia (February 2011)<sup>62</sup> regarding its failure to take-up new innovations and maintain competitive position against the twin pressures of new 'smart' phones and cheap mobile phones (the emergence of frugal innovation again), also highlights the role of corporate culture limiting the development and take-up of innovations<sup>63</sup>. The presence of cultural norms, creating institutional inertia, is then a powerful force hindering the emergence of new ideas and the take-up

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55 Ibid. p22

56 Ibid.

57 Chen, L., 2008. Institutional inertia, adjustment, and change: Japan as a case of a coordinated market economy. *Review of International Political Economy*, 15(3), pp.460-479.

58 Anchordoguy, M., 2005. *Reprogramming Japan: The High Tech Crisis under Communitarian Capitalism*. Ithaca, NY: Cornell University Press.

59 The Economist (2010) From Walkman to hollow men. November 6th p.73

<sup>60</sup> The Economist (2010) From Walkman to hollow men. November 6th p.73

61 Christensen, C. (1997) *The Innovators Dilemma*. Harvard Business School Press. Boston, Massachusetts

62 <http://www.bbc.co.uk/news/technology-12403466>

63 <http://www.bbc.co.uk/news/technology-12414595>

of innovation. That these can come to characterise whole societies, and so economies, is one reason that lags can be so visible.

### **Framing effects – harnessing culture and group dynamics**

Understanding the reasons for the behaviour of certain groups within society can also greatly increase chances of innovative changes being successful. Educating high school pupils in Florida about the dangers of smoking had little effect on smoking rates, but the substitution of their 'rebellious' smoking with 'rebellion' against manipulative tobacco companies proved far more effective (Hicks, 2001). Likewise, reminding people of money could be counter-productive when trying to get them to engage in collective or philanthropic behaviour: Vohs et al. (2008) found that reminding subjects of money (e.g. by playing Monopoly with them, or seating them near pictures of money) reduced their inclination to help others or to cooperate on tasks (preferring to attempt tasks alone instead).

Innovation and change is most likely to take place when there is a successful attempt to engender cultural shift. This was seen in Zaragoza, where a campaign to reduce water usage saw 592 million litres of water saved between October 1997 and April 1998 (Edo, 1998). The campaign to encourage water responsibility addressed everyone – with measures aimed at businesses, schools, the council and the general public – and was accompanied by a heavy media campaign. By highlighting the campaign to all sections of society, the local authority was able to initiate a shift in the town's attitude towards water usage as a whole. The case of the University of Prishtina, on the other hand, demonstrates the ways in which culture can be a hindrance: the university's cultural significance to Kosovan Albanians resulted in great internal resistance to international efforts to help reconstruct its educational capacity, as a result of fears that the proposed changes would take curriculum and policy control from Kosovo (Bache & Taylor, 2003).

One of the reasons for this is the importance of surrounding behaviour for our own behaviour. Or, to put it another way, we're more likely to adopt an innovation if our friends and neighbours have already done so. The importance of surrounding behaviour is reflected in a recent study from Michigan State University<sup>64</sup> which found that people are more likely to enrol in conservation programs if their neighbours do. The study focused on a Chinese government initiative called Grain to Green that pays Chinese farmers to convert cropland back to forest. While money is a key factor in whether people sign up for the voluntary program, peer pressure also plays a surprisingly large role. As one of the authors of the study identifies: "That's the power of social norms," Liu said. "It's like recycling. If you see your neighbours doing it, you're more likely to do it." Behaviour, it seems, is just as much learnt from observing the behaviour of others - and their response to given behaviour - as it is from individual trial and error experiences<sup>65</sup>.

### **Innovation take-up – tipping points**

Malcolm Gladwell<sup>66</sup> describes the point at which an innovation is substantially taken up as the 'tipping point'. At this point, change happens dramatically and the innovation is taken up by the majority, as it is now the accepted norm. He sees three important factors in reaching this point. Firstly, the need for an initial few people to spread the word: these must be the right people in that

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<sup>64</sup> Chen X, Lupia, F, He G, and Liu, J (2011) Linking social norms to efficient conservation investment in payments for ecosystem services sourced from [www.pnas.org/cgi/doi/10.1073/pnas.0809980106](http://www.pnas.org/cgi/doi/10.1073/pnas.0809980106)

<sup>65</sup> Jackson, T., 2005. *Motivating Sustainable Consumption: a review of evidence on consumer behaviour and behavioural change*. Guildford: Centre for Environmental Strategy.

<sup>66</sup> Gladwell, M. (2000) *The Tipping Point* Abacus

they must be able to connect, to sell and to be respected for their knowledge. Secondly, the innovation must also be 'sticky' Gladwell argues. It will not spread beyond these few early adopters if it does not have resonance. And finally, it depends on the context. Innovations will be taken up when the context is supportive.

### **Group think – following the crowd**

Thaler and Sunstein make the same point in their book "Nudge"<sup>67</sup>. They argue that people tend to go along with the status quo, but that small changes in context can have a big impact on the choices that are made. This is because people's choices tend to be influenced by their own experience, the level of information available to them (often gained from friends and immediate contacts) and the speed of feedback available. Consumers, it seems, tend to follow the herd – as evidenced by the behaviour of fund managers – particularly when feedback on the choices made is limited.

The manner in which individual behaviour aggregates to collective consumption is clearly relevant to any consideration of lags in the take-up of innovations. Watts considers the importance of information cascades in this process. Again, he highlights that people tend to go with the crowd in making their choices, a proposition forcefully put forward by Surowiecki<sup>68</sup> as well. Thus, if a population begins to change its behaviour, as Gladwell identifies, then so will the individual. Information cascades from the group to the individual and as more individuals change their behaviour, so the cascade effect is strengthened. How these information cascades start and propagate though remains open to debate and it seems unlikely that there is necessarily a single model.

The size of the group can also be significant. In his work, Surowiecki notes that a wealth of research suggests that small homogenous groups – such as the Board of a company – can effectively inhibit the take-up of innovations as their individual decision making is, inescapably, influenced by that of the rest of the group. They tend to confirm each others own starting assumptions as to whether something is desirable or not and they tend to believe that they know more than they really do. In consequence, a small group finds it difficult to incorporate new information as there is a tendency to only talk about the information that they all share. The result of this is that they exaggerate the status quo. However, Surowiecki also reports that this need not be true, reporting on research by Blinder and Morgan<sup>69</sup>. In this Blinder and Morgan found that groups were able to make decisions more quickly and more intelligently than was the case when they tried to make the same decisions as individuals – owing to the ability to pool information.

### **Consumer choice – make the choice to adopt easy and simple**

Consumer choice is a vital factor underpinning the speed at which an innovation is or isn't taken up. For the most part, individuals take the place of consumers – the end users of new products and services. Literature suggests that if consumer behaviour is not understood during product development and marketing, there is a clear possibility that the end product will not be adopted.

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<sup>67</sup> Thaler, R. And Sunstein, C (2008) Nudge Penguin

<sup>68</sup> Surowiecki, J. (2004) The Wisdom of Crowds: why the many are smarter than the few Penguin

<sup>69</sup> Blinder, A. And Morgan, J. (2000) Are Two Heads Better Than One? Monetary Policy by Committee. National Bureau of Economic Review working paper 7909

One aspect is change will be rejected if they believe it will be difficult – so innovations and changes that are made to feel easy will be more accepted. De Bruijn and van den Putte (2009)<sup>70</sup> illustrated this by looking at soft drink consumption and television viewing in Dutch secondary school pupils, in the context of investigating how to change habits in young people to promote better health. They determined that there was a correlation between television watching and unhealthy soft drink consumption, and that people have an 'automatic clustering of strongly habitual healthy behaviours'. They found that attempts to change behaviours often failed if the intervention was isolated. Instead, 'changing unhealthy behaviours may require contextual changes in order to disrupt the automatic activation of strongly habitual unhealthy behaviours and to make enactment in more healthy behaviour easier. This may involve making healthier food more readily available in a television viewing context.'<sup>71</sup> This shows us that innovations may fail to be adopted when they are simply an external (even alien) choice to people.

### **Guiding consumer choices**

Trying to guide consumer choices has been a mainstay of the advertising process for decades. Lessons from successful advertising campaigns can offer interesting insights into the adoption of innovations. The story of the inventor James Dyson is well known. Having redesigned the traditional vacuum cleaner he was unable to sell his product to any of the major manufacturers (who were 'locked-in' to their existing models). Instead, he took his product to Japan where the design was particularly appealing to prevailing cultural and social mores. After success in the Japanese market Dyson turned his attention back to the European market and launched a major marketing campaign through the independent media – but through newspaper reporting rather than simply advertising. In a review of this material, Emily Boyle<sup>72</sup> identifies how the content and linguistic style of the newspaper reports had a positive influence on people's purchasing choices, leading them to move away from traditional vacuum-cleaners and embrace Dyson's new concept. The information cascade had begun.

### **Choice saturation**

Strangely, too much choice can also jeopardise the adoption of innovations. We are not, it seems, good at making choices when faced with many different options. The rejection of innovative green energy tariffs is a clear example of the way in which simple choice does not necessarily lead to the adoption of an innovation. The basic point is simple – that people prefer green electricity when asked, but they have not purchased it in the real world when given the choice. The hypothesis is that the way in which an innovation is presented has a major impact on its adoption rate – the framing conditions referred to earlier. Pichert and Latsikopoulos<sup>73</sup> conducted four experiments to determine whether the rejection of a new option was conscious or not. They used systems where green tariffs were set as defaults and people would have to consciously change from them to cheaper, but dirtier energy. The result was that a greater proportion of people stayed with the more expensive green default option than had previously chosen to adopt this when they had to actively decide to do so. The implication is clear: innovations stand a greater chance of being adopted if they appear as somehow being pre-accepted (in this case by being a default option), and that new innovations that are simply one of many choices may well be rejected.

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70 de Bruijn, G. and van den Putte, B., 2009. Adolescent soft drink consumption, television viewing and habit strength. Investigating clustering effects in the Theory of Planned Behaviour. *Appetite*, 53, pp.66-75.

71 *Ibid.* p74

72 Emily Boyle, (2004) "Press and publicity management: the Dyson case", *Corporate Communications: An International Journal*, Vol. 9 Iss: 3, pp.209 - 222

73 Pichert, D. and Katsikopoulos, K.V., 2008. Green defaults: Information presentation and pro-environmental behaviour. *Journal of Environmental Psychology*, 28(1), pp.63-73.

The Policy Studies Institute<sup>74</sup> explored this by analysing the consumption decisions of individuals with regards to environmental products. Their assertion is that products and innovations can fail to be adopted if they are simply one of many facing consumers, as people simplify their decision making processes and are more likely to rely on heuristics. Their recommendations include that:

- Products and innovations are more likely to be adopted if they are developed and marketed to a specific audience, rather than all consumers, as there can't be a one size fits all approach.
- Research into the unconscious, emotional reasons behind consumer choice is also important, as people themselves are often unaware of their irrationality.
- An innovation that is designed and sold not as a product, but rather as a way to address a need, may be more likely to succeed.
- A shift away from providing information to consumers, and towards reinforcing peer-to-peer communication is likely to lead to speedier adoption.
- Incentives can crowd out the intrinsic value of a product, so simplicity of message may be most effective.

#### 4.5 Knowing about an innovation is essential: diffusion of knowledge and awareness

Whilst it is a truism that to adopt an innovation you must be aware of it, not all knowledge is available in all places at the same time. Differential rates of diffusion of knowledge can, and do, lead to lags in the take-up of innovations. This diffusion and adoption of an innovation has a lifecycle that depends on types of people adopting at different times. We don't all purchase a new type of good, or service, at the same time. Some of us are more cautious than others, others are attracted by the 'new'. And the same is true of firms.

##### **Diffusion theory – different types of innovation adoption behaviour**

Frank Bass was among the first to write in this area and his 1969 diffusion model<sup>75</sup> has been adapted in various ways since. Ryan and Gross<sup>76</sup> developed five categories of people according to their ability and willingness to adopt an innovation. These are: innovators, early adopters, early majority, late majority, and laggards<sup>77</sup>. On the one extreme, Innovators are the small minority, driving change and adopting innovations almost regardless of costs. On the other extreme, Laggards are seen as traditional and critical of new ideas, with price and reliability being very important to their decision making. It is possible to chart the groups that adopt an innovation over time (Fig 4.1). These populations need not be evenly distributed across territories.

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74 Policy Studies Institute, 2009. Designing policy to influence consumers: Consumer behaviour relating to the purchasing of environmentally preferable goods [online]. London: Policy Studies Institute. Available from: <http://ec.europa.eu/environment/enveco/pdf/RealWorldConsumerBehaviour.pdf> [Accessed 7 December].

75 Bass, F. (1969) A new product growth model for consumer durables. *Management Science* 15 (5): p215–227.

76 Ryan, B. and Gross, N. (1943), "The Diffusion of Hybrid Seed Corn in Two Iowa Communities," *Rural Sociology* 8 (March): 15

77 Rogers, E. M. (1983), *Diffusion of innovations* (3rd Ed). New York: Free Press

Figure 4.1. Categorisation of adopters according to “innovativeness”

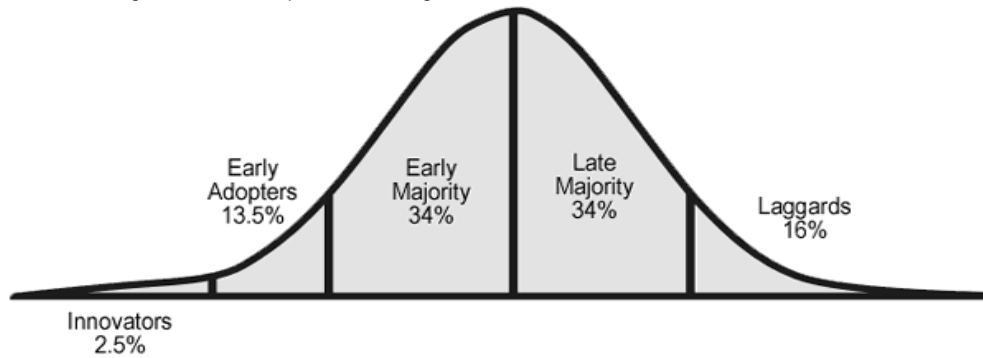


Diagram adapted from Rogers, E.M. (2003). Diffusion of innovations. New York: Free Press. p281

In the 1960s, Rogers developed the ‘Diffusion Theory’ to explain the spread and adoption of innovations<sup>78</sup>. He looked at the way innovation is communicated through different channels over time, to members of a social system. His argument was that successful innovations do not simply “arrive” but must rely on raising awareness through everything from word of mouth to formal media campaigns if it is to be a success. Rogers also draws attention to the importance of an innovation’s characteristics on its rate of adoption. Innovations are not all “born equal”, and the level to which they are taken up throughout the diffusion process is influenced by:

- Relative advantage - ‘the degree to which an innovation is perceived as better than the idea it supersedes’
- Compatibility – ‘the degree to which an innovation is perceived to be consistent with the existing values, past experiences and needs of potential adopters’
- Complexity – the extent to ‘ which an innovation is perceived as difficult to use’
- Trialability – ‘the opportunity to experiment with the innovation on a limited basis’
- Observability – ‘the degree to which the results of an innovation are visible to others’

The Playstation Portable Go (PSPGo) is an example of an innovation that failed to get widespread acceptance or adoption. It failed to achieve critical mass - the ‘minimal number of adopters of an interactive innovation for the further rate of adoption to be self-sustaining’<sup>79</sup>, as it failed to match at least three of these criteria. Released in 2009, some online commentators<sup>80</sup> were quick to predict failure for the PSPGo. First, with a price point of \$249 it was only marginally cheaper than a home games system. Second, it had no backwards compatibility with the original PSP games and relied on digital content rather than physical discs. This meant, it failed compatibility and complexity criteria. Third, no original PSP accessories worked with the machine, meaning these two criteria were failed again. And fourth, technological innovations were small and didn’t signify major steps on from the original it was replacing, meaning relative advantage was small. As a result, adoption of the product was slow and small and diffusion was limited. Despite price reductions the PSPGo was selling just over 3,000 units per week in October 2010 against the original PSP’s figures of almost 39,000 per week<sup>81</sup>.

78 Rogers, E. M. (1962). Diffusion of innovations. New York: Free Press

79 Byeong-Lak Lim, Munkee Choi, Myeong-Cheol Park, (2003). The late take-off phenomenon in the diffusion of telecommunication services: network effect and the critical mass. Information Economics and Policy 15 (2003) 537–557

80 Business Schooled, (2009). Diffusion of innovation models: predicting the failure of the PSPGo. <http://www.business-schooled.com/2009/10/diffusion-of-innovation-models.html#>

81 <http://www.computerandvideogames.com/274358/news/psp-go-sales-triple-in-japan/>

## Critical mass and diffusion

The take-up of innovations then needs to reach a certain critical mass before it will 'take-off'. Rogers argues that 'after the critical mass point, individuals in a system perceive that "everybody else" has adopted the interactive innovation. With each successive adopter of an interactive innovation, the new idea becomes more valuable not only for each future adopter, but also for each previous adopter.'<sup>82</sup> This is particularly the case for communications technologies where the existence of network externalities means that the full value of a product can only be achieved when many others also own a comparable product.

Minitel, a French digital communications network, provides an example of how critical mass can be achieved<sup>83</sup>. The overriding objective in Minitel's initial development was not the development of high profits through high costs to customers. Instead the emphasis was placed on securing a large network membership for its new video communications technology, in order that critical mass could be achieved. A central element of this process was the setting of a zero price point for new customers, set off by an initial subsidy. The objective was to develop a user base and then charge for the product as its inherent value increased. An important lesson learned from Minitel is that many innovations that fail to reach critical mass are seen as a novelty, rather than a necessity. If an innovation is too removed from existing technologies, there is the potential that it will not be accepted. Minitel addressed this by focusing on 'reducing the fear of an unfamiliar activity'<sup>84</sup> by ensuring their new product bore resemblance to existing communications technologies – thereby meeting both Rogers' complexity and compatibility criteria. Ironically, the very success of Minitel is held up to be one example why France was relatively slow in adopting broadband computer technologies. The substantial investment in Minitel and its adoption by a large proportion of the national population had locked France in to a particular technology which took time and money to supersede.

## Social factors in diffusion

Building on Roger's work, and echoing that of writers such as Surowiecki and Gladwell, Young (2009) goes on to illustrate three differing ways in which innovations can be diffused:

- Contagion, which is when people adopt when they come in contact with others who have already adopted. In this sense innovations spread much like epidemics.
- Social influence. People adopt when enough other people in the group have adopted, meaning that innovations spread by a conformity motive.
- Social learning. People adopt once they see enough empirical evidence to convince them that the innovation is worth adopting, where the evidence is generated by the outcomes among prior adopters. Individuals may adopt at different times due to differences in their prior beliefs, amount of information gathered, and idiosyncratic costs<sup>85</sup>.

Importantly, this highlights the way in which diffusion can be informal, between consumers. But more formalised processes are equally important. New technologies and media have 'led diffusion

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82 Rogers, E. M. et al (XXXX), Diffusion of innovations. Stacks, D. and Salwen, M. (eds) An integrated approach to communication theory and research. New York: Routledge

83 Allen, D. (1988). New telecommunications services, Network externalities and critical mass. Telecommunications policy, Sep 1988.

84 Ibid. p263

85 Young, H. P. (2009). Innovation Diffusion in Heterogeneous Populations: Contagion, Social Influence, and Social Learning. American Economic Review 2009, 99:5. p1900

processes beyond the classical scenario of a single-market monopoly of durable good in a homogenous, fully connected social system<sup>86</sup>. The diffusion of knowledge and awareness takes place across a complex network of differing media and platforms and outputs. The relative speed of movement of information, awareness and knowledge across these networks can thus be one crucial determinant of the speed of take-up of innovations. The diffusion and application of knowledge can be influenced by prevailing norms of activity and behaviour – the 'way things are done'. New ideas are not simply picked up by firms, for example, and brought into use. Old ideas must be 'unlearned', production processes altered and new skills acquired (Lundvall and Johnson 1994). Inherited institutions and routines may influence the rate at which firms within an economy adapt to changing circumstances; as inertia forestalls adaptation. Habits and routines tend to be slow to change and patterns of behaviour are reproduced and replicated, with new ideas having to compete with previously accepted norms of behaviour and action (Nelson and Winter 1982). Where an economy is dominated by particular industrial forms and structures this inertia may be especially prevalent (Dosi 1984), a contribution to the path dependent patterns previously identified.

### Network effects in diffusion

Studies of the spillover, or diffusion, of knowledge between parties have demonstrated the importance that geographical proximity can play, but also that other factors are also at work. Writers such as Ron Boschma<sup>87</sup> and Meric Gertler<sup>88</sup> suggest that other forms of proximity can also be influential in promoting the diffusion of knowledge, singling out features such as: cognitive proximity, where a shared knowledge base enables learning to occur; organizational proximity, both across and within organizations, which influences the capacity to co-ordinate an effective exchange of knowledge; social proximity, where embedded social relations support trust and reciprocity in the sharing of knowledge, and institutional proximity, where common habits, rules and routines encourage a sharing of knowledge.

Strategic networks are able to combine many of the dimensions of proximity and so promote the spread of innovations. These are said to compose of inter-organisational ties that are long term and important for firms (Gulati et al., 2000), they also involve long term, repeated exchange relationships (Podolny & Page, 1998). Membership of such networks can promote the spread of innovations, but exclusion may equally cause visible lags in the diffusion of knowledge and the take-up of innovations. Inkpen and Tsang (2005) examine the way in which these networks can vary in form, from heavily structured to quite informal, identifying the following forms<sup>89</sup>:

- Intra-corporate Networks consists of a group of organisations operating under a single corporate identity. The strength of the link varies greatly along several dimensions, such as the extent of decentralizing decision-making authorities to subsidiaries, the nature of the industry concerned, and the physical and cultural distances between headquarters and subsidiaries.
- A strategic alliance is a group of firms entering into voluntary arrangements that involve exchange, sharing, or co-development of products, technologies, or services

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86 Peres, R. Muller, E. and Mahajan, V. (2009). Innovation diffusion and new product growth models: A critical review and research directions. *International Journal of Research in Marketing* Volume 27, Issue 2, June 2010. p3

87 2005

88 2008

89 Inkpen, A. C and Tsang, E. W. K. (2005). Social capital, networks and knowledge transfer. *Academy of Management Review* 2005, Vol. 30, No. 1. pp148-149

- An industrial district (similar to clusters) sees a network of producers, supporting organisations, and a local labour market
- Beyond these, trade associations and R&D partnerships are other examples of networks that can facilitate knowledge transfer

Innovation is much more likely to occur in an environment where information is effectively accessed and shared, such as that provided by the Environmental Protection Agency (EPA) when the Green Lights Programme (GLP) was developed in 1991<sup>90</sup>. Prior to the establishment of the GLP, many US firms looking at energy saving lighting struggled to access information about technological options available to them, and the evaluation of existing technologies that do exist. In this instance it was clearly the role of the government to facilitate access to such information. Through the work of the EPA, the GLP enabled businesses to undertake energy saving lighting upgrades that would improve quality and efficiency, whilst remaining profitable. In return for a corporate commitment to survey facilities and make the indicated lighting investments over a five-year period, the EPA provided technical information, current data on utility rebate programmes, and advertising and public relations support. In addition, the EPA developed a sophisticated and powerful expert system that could assist companies in analysing their lighting needs and performing economic analyses of the upgrade possibilities. Through the sharing of knowledge, data and information, 140 major corporations joined the programme within the first year and were able to improve their lighting systems using innovative energy saving lighting upgrades.

#### 4.6 Skills and education

Technological change, the taking up of innovations, is skills-biased<sup>91</sup>. Equally, early adopters of new innovations are more likely to have high education levels. Education, skills and qualifications are all therefore important contributors to the swift take-up of innovations. Where education systems are less well-developed then lags in innovation may occur. This requirement for knowledge and capabilities is often referred to as 'absorptive capacity'.

##### Research Capacity

Without absorptive capacity, companies are unable to actually absorb and use available information to take-up prevalent innovations<sup>92</sup>. This capacity rests on basic skills and prior knowledge, as well as a shared language and knowledge on the most up to date issues in the field. Importantly, ongoing internal R&D activity also helps to underpin absorptive capacity, allowing companies to 'assimilate and exploit new knowledge'<sup>93</sup>. This is because companies wishing to use external knowledge in their innovation process, may 'conduct basic research less for particular results than to be able to provide themselves with the general background knowledge that would permit them to exploit rapidly useful scientific and technological knowledge through their own innovations or to be able to respond quickly-become a fast second-when competitors come up with a major advance'<sup>94</sup>.

90 DeCanio, S.J., 1993. Barriers within firms to energy-efficient investments. *Energy Policy*, 21(9), pp.906-914.

91 Berman, Eli, John Bound and Zvi Griliches, "Changes in the Demand for Skilled Labor within U.S. Manufacturing Industries: Evidence from the Annual Survey of Manufactures," *Quarterly Journal of Economics*, May (1994)

92 Wesley M. Cohen, W. M. and Levinthal, D. A. (1990), Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, Vol. 35, No. 1, Special Issue: Technology, Organizations, and Innovation. (Mar., 1990), pp. 128-152.

<http://links.jstor.org/sici?sici=0001-8392%28199003%2935%3A1%3C128%3AACANPO%3E2.0.CO%3B2-5>

93 Ibid. P148

94 Ibid. p148

Companies with low absorptive capacity have been shown to struggle in building innovation capabilities. This was demonstrated across a series of Taiwanese manufacturing and finance industries. Using a series of 362 questionnaires, they presented a positive correlation between absorptive capacity and a firm's ability to innovate, with statistical analysis of survey results showing a clear relationship between knowledge acquisition, product innovation, process innovation, and management innovation<sup>95</sup>.

Analysis of the pharmaceutical industry also illustrates the importance of internal knowledge, as it allows firms to monitor and understand external developments. Research which looks at panel set data for 83 firms in the pharmaceutical and biotechnology industries between 1976 and 1995. The research examined the way in which firms cited published scientific research in patents, and the speed with which they exploit existing knowledge in new patented inventions. Findings showed that firms which have poor research capacity, and poor linkages to universities are unlikely to develop patents with external materials cited. Indeed, 'firms with more internal basic research and collaborations with university scientists' cite materials more frequently in patents, and cite referenced prior knowledge more quickly<sup>96</sup>.

### **The role of training**

Even at a more prosaic level, training can influence the extent to which innovations are diffused and taken-up. In a study in the US Azevedo et al<sup>97</sup> found that it took between 6-9 months for firms to respond to changing market conditions (which can include the introduction of new products and processes) with appropriate training for staff. Reasons for this delay ranged from insufficient finance to uncertainty that the market changes would 'stick' or prove successful. Whilst comparable work is not available for other economies it is likely that similar, if not longer, durations would also be visible.

In a recent review of the literature for the OECD<sup>98</sup> Toner argues that "there are large differences across advanced nations in workforce skill formation systems, especially for vocational skills. Such differences result in large disparities across nations in the share of their workforce with formal vocational qualifications, and in the level of these qualifications. The resulting differences in the quantity and quality of workforce skills are a major factor in determining the observed patterns of innovation and key aspects of economic performance". Similarly, economies where skill sets are static or sclerotic find it more difficult to adapt to change – one reason why economies which have been dependent in the past on particular skill sets may struggle to adopt new technologies or industrial processes.

### **Important role of universities**

The role of universities in producing a high skilled workforce is argued to contribute to both the creation and adoption of innovation. Mowery and Sampat (2005) argue that Universities provide an important combination of services for economies and innovation systems – providing both trained

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- 95 Shu-Hsien, L. et al. (2009), Knowledge Acquisition, Absorptive Capacity, and Innovation Capability: An Empirical Study of Taiwan's Knowledge-Intensive Industries. World Academy of Science, Engineering and Technology 53 2009
- 96 Fabrizio, K. (2006). Absorptive Capacity and Innovation: Evidence from Pharmaceutical and Biotechnology Firms. Goizueta Department: Organization and Management. Paper number GBS-OM-2006-002. <http://gbspapers.library.emory.edu/archive/00000253/01/GBS-OM-2006-002.pdf>
- 97 Azevedo, R.E., Park, J. S., Akdere, M. (2008) Lags in Training Response to Changes in Economic Activity: An Exploratory Inquiry for Five Industries available at [http://eric.ed.gov/ERICWebPortal/search/detailmini.jsp?\\_nfpb=true&\\_ERICExtSearch\\_SearchValue\\_0=ED504404&ERICExtSearch\\_SearchType\\_0=no&accno=ED504404](http://eric.ed.gov/ERICWebPortal/search/detailmini.jsp?_nfpb=true&_ERICExtSearch_SearchValue_0=ED504404&ERICExtSearch_SearchType_0=no&accno=ED504404)
- 98 Toner, P. (2011) Workforce Skills And Innovation: An Overview Of Major Themes in The Literature OECD

personnel and advanced research<sup>99</sup>. Whereas firms are likely to specialise in one particular area, universities rarely do. Instead they impact on numerous sectors, for example, by providing trained personnel for industry that may help diffuse and in turn use scientific research, or by responding to demands for developing curricula that are relevant to industrial needs.

### Impact of differences in skills levels

The innovation gap between firms in Canada and the United States provides an illustration of the negative impact that lower skill levels are believed to have on innovation. Research has used firm level data to examine the importance of both skills and government support for innovation, focusing on both product and process innovation. Empirical analysis looked at factors such as the education level of employees in businesses, R&D expenditure, labour productivity, and share of employment in knowledge-based roles. The conclusion was that 'hiring of experienced employees and new university graduates, co-operation with other firms, product market competition and government support for R&D, training and technical support and assistance programs, are the important drivers of product and process innovation.'<sup>100</sup> In cases where companies did not have highly skilled, university educated staff, they were less likely to adopt innovations. This was also the case at an inter-industry level in Canada, where it was shown that 'differences in Canadian manufacturing labour productivity levels are shaped by differences in skills, especially university education, capital intensity, R&D intensity and industry characteristics. In addition, skills also influence productivity via their impact on R&D spending.'<sup>101</sup>

Looking elsewhere in the OECD, it is possible to argue that 'skilled labour has a higher growth-enhancing effect closer to the technological frontier under the reasonable assumption that innovation is a relatively more skill intensive activity than imitation'<sup>102</sup>. Datasets on productivity growth and educational attainment show a correlation, and that 'the growth-enhancing margin in OECD countries is that of skilled human capital rather than that of total human capital.'<sup>103</sup> Importantly, 'skilled human capital has a stronger growth-enhancing effect in economies which are closer to the technological frontier'<sup>104</sup>. This is because as a country approaches the "technological barrier" it shifts from imitation-based productivity towards innovation-based productivity, the latter of which is more skill intensive, and creates higher values from skilled input.

EU innovation policy acknowledges the importance of skills, with Innovation Union stating that its first objective is 'to create an excellent, modern education system in all Member States'<sup>105</sup>. This is spurred by gaps between the EU and competitors in numbers of science students, numbers of researchers and the attraction of global talent amongst other things. The Aho Report also brought together experts to discuss the future direction for EU innovation policy, and it highlighted gaps in education levels as a key stumbling block impeding Europe's bridging of the innovation gap between it and Japan and the US<sup>106</sup>.

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99 Mowery, D.C., Sampat, B.N., 2005. Universities in national innovation systems. In: Fagerberg, J., Mowery, D.C., Nelson, R.R. (Eds.), *The Oxford Handbook of Innovation*. Oxford University Press, Oxford. P209

100 Roa, S. et al. (2002), the importance of skills for innovation and productivity. *International productivity monitor*. No 4, 2002.

101 *Ibid.* p20

102 Vandenbussche, J. et al. 2005. *Growth, Distance to Frontier and Composition of Human Capital*. London: Institute for Fiscal Studies, (W04/31). p.1

103 *Ibid*

104 *Ibid*

105 SEC(2010) Europe 2020 Flagship Initiative Innovation Union. COM(2010) 546 final. P8

106 European Commission. (2006). *Creating an innovative Europe- Expert Group on R&D and Innovation* appointed following the Hampton Court Summit and chaired by Mr. Esko Aho

## 4.7 Market and organizational structures influence decision-making

There is an ongoing debate as to the role that structures – be they of organisations or markets – play, in influencing the take-up of innovations. Whilst much of this is couched in the language of the development of new or improved products and processes, it applies equally to the adoption of these developments. The role of universities within the innovation process is also important – not for themselves so much but in their role as ‘pipelines of knowledge’<sup>107</sup>, channelling and brokering the potential to take-up innovations into the local economy.

### **Organisational structures – open systems and dynamism**

An organisation's structure has a significant effect on the capacity for innovation to be taken forward or potentially rejected. Much of the literature agrees that where organisations show inability to change, their structure or practices are at least partly to blame. In fact, innovation sometimes needs to occur outside existing organisational structures in order to ensure that unsuitable organisational environments don't stifle its effective utilisation. This often involves the founding of separate spin-off companies to make use of knowledge spillovers, allowing the development of totally new products not suited to established company aims of structures (Desyllas & Hughes, 2010; Benner, 2009).

One example is Xerox. In the 1970s, the company set up a major research and development centre (PARC – the Palo Alto Research Centre). Numerous groundbreaking innovations began at the centre, including graphical user interfaces and bitmap screens, yet many innovations yielded little economic value for Xerox despite being of enormous economic value<sup>108</sup>. Chesbrough analysed numerous projects and interviewed past and present managers. The end argument was that Xerox missed out on the end financial benefits of a great number of innovations because of the innovation structure and system it employed.

Xerox employed a closed innovation system, based on the internalisation of product development from idea stage to distribution. However, many of the technological developments achieved at the research centre could only be fully exploited in a more open innovation system. By looking at the life of numerous projects and successful innovations, Chesbrough determined that the key factor was often staff leaving the closed innovation system and working in smaller or start up companies. These were devoid of vertical hierarchies and appeared more dynamic, focusing on creating ‘systems and architectures that enabled their products to work with other companies’ products<sup>109</sup>. In other words these more dynamic, open organisations were better suited to exploiting and implementing individual innovations than a multifaceted corporation.

A specific product example from Xerox is Adobe, software which would have been of relatively little value or use within Xerox's corporate structure that proved highly successful when developed and marketed by a break-away company with a different strategy than the closed system of Xerox. In this case, the focus became licensing the software out to different manufacturers, rather than keeping it as an exclusive component of Xerox's hardware. After taking this step, Adobe came to be worth more than Xerox (as a company) by 2000 (Chesbrough & Rosenbloom, 2002).

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107 Bennenworth, P. and Hospers, G-J. (2007) 'The New Economic Geography of Old Industrial Regions: Universities as global-local pipelines' Environment and Planning C: Government and Policy Vol. 25 pp. 779-802

108 Chesbrough, H. W. (2003), Open Innovation – the new imperative for creating and benefiting from technology. Harvard business School Press, Boston.

109 Ibid. p4

Although the end success of spin-off companies was largely unforeseen, the process of shifting them out of Xerox was a conscious decision. Within Xerox, many products did not fit with the overall business of the corporation, and so internal funding was stopped and spin-offs were allowed to be created. Success was achieved due to the resulting increased linkages to external events and influences, and dedicated time and resources spent on the development and transformation of the individual projects that would not have occurred within the closed innovation system of a major corporation. Thus the ability of an economy to spawn new start-up companies can prove fundamental to the development of innovations, whilst the structures of particular organisations can slow-down the take-up of new innovations.

### **Market organisation – role of public-private partnership**

Similarly, the organisational structures across an economy can influence the speed with which innovations are taken-up. For example, it has been suggested that the Greek economy is an example of a system where innovation has been hampered by not having close linkages between businesses and universities, leading to innovation lags and gaps. National laws limit the creation of significant linkages between universities, public and private sectors, immediately hampering the innovation process and diffusion of knowledge of new innovation possibilities<sup>110</sup>. Also, despite the need 'to steer more students toward technical education the various educational reforms stumble on the Greek mentality, which is negative to technical education (as it does not provide the desired social recognition and social status to its graduates) placing more emphasis on social sciences'<sup>111</sup>. The result, it is argued, is a national system that fails to promote the development of vital relationships for innovative outcomes.

The importance of universities to the innovation process is elaborated by Betts and Lee<sup>112</sup>. They outline four roles that universities have in driving innovation. First, as an innovator, commercialising and generating knowledge. Second, as a partner for the private sector, providing technical skills and knowledge. Third, as a talent magnet, attracting highly skilled, talented individuals to a given area. And fourth, as a facilitator, acting as a networking link between the public and private sectors. The key argument is that it is only possible to truly appreciate the importance of good quality universities on innovation processes if a multifaceted approach is taken. Simply focusing on one dimension of a university's activities risks missing the complex way in which they influence, are influenced by and are linked to industry. These arguments are backed up by specific case studies. Armstrong et al<sup>113</sup> analyse the contribution that universities in the state of Pennsylvania have made to intellectual property creation as well as in supporting employment creation and economic activity. Looking at the activities of 14 state universities, the researchers were able to determine that universities were actively engaged in commercialisation activities with partner businesses. They also concluded that the universities were often linked to induced economic development activities including partnerships with institutions and government, workforce development, and business acceleration.

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110 Piperopoulos, P. and Piperopoulos, G., 2010. Is Greece Finally on the Right Path Toward Entrepreneurship, Innovation, and Business Clusters? *International Journal of Public Administration*, 33(1), pp.55-59.

111 Ibid. p57

112 Betts, J. R. and Lee, C. W. B. (2004). *Universities and drivers of regional and national innovation: an assessment of the linkages from universities to innovation and economic growth*

113 Armstrong, T.O., Bernotsky, R.L., Bohl-Fabian, L., Loedel, P.H. and Yazdi, K., 2006. *Economic Impact Study of the Pennsylvania State System of Higher Education*. 2006 Pennsylvania Economic Association Conference, 1-3 June 2006, Indiana, PA. Indiana: Indiana University of Pennsylvania.

## Market structure and innovation – monopoly effects

The relationship between market structure and innovation is complex and contested, as reflected by Symonds (2001) for example, who argues that 'strong theoretical predictions on the effect of competition on innovation cannot be made'<sup>114</sup>. Looking at industries affected by the 1956 Restrictive Trade Practices Act 'produced no evidence of any significant effect of price competition on innovation at the industry level'<sup>115</sup>.

As early as 1968 Kamien and Schwartz postulated a dynamic relationship between innovation and concentration. Rather than stating that monopolies simply do or do not lead to innovation, they argued that a more intermediate balance between competition and monopoly is most effective. This is because of several factors:

- Current profitability delays innovation
- Post-innovation profits drive innovation
- Losses incurred when a rival innovates successfully, drives innovation
- Intermediate rivalry is best to promote innovative activity

Essentially, if a company is the holder of a complete monopoly, it will have little cause to innovate as its profits may remain high regardless. Yet if there are some competitors, there is both a push and pull to innovate. Too much rivalry will mean little incentive to innovate as the gains may be shortlived as others constantly compete, whereas too little rivalry means that there is insufficient threat from rivals to push innovation<sup>116</sup>.

In 1979, Dasgupta and Stiglitz criticised the search for a causal relationship between monopoly, competition and research. Their position was that there should be a distinction made between competition in the present product market and competition in R&D. Having made this split, they concluded that:

- If the present product market is dominated by a monopolist, there is likely to be more R&D as post-innovation profits will be higher – supporting Schumpeterian arguments
- If there is competition in R&D, there will be more research than in a monopoly, as 'with free entry, expected average returns must equal average costs...competition may result in excessive expenditures on R&D relative to the social optimum.

Drawing on game theory, they go one step further to argue that even if there is open competition in R&D, it may not lead to the breaking of monopolies in the product market. This is because if the R&D technology is also available to the monopolist, it can simply engage in faster research to deter competitor entry to the market. In this sense R&D competition has a positive impact on the speed of R&D in a monopolistic product market<sup>117</sup>.

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114 Symonds, G. (2001). Price Competition, Innovation and Profitability: Theory and UK Evidence. Discussion paper, University of Essex. <http://www.essex.ac.uk/economics/discussion-papers/papers-text/dp530.pdf> p3

115 Ibid.

116 Van Cayseele, O. J. G. (1998), Market structure and innovation: a survey of the last twenty years. *De Economist*, 146, NO. 3, 1998. p394-5

117 Dasgupta, P. and J. Stiglitz (1979). Uncertainty, Industrial Structure, and the Speed of R&D. *Econometric Research Program Research Memorandum No 255*. <http://www.princeton.edu/~erp/ERParchives/archivepdfs/M255.pdf>

## Competition as innovation enabler and inhibitor

An interesting model is presented by Aghion et al (2003), who show an inverted U-shape model of competition and innovation. They argue that 'competition may increase the incremental profits from innovating, and thereby encourage R&D investments aimed at "escaping competition"<sup>118</sup>. This attempt to escape competition will become more intense and widespread in industries in which firms are neck and neck, with similar production costs. Their empirical results demonstrated that there is an inverted U-shaped relationship between product market competition and innovations. In this, when competition is low, so innovation rates are high as firms seek to escape competition completely. However, as competition reaches high levels, so does the Schumpeterian effect and benefits decrease, leading to decreased innovation.

Market structure is also highly relevant to the extent that it provides the right conditions to enable innovation take-up. This is closely related to access to finance, relevant to both consumers and firms. For firms it is necessary for entrepreneurs and firms to be able to develop the innovation, to get it to market, obviously if it is not possible to get a product from development to market then this will form a major lag in its adoption. Similarly access to finance is necessary for firms and consumers for them to be able to purchase the innovation in question, this is particularly relevant to the high value innovations. Access to finance in the context of environmental improvement and resource efficiency has always been something of a hard sell to financiers. The problem revolves around the double externality problem of eco-innovations, examined by Renning<sup>119</sup>, this is based on the fact that the benefits of eco-innovation do not just go to the innovator representing a negative externality to them, but a positive externality for society, doubly, the negative externalities of non eco-innovations are rarely forced to internalise the costs of their environmental damage. While not a problem specific to take-up of innovation, it is certainly an issue in promoting eco-innovation and a contributor to lags in the whole process.

A final aspect of market structure relevant to lags in the context of this study is the ability of innovative products and entrepreneurs to expand into other countries. Differences in language, culture and regulation all multiply the difficulty in taking an innovation product from one market to another. This is apt to the EU where there is a diversity of languages and these other features across the union. This forms a significant barrier to take-up and one which often only the most entrepreneurial firms successfully cross and even then at considerable time and expense. The result is the effective creation of lead markets for innovative products in first moving countries, with a lag in diffusion as these other barriers are broken down. This is typical and natural to innovation diffusion in any case, but the barriers are understood to lengthen the time taken<sup>120</sup>.

## 4.8 Policy makers can hinder as well as assist

Regulation and Standards play a crucial, but ambiguous, part in the take-up of innovations. On the one hand they can slow the adoption and take-up of innovations, on the other they can enhance it. What is clear though is that differential standards of regulation can play a clear role in affecting the speed at which innovations are adopted across economies and territories. In a well publicised story, the potential impact of the regulatory environment on the differential take-up of innovations was well illustrated recently in the UK<sup>121</sup>. There the Segway, that innovative motorised personal

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118 Aghion, P. Bloom, N. Blundells, R. Griffin, R. and Howitt, P. (2003). Competition and Innovation: An Inverted U-Relationship. P2

119 Rennings, K., (2000) Redefining innovation – eco-innovation research and the contribution from ecological economics

120 Rennings, K., (2011) Eco-innovation policies: concepts and best practices – presentation to Nottingham University Business School 4th March 2011

121 Beckford, M. (20.01.11) Segways, the future of transport, left with nowhere to go after court ruling Daily Telegraph p.1

transportation device, was recently classed as a motor vehicle. This means that they cannot be used on pavements. Yet, neither are they legally allowed to be used on the UK's roads, as they do not comply with road traffic law. This means that, effectively, the Segway can only be used on private land and so fundamentally limits the potential for the use of this innovative product which, it has been suggested, might revolutionise urban transport. In contrast, in most of the US and in many other countries of the EU it is legally possible to ride a Segway on the pavement, and so opens the door for the take-up of this product.

### **Regulation as a driver of innovation**

In other cases, the slow change in regulatory environments means that innovations are taken-up first in those places which more rapidly change regulations to enable certain actions. An example explored by Janicke and Jacob (2004) is the catalytic converter. They explain that Californian standards for air quality and automobile emissions were adopted by the US Congress in the 1970s at a time when existing technology could not meet them. There was too short a period before implementation of standards to develop new engines, and the catalytic converter became the "innovative" manner of controlling emissions. Other countries with automobile industries later adopted the regulations, with Japan doing so to 'adapt its car industry to global markets and enhance its competitiveness'<sup>122</sup>. Similarly, Olinjer and Fernando-Cornejo (1998) examined data on all new chemical pesticide registrations introduced by the major (top twenty) chemical pesticide firms between 1972 and 1991. Their method was to determine changes in company R&D expenditure and the final toxicity of products, set against the regulatory context. They found that 'research expenditures, firm market share growth, and international entrants relate positively to new chemical pesticide registrations'<sup>123</sup>. In addition, their research suggested that regulation 'encouraged the development of less toxic chemical pesticides'<sup>124</sup>, suggesting a clear link between innovation and "standard setting" regulation. In contrast, in the UK at least, Gann et al. (1998)<sup>125</sup> report that building regulations have been found to inhibit the take-up of innovations by locking in past practices and technologies.

How regulations interact can also have a significant impact on the overall propensity of an economy to develop and adopt new innovations. Analysis has showed that regulation was one of the most important factors in determining innovation activity in China, as companies were often unable to undertake innovative actions, or unaware of how to navigate co complex rules (Ma et al. 2010). Analysis of the regulations and policies put in place, linked to firm outputs, showed that problems include<sup>126</sup>:

- Poor, repetitive and sometimes contradictory policy content
- Insufficient attention paid to SMEs in manufacturing
- Too much emphasis on established firms rather than newer firms that may look to innovate and experiment

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122 Ibid. p34

123 Michael Ollinger, M. and Fernandez-Cornejo, J. (1998). Innovation and Regulation in the Pesticide Industry. *Agricultural and Resource Economics Review*, April 1998. p24

124 Ibid.

125 Gann, D.M., Wang, Y. and Hawkins, R. (1998) "Do regulations encourage innovation? – the case of energy efficiency in housing" in *Building Research and Information* Vol 26, No 4, pp 280-296

126 Ma, J., Wang, S. and Gui, J., 2010. A Study on the Influences of Financing on Technological Innovation in Small and Medium-Sized Enterprises. *International Journal of Business and Management*, 5(2), p209

## Regulation as hindrance to innovation

However, once again there are paradoxical messages emerging. Whilst the work by Ma et al criticise incomplete intellectual property rights legislation - showing that innovation could be abandoned in the absence of adequate legal support for ownership - Van Alphen et al. (2010)<sup>127</sup> show that in the case of new and emerging technologies, - such as carbon capture storage technology - innovation is much more difficult in overly-strict regulatory conditions, due to its constraining of knowledge spillovers or organisational cooperation.

## Policy and increased take-up - procurement

One area where the literature is more consistent is that public policy can act as a force to promote the take-up of innovations, or to hinder it, as a consequence of its procurement decisions. In the most active cases the public sector takes the role of lead market, meaning that 'diffusion processes start earlier, and market penetration is typically more complete'<sup>128</sup>.

The role of procurement as a demand-side driver for innovation has been an important dimension of European discussions on innovation, and how to bridge the innovation gap between the EU and its competitors. The Aho Report for example, emphasised the use of public procurement to drive innovation, with the public sector taking the role of intelligent customer. This role would involve public sector organisations utilise their skilled staff to maintain an awareness of potential new solutions to challenges presented, and to both specify and manage contracts<sup>129</sup>.

An expert group report on developing procurement practices<sup>130</sup> provided a series of recommendations that underpinned this strategic EU policy agenda. Its fundamental argument was that the role of the public sector was as a main actor in lead markets, able to 'lower the risk for the developing firms and subsequent customers by acting as a launching customer for innovative technologies and solutions'<sup>131</sup>. In addition, it promoted the 'introduction of innovation-orientated technological requirements in tendering procedures [that] can stimulate the use of new but not yet commercialised technologies. This in turn can foster investment in R&D to improve these technologies or develop new ones, creating a dynamic knock-on effect through the EU economy.'<sup>132</sup>

Nine case studies of public procurement for products involving technology in six different countries (Germany, Austria, UK, Netherlands, Italy and Norway), covering a variety of products including new lighting, radio systems and a benefit card<sup>133</sup> give a series of lessons for using public procurement to drive innovation. The research determined that there is no single best practice for procurement to promote innovation, but that there are a series of lessons for an effective process. The procurement process should include<sup>134</sup>:

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127 Reference

128 Janicke, M. and Jacob, K. (2004). Lead Markets for Environmental Innovations: A New Role for the Nation State. *Global Environmental Politics* 4:1, February 2004

129 European Commission. (2006). Creating an innovative Europe- Expert Group on R&D and Innovation appointed following the Hampton Court Summit and chaired by Mr. Esko Aho

130 European Commission, (2005). Expert Group Report. Developing procurement practices favourable to R&D and innovation. EUR 21793 EN

131 Ibid. p11

132 Ibid. p11

133 Edler, J., Rigby, J., Hommen, L. and Tsipouri, L., 2005. Innovation and Public Procurement. Review of Issues at Stake. Study for the European Commission. Brussels: Institute Systems and Innovation Research.

134 Ibid. pp.ii-vii

- A careful identification of requirements
- Market intelligence gathering
- High quality tender specifications with a balanced gap between requirements of the outcome, and the capabilities of potential suppliers
- Expert-led tender assessment and selection
- Precise monitoring and management of contracts

Countries where regulators and public procurement agencies are able to grasp the potential of new innovations are more likely to witness the take-up of such innovations. It is in countries where this does not happen that lags in take-up can be found.

## 5 Understanding innovation lags: evidence from contrasting cases

### 5.1 Introduction

The previous chapter, while acknowledging that other factors can also be important, put forward seven principle reasons for innovation lags. The evidence was presented in the context of various local and specific examples, but was primarily based on the theoretical and scientific work on the subject. The question then occurs - are these reasons evident in the lags that exist in the adoption of specific technologies at a wider global or macro level?

This section presents five global case studies of lags in innovation adoption. The selected cases are each highly significant in their impact or potential. They represent some of the most powerful innovations of recent decades, such as internet and mobile telephones; what many thought could and should have been major innovations in recent decades such as alternative vehicle and fuels and energy efficiency technologies; and also process innovations, which are at the heart of all production efficiency improvements, and will be crucial in a world with increasing pressure on resources.

The cases build upon the previously examined context of innovation and evidence of the level and timeliness of take-up and the existence of lags. The cases directly explore the specific reasons used to explain the lags. The final section draws together the common threads from each of these cases, relating these back to the seven principle reasons established previously.

### 5.2 Case study: Automotives - alternative vehicle and fuel technologies

The biggest concern in innovation for alternative vehicles and fuels is the extent to which they have not succeeded in having market impact in all but a few niche areas or markets. The petrol-based internal combustion engine has remained dominant for nearly a century, with significant but only incremental improvements to the design and efficiency of vehicles. The failure to move beyond this technology to a less polluting and more efficient alternative is an interesting problem and one with many explanations.

Below, we explain the reasons for lags in uptake, adoption or availability.

#### **Technological Readiness – are alternative vehicle and fuel technologies ready?**

Among the primary reasons cited for the general inertia in alternative vehicle and fuel adoption is technological readiness. There is a strong argument that the alternative vehicle and fuel technologies are not yet developed enough to be cost efficient, practical or that they sufficiently overcome the shortcomings of the existing standard technologies, which themselves continue to gradually improve over time.

Battery technology is a major sticking point for the development of electric vehicles. The lead-acid batteries found on almost all vehicles are heavy and have only a low storage capacity, in a

comparison in 1996<sup>135</sup>, they stored 40 watt-hours per kg (Wh/kg), as opposed to petrol which contains closer to 13,000 Wh/kg and this, while not covering all issues, has been at the heart of the problem. New developments for Lithium-ion batteries are pushing capacity up to closer to 200 Wh/kg and bringing down costs, yet there is still some distance to travel. It is noteworthy that the first fully BEV, the Nissan Leaf, is not expected to be profitable for Nissan at first, according to their US Sales and Marketing chief "Over the course of the vehicle life, it is profitable – in year three."<sup>136</sup> This provides strong evidence that the technology for electric vehicles is on the cusp of cost competitiveness but is not yet there. Yet this is also understood to be the business model adopted by Toyota in releasing the Prius HEV, whereby it is claimed that until 2002 or 2003, a few thousand dollars was lost on each vehicle sold<sup>137</sup>. It may be necessary therefore for alternative vehicles to run as a 'loss-leader' for firms in the first instance, not an attractive proposition for most companies.

Ethanol based biofuels, although one of the few alternative technologies to make an impact, have their benefits called into question. This is particularly the case with US and European biofuels which have poor energy and GHG balances and require substantial amounts of land, though the situation is different for Brazil. The sugar cane crop used in Brazil has higher energy density than the corn or rapeseed crops used in the US and Europe and the industry is also highly developed with Brazil a clear world leader in the field. It is estimated to achieve an energy balance<sup>138</sup> of aprx. 8-10<sup>139</sup> times greater than energy inputs, whereas in the US, corn-based biofuels achieve energy balances of only 1-2, some have even estimated negative energy balances over the full life cycle.

These successes in Brazil, are the result of a variety of factors including a climate and crop (in the form of sugar cane), that is well suited to biofuel production and vast areas of suitable arable land. That Brazil is the only country where biofuels have developed to this extent, despite other tropical and sub-tropical countries with similar abilities to grow the crops, points to other factors at work. Something that sets Brazil aside has been major government intervention, through a set of strict regulations, mandating biofuel use and markets for it, and subsidies that supported the growth of production capacity and infrastructure. These framework conditions were introduced in the 1970s, earlier than almost anywhere else and have seen strong and sustained support since their introduction. The only other country with a comparable history of government intervention and subsidy is the US, which also started its support programmes in the late 1970's. These have also been successful to the extent that the US is the worlds biggest biofuel producer and a leading user, by proportion of total fuel, but the US is still far behind Brazil in proportional usage. This suggests that the development of biofuels is also regulation and subsidy led.

In Brazil, the subsidies for biofuels have been phased out and it is usually price competitive with standard fuel, though standard fuel is heavily taxed in comparison to the US. This indicates a situation where support has contributed to the successful creation of a new industry, with success determined by the ability to withdraw funding and the sector to continue to hold its own. On the other hand, the use of higher taxes on standard fuels suggests there is continuing indirect support for the sector. This may point to a potential form of path-dependency emerging, that the previous investments and commitments to grow the biofuels sector are having a powerful influence on current and future policy and choices, tying Brazil to further biofuel development.

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135 Cowan, R. and Hulten, S., (1996) Escaping Lock-In: The Case of the Electric Vehicle. *Technological Forecasting and Social Change*, 53, pp.61-79.

136 <http://green.autoblog.com/2010/05/15/nissan-leaf-profitable-by-year-three-battery-cost-closer-to-18/>

137 Dijk, M. and Yarime, M., (2010) The emergence of hybrid-electric cars: Innovation path creation through co-evolution of supply and demand. *Technological Forecasting and Social Change*, 77, pp.1371-1390.

138 Energy balance is the balance between the energy inputs applied to produce the crop compared to the energy outputs produced from its use.

139 Borjesson, P., (2006). Energy balance for bioethanol a knowledge overview. *Environmental and Energy Systems Studies*. Lund University. Report No. 59.

The situations in the US and Brazil when biofuels policies were developed were both similar and very different. At the start of the 1970's the US was moving into a period where its consumption of oil was first beginning to exceed its own production. In Brazil at the beginning of the 1970s around 70-90% of its fuel needs were met through fuel imports<sup>140</sup>. Although the US had a very different starting point, it was also beginning to become a fuel importer. The reaction by both was to attempt harness their high land availability and advanced agricultural production to produce fuels. Since the 1970's US oil consumption has continued to exceed production, while on the contrary, Brazilian oil production has markedly increased, to a point where it is now largely self-sufficient for oil<sup>141</sup>. Major recent offshore oil finds suggest Brazil may also become an oil exporter over the next decade. It is hard to conclude clearly on the role of fuel scarcity (self-sufficiency) in biofuel development, it may be a necessary condition to induce support to start an industry, but its elimination as a problem has not drastically reversed its progress in Brazil, at least not to date.

The balance of evidence suggests that biofuel technology is close to readiness in Brazil where the crop is highly suited, but even there it has required strong subsidy and regulation to start an industry and bring high take-up. Therefore while there is potential to replicate this technology in other tropical and sub-tropical countries it may take time and significant government support. In the US, even with significant support, take-up has been slower and is less than Brazil, this seems to most strongly reflect that corn-based biofuel technology is not yet ready for widespread take-up although relatively low standard fuel taxes may also reduce the attractiveness of alternative fuels. A similar conclusion could also be logically drawn for other current biofuel technologies in high and low latitudes.

#### **Existing infrastructure – current automotive technology and systems are 'locked-in'**

Path dependency is a serious issue in the automotive sector. This is understandable given the length of time the standard petrol-based internal combustion engine has dominated personal transport and the infrastructure, firms and lifestyles that have developed around the specific attributes of it. Cowan and Hulten<sup>142</sup> found that in cases of historically dominant technologies such as the internal combustion engine it is very difficult to escape the technological lock-in.

The lock-in is not only technological though, it is also based on interdependencies with other sectors both upstream and downstream of the automotive sector, specifically in the fuel infrastructure, car sales dealerships and auto mechanics. Cowan and Hulten believe the size, scale and strength of these networks have combined to make the position of the petrol-based vehicle unassailable. For firms the reasons for lock-in are simple and compelling, they are engaged in what is a highly competitive market and also where the size of the R&D investment required and the risk involved is high, particularly given that the potential financial return is likely to be low in the short term.

A key factor in this path dependency is scale, the resources required to develop alternative vehicles are significant. The small scale of the electric vehicle industry compared to standard vehicles makes it very difficult to achieve the same economies of scale, technological learning and to support the development of electric vehicle specific components. This acts to practically exclude new entrants to the market and introduces a dependency on the existing firms in the sector to

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140 Economy and Energy 40 - [http://ecen.com/eee40/brazilian\\_energy\\_analysis-1970\\_to\\_2002\\_period.htm](http://ecen.com/eee40/brazilian_energy_analysis-1970_to_2002_period.htm)

141 <http://www.eia.doe.gov/cabs/Brazil/Oil.html>

142 Cowan, R., Hulten, S., (1996) Escaping lock-in: The case of the electric vehicle. *Technological Forecasting and Social Change* 53, 61-79.

generate the innovations to move to alternative vehicles. There are a variety of reasons for firms already existing in the sector to not pursue this course of action, not least the costs and risks associated with potentially re-tooling or making redundant large parts of their production process, perhaps requiring the write-off of expensive capital equipment. In addition a number of firms have developed their business models around certain types of vehicles and production, notably SUVs in the US, and there is little financial incentive for a switch away from areas where high profits can be secured from existing technologies.

A counter-argument to path-dependency preventing innovation in the automotive sector is provided by Ahman & Nilsson<sup>143</sup>, they argue that while it has been a major factor in the automotive sector in the past it does not have to continue to be in the future. Developments in other sectors could prove the key to breaking lock-in, this is important as many of the key components required to transition to electric vehicles are based on or reliant on technologies used in other sectors. They point out that advances in the electronics and battery industries, have provided technologies that have then been able to be applied to the commercialisation of the electric drivetrain as used in HEVs. While noting that there is still significant progress to be made in developing this technology, e.g. the electric drivetrain in Prius accounts for only around 30% of total vehicle power, they argue that cross-overs from other sectors such as this will enable continued alternative vehicle development to break the lock-in. In respect of biofuels path-dependency is also likely to work in favour of continued development towards 2<sup>nd</sup> generation biofuels as a biofuel infrastructure has already developed in many countries.

An aspect of innovation development relevant to the emergence of lags is the timing of innovation. A study<sup>144</sup> into the timing of innovation in the automotive industry in relation to the business cycle concluded that for large firms their innovation spend is generally pro-cyclical or inline with that of the general business cycle. The analysis suggested that strategic timing, as elaborated by Barlevy<sup>145</sup>, was the primary factor at work, that firms would try to maximise gains from innovation in the timing of its release in the expectation that other firms would potentially be able to adapt and improve upon the innovation. This may have an implication in respect of lags in alternative vehicle innovation, in that without a first mover in the field then firms do not have a lead technology to adapt and improve, and also that the incentive to be a first mover is diminished by the understanding that the benefits may be short-lived.

### **Market conditions – innovation hoarding and size of initial investment excludes new entrants**

Lags exist within markets for alternative vehicles to the extent that only a few manufacturers are yet capable of mass-producing these technologies. As a result it can be argued that overall vehicle performance lags behind the frontier of what is possible if best practice technology could be shared and applied across all new vehicles. This issue was reviewed by Los and Verspagen<sup>146</sup>, they explored the competition issues at stake and how any policy intervention in this area would be highly controversial. To eliminate or reduce lags across countries and manufacturers would require the best practice or latest technology to be shared across all, this would throw up a myriad of legal issues, intellectual property rights and would also be regarded as unfair. For these reasons alone

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143 Ahman, M. and Nilsson, L., (2007) Path dependency and the future of advanced vehicles and biofuels. *Utilities Policy* 16 2008 pp80-89.

144 Giedeman, D.C., Isely, P.N. and Simons, G.P.W., (2006) Innovation and the Business Cycle: A Comparison of the U.S. Semiconductor and Automobile Industries. *International Advances in Economic Research*, 12, pp.277–286.

145 Barlevy, G. (2004), On the timing of innovation in stochastic Schumpeterian Growth models. NBER Working Paper 10741.

146 Los, B. and Verspagen, B., 2009. Localized innovation, localized diffusion and the environment: an analysis of reductions of CO2 emissions by passenger cars. *Journal of Evolutionary Economics*, 19, pp.507-526.

the idea is a non-starter, but it raises the issue that in a competitive market there will always be some companies that are ahead of the rest and others that lag and that this is likely to distort innovation adoption patterns. This is simply demonstrated by the development of HEVs in Japan where the first models were on sale in 1997, whereas the same models were not released to the US market until 1999, a built in 2 year lag and also an example of the deliberate choice by firms for lead-markets.

A lack of ambition or commitment from industry is sometimes cited as a key factor in failure to switch to alternative vehicle or fuel technologies. A study into fuel cell development<sup>147</sup> made this point, that firms are happy to 'let the market decide' and that they have formed an alliance to argue this. For new technologies without established consumer understanding or a product at market it could be easy to argue there is no demand. Perhaps the more worrying aspect is the agreement between manufacturers in favour of this approach, suggesting that they may collude to avoid further technological development.

### **Consumer perception – are people ready for and demanding alternatives?**

Consumer perception and how it translates into demand for products is a crucial factor in innovation diffusion. Cowan and Hulten<sup>148</sup> note that consumer perception is a strong factor, particularly in respect of escaping the situation of lock-in in the automotive sector. Aside from the technological aspect of standard automobiles fulfilling the practical needs of consumers they are now also established as the definitions of cars and personal transport<sup>149</sup>. Establishing alternative vehicles within this definition is likely to be a significant challenge as alternatives will need to offer at least the same functionality as standard vehicles and also something extra, although the extra is logically offered through reduced pollution, emissions and noise. For this reason it has been recommended that demonstration and other trial projects explicitly have a social vision to help overcome the non-technical issues faced<sup>150</sup>.

Consumer perception is seen as an important factor in innovation diffusion as consumer demand provides a market pull for innovation. In respect of HEVs it is understood that consumer perception has played an important role in their initial success, down to both their value as a status symbol and also the perception that they are 'socially responsible' and 'the right vehicle for society'<sup>151</sup>. These perceptions form a social narrative that becomes associated with a product, either positive or negative, which can influence potential adopters. It can also have important effects on the actions of producers.

Importantly though the same study identified that around 95% of consumers were satisfied with standard technology vehicles, their main concern was for 'sufficient performance engines at the lowest price or higher performance engines at a slightly higher price'. Dissatisfaction was reported by only 5% of those surveyed that preferred cleaner and more efficient engines and were willing to pay a price premium for this. Some studies have argued that this represents wider unsatisfied demand for electric vehicles and other environmentally adapted vehicles. Dabels<sup>152</sup> commented on

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147 Harborne, P., Hendry, C. and Brown, J., 2007. The Development and Diffusion of Radical Technological Innovation: The Role of Bus Demonstration Projects in Commercializing Fuel Cell Technology. *Technology Analysis and Strategic Management*, 19, pp.167-187

148 Cowan et al (1996)

149 Hard, M., and Knie, A., (1993) *The Ruler of the Game: The Defining Power of the Standard Automobile*, WZB Publ., Berlin.

150 Harborne et al (2007)

151 Dijk, M. and Yarime, M., (2010) The emergence of hybrid-electric cars: Innovation path creation through co-evolution of supply and demand. *Technological Forecasting and Social Change*, 77, pp.1371-1390.

152 Dabels, J., (1992) *Environmental Requirements and the Impact Prototype Vehicle*, OECD, Paris.

the launch of alternative vehicles by Volvo and General Motors when each received a number of immediate orders after they presented their ECC and Impact concepts, despite no actual production plans existing. The weight of the evidence though, supported by work by Beise and Rennings<sup>153</sup> Train and Winston<sup>154</sup>, tends to support the conclusion that market demand for performance is the dominant factor in the adoption of automotive innovations. Even significant price cuts, in the order of 50%, may not be enough to bridge perceived performance and quality deficiencies. This has important implications for the diffusion and adoption of alternative vehicle technologies, at first only a niche market may be interested in them, but if they can change the perceptions of the majority of consumers then widespread diffusion is likely to follow but that this will take time.

Consumer inertia in decision making such as this, has also been studied in a general context and in other sectors. A study by Dube, Hitsch and Rossi<sup>155</sup> found that by comparing three possible options for consumer inertia: loyalty, consumer search and learning; that loyalty was most consistent with the results. That consumers will continue to purchase the same product or brand if the costs of exploring a different option are high and that they attach a high cost to switching. They found less evidence to support the other options, searching or learning. This could be consistent with alternative vehicle technologies, to the extent that they automobiles are high cost products and therefore the switching costs are also high. Some of this may be overcome within brand loyalty, if a trusted brand produces a HEV for example, there may be a higher likelihood to switch. Also if a switch to an alternative fuel vehicle is made then a consumer is potentially more likely to stick with it.

A further strand of thinking in relation to alternative vehicle technologies is their role as status symbols. Status and displays of wealth are regarded as basic and important human instincts and traits. The purchase of 'green' alternative vehicle technologies is believed to fit with this based on self-sacrifice and altruism associated with the higher cost and environmental benefit to society, displaying a high level of status and wealth, the pro-societal aspect being significant<sup>156</sup>. Research into ownership of the Prius HEV<sup>157</sup> has shown that this type of signalling 'making a statement about me' is the most cited reason for purchasing the vehicle. Work in this area suggests that activating these status motivators could play an important role in improving adoption rates of environmentally friendly products and innovations, indeed the publicised purchase of Prius's by a range of celebrities may be a factor in their success. In promoting these technologies similar endorsements may boost adoption rates.

### **Regulation as a driver of innovation – standards and the Porter hypothesis**

The Porter hypothesis puts forward the notion that strict environmental standards can be used as a driver of innovation and to induce efficiency improvements that deliver commercial benefits. Regulation based around standards such as the CAFE in the US has helped to improve automotive fuel efficiency over time, yet the US vehicle fleet lags behind European and Japanese fleets in terms of fuel efficiency. Evidence presented by Frondel and Vance<sup>158</sup> suggests though that regulatory standards may not be the most effective instrument for reducing emissions as

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153 Beise, M. and Rennings, K., (2005) Lead markets and regulation: a framework for analyzing the international diffusion of environmental innovations. *Ecological Economics*, 52, pp.5-17

154 Train, K.E., and Winston, C. (2004) Vehicle choice behaviour and the declining market share of US automakers

155 Dube, J-P., Hitsch, J.G., and Rossi, P.E., (2010) State dependence and alternative explanations for consumer inertia

156 Griskevicius, V., Tybur, J.M. and Van den Bergh, B., 2010. Going Green to Be Seen: Status, Reputation, and Conspicuous Conservation. *Journal of Personality and Social Psychology*, 98, pp.392–404

157 Maynard, M., 2007. Say 'Hybrid' and Many People Will Hear 'Prius' [online]. New York: New York Times. Available from: <http://www.nytimes.com/2007/07/04/business/04hybrid.html> [Accessed 21 January 2011].

158 Frondel, M. and Vance, C., (2009) Do High Oil Prices Matter? Evidence on the Mobility Behavior of German Households. *Environmental & Resource Economics*, 43, pp.81-94.

improvements in fuel efficiency have a rebound effect, sometimes referred to as the Jevons Paradox<sup>159</sup>. In Europe, binding standards have only recently been introduced, but fuel taxes in the EU have typically been much higher than in the US and for much longer, on average representing up to 75% of fuel price, compared to less than 20% in the US. The evidence explains that this lag in fuel efficiency performance can be, at least partially, explained by the US standards based approach with the absence of price based signals (taxes), suggesting that the recent EU moves towards a standards based approach may be misplaced.

Similar evidence of rebound type effects, where efficiency gains are used for other purposes, has been found in relation to the application of technologies such as direct fuel injection and variable valve timing to standard combustion engine. These were rapidly adopted in the early 1990's in Western Europe and resulted in improved fuel efficiency but also a trend towards heavier and more powerful vehicles<sup>160</sup>.

A point raised regarding standards in research by Lee et al<sup>161</sup>, was in cases where the standard being set was not capable of being met through incremental improvement of existing technologies. It cited the case of the clean air regulations in US in the 1970's and their tough requirements on NOx emissions, automakers originally attempted to meet the standard through improving their existing technologies but this still fell far short of what was needed. The impossibility of meeting the standards using existing technologies led to the adoption of new approaches and technology, eventually producing the catalytic converter devices that are standard on vehicles today. This perhaps points to how standards could be used as a driver of innovation in the automotive sector, by setting the standards at high levels, that may be regarded as unreasonable at the time, and importantly to have strict penalties and enforcement. This provides a level of certainty for firms in the sector that is necessary to justify often expensive innovation efforts. A similar case in favour of a regulatory push effect is made in respect of Zero Emission Vehicle (ZEV) legislation introduced in California in the 1990's<sup>162</sup>.

A further regulatory type measure considered in the literature is direct planning by government. This is reviewed in the context of Japan and their strategic plan to bring about electric vehicle technology<sup>163</sup>. The study finds that the plan, initiated in 1976, has to some extent been a failure, it has been costly and against almost all of its targets has failed. The main findings of the study were that it is not easy for government policy to "pick winners" and that a multi-objective, flexible and adaptable approach is necessary to try to ensure ideas make it to market. Indeed in the context of multiple alternative technology options, attempting to pick winners is recognised as a problem<sup>164</sup> and one that may be used to preclude policy or other support to any. One positive that resulted in Japan in the context of the strategic plan was the electric drivetrain now being utilised in HEVs. The result of this has been to establish Japanese car manufacturers as world leaders in HEVs with other nations lagging behind. Whether the costs-benefits of this are positive in the long run or whether this would have happened anyway is impossible to say.

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159 This is where efficiency savings actually lead to increased demand for the service as the marginal cost decreases, in this case it costs less fuel to drive the same distance which enables a greater distance to be driven for the same cost – this fuel efficiency elasticity effect was estimated at around 52% of the total efficiency savings in a study in Germany, significantly reducing the actual savings that could be achieved by increased fuel efficiency. The results of their study also noted that fuel price elasticity did not suffer from a rebound effect such as this and achieved 35% reductions as compared to price increases.

160 Dijk et al (2010)

161 Lee, J., Veloso, F.M., Hounshell, D.A. and Rubin, E.S., (2010) Forcing technological change: A case of automobile emissions control technology development in the US. *Technovation*, 30, pp.249-264.

162 Calef, D. and Goble, R., (2007) The allure of technology: How France and California promoted electric and hybrid vehicles to reduce urban air pollution. *Policy Sciences*, 40, pp.1-34.

163 Ahman, M. (2006) Government policy and the development of electric vehicles in Japan. *Energy Policy* 34, pp.433-443

164 Harborne, P et al (2007)

### 5.3 Case study: broadband and internet technologies

The history of Broadband represents the latest chapter in the ongoing development and technological advancement of the Internet. In essence the History of Broadband is the history of the Internet, which went from a scientific and communications experiment to a trillion-dollar worldwide industry within thirty years. There can be no doubting that the establishment and continued development of Broadband technologies has revolutionised the mechanisms through which humans communicate with each other. This case study explores the reasons behind the variations in broadband uptake.

Below, we explain the reasons for lags in uptake, adoption or availability.

#### **Policy and Regulation – help or hindrance?**

An article by Hargittai<sup>165</sup> contends that the institutional, legal and regulatory environment in a country is relevant to the Internet's spread because national policies can enhance or hold back diffusion of a technology, depending on their approach to regulating mechanisms, privatisation and free competition. A number of reports advocating the importance of free competition in the communications sector have been published by the OECD<sup>166</sup> and International Telecommunications Union (ITU)<sup>167</sup>. This is important in the context of most telephone companies originally being a state-owned monopoly.

In an infoDev publication prepared by ECORYS<sup>168</sup>, it was shown how the introduction of appropriate legislative, regulatory and policy initiatives in the Baltic States and Poland had played a significant positive role in the development of its information society. This was in contrast to Russia, where the Government was far slower in establishing a policy and regulatory environment that was conducive to greater ICT adoption and utilisation. In particular, a weak enforcement of Intellectual Property Rights together with regulation, had been a major inhibitor for the development of the ICT market.

The difficulties faced by Russia were not unique, with related examples in Greece and Cyprus, where both nations possessed interconnected political infrastructures that serve to hinder innovation and technological advancement. In a recent progress report on the European Telecommunications market<sup>169</sup> it was found that the electronic communications sector in Cyprus had not yet grasped the full potential of a liberalised market. The state-owned incumbent operator in the country has retained a strong presence in the fixed, broadband and mobile markets, and although broadband penetration rates had increased, progress in the roll out of broadband and mobile networks has been hampered by delays in auctions for fixed wireless broadband frequencies and third generation mobile licenses. In Greece, the perceived negative impact of the state 'plays out' in a different way and is closely related to social conformity imposed by state laws and decrees. In particular, relationships between universities and business are unnecessarily hampered by a policy forbidding police entry to the yards and buildings of universities, a policy that

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165 Eszter Hargittai, 1999, Weaving the Western Web: explaining differences in Internet connectivity among OECD countries. *Telecommunications Policy*, 23(10-11), pp.701-718.

166 OECD, 1996. Information infrastructure convergence and pricing: The Internet. Paris: OECD

167 Garcia-Murillo, M., 2005. International Broadband Deployment: The Impact of Unbundling. *Communications & Strategies*, 57(1), pp.83-105.

168 ICT, Innovation, and Economic Growth in Transition Economies: A Multi-Country Study of Poland, Russia and the Baltic Countries. Washington, D.C.: infoDev/World Bank.

169 <http://www.eubusiness.com/topics/telecoms/telecoms-report.2009>

gives disruptive, anti-capitalist elements a lot of room to disrupt cooperation between higher education and business.

In addition to positive examples in Poland and the Baltic states, South Korea also provides an example of the success of active policy and regulatory support for broadband. A study into the country's global leadership in Broadband adoption<sup>170</sup> found that Korea's rapid Broadband growth can be traced, in large measure, to the impact of central Government initiatives. Korea was one of the first countries to emphasize the importance of ICT as an economic stimulus measure. It gave greater support to the private sector, opened telecommunications markets to foreign investment and actively encouraged greater levels of competition between ISPs and the developers of the technology. The openness of this policy was characterised by the facilitation of relatively high foreign ownership in telecommunications, with the Government allowing 49% of the telecommunications market to be owned by external organisations. This supports the view that a regulatory environment that promotes open competition through privatisation of services and that supports local businesses and communities can lead to technological advancement and the more rapid spread of innovation.

It is important though to also consider the potentially positive impacts that a closed market can have on the development of innovations. Grabowski and Moe<sup>171</sup> in a study of the pharmaceutical sector argue that established firms are reluctant to invest in new products and new innovations with uncertain payback periods or when there is the distinct possibility of new developments and products being copied because of weak IPR protection. It is for this reason, they argue, that current EU regulation allows a ten year exclusivity period for new drugs and biological entities receiving approval from the European Agency for the Evaluation of Medicinal Products. This policy encourages investment as it gives companies enough time to invest in production and see a return on their innovation. A longer exclusivity period also helps to prevent patent challenges, which deter R&D investments. However, this line of argument does need to be treated with caution for two reasons. Firstly, the impacts only relate to the development of new technologies and not its roll out and wider usage, and secondly it is difficult to evidence that such a policy would work in the area of telecommunications and broadband.

### **Competition – have telecoms monopolies lead to lags in broadband penetration?**

There is a general common sense consensus among academics and policy makers, that competition is one of the main drivers of the adoption of broadband technologies<sup>172</sup>. Where competition and competitive activity is limited, technological advance and broadband penetration rates are generally slower to react. As Bar et al<sup>173</sup> argue, all telecom industry players recognise the importance of broadband and have undertaken massive efforts to upgrade existing local telephone and cable infrastructures and to develop new wireless broadband access. They argue dominance or monopoly power in broadband access raised serious threats to the public interest in the US and that the absence of a policy to promote and ensure open access results in vertical integration and

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<sup>170</sup> Lau, T.Y., Wook Kim, S. and Atkin, D., 2005. An examination of factors contributing to South Korea's global leadership in broadband adoption. *Telematics and Informatics*, 22(4), pp.349–359.

<sup>171</sup> Grabowski, H.G. and Moe, J.L., 2010. *Impact of Economic, Regulatory, and Patent Policies on Innovation in Cancer Chemoprevention*. Durham, NC: Duke University.

<sup>172</sup> Distaso, W., Lupi, P. and Manenti, F.M., 2006. Platform competition and broadband uptake: Theory and empirical evidence from the European Union. *Information Economics and Policy*, 18(1), pp.87–106.

<sup>173</sup> Bar, F., Cohen, S., Cowhey, P., DeLong, B., Kleeman, M. and Zysman, J., 2000. Access and innovation policy for the third-generation internet. *Telecommunications Policy*, 24(6), pp.489–518.

closed access which can lead to lags, a point that can be supported through the work of Analysys Mason<sup>174</sup>.

In their analysis of Europe's digital deficit<sup>175</sup>, the varying impact of limited competition on the Belgian and German telecommunications markets was discussed. In Belgium, the fixed telecoms market, which includes broadband, is characterised by two large players; the incumbent Belgacom and the non-overlapping cable operators, which have a combined market share of 96%. Under this structure, the stability of Belgacom's market share and poor take-up of unbundling suggests that breaking into the broadband market has been extremely challenging for new entrants. The net result of the duopolistic market structure in Belgium and the lack of success of competitive ISPs is that prices for end users are higher than in neighbouring countries and Belgacom has no incentive to offer more than moderate retail Internet speeds. A similar environment has been established in Germany, where the market is characterised by the ongoing dominance of fixed incumbent Deutsche Telekom (DT). According to the analysis, there have been a number of reports of anti-competitive activity by DT in recent years, including a competition case where DT was fined for margin squeeze. Like Belgacom, the activities of DT, which have included refusing access to their 'cabinet' have prevented alternative operators from investing due to financial and practical difficulties. A variation on this is found in the UK where a stronger regulator has recorded greater success<sup>176</sup>. In forcing an incumbent to open its infrastructure to speed broadband access and adoption.

Looking at inter-platform competition, there is a common argument, that the availability of alternative connection platforms could have a positive effect upon broadband supply<sup>177</sup>. The cited study argues that the contribution of alternative platforms could be both direct, through the provision of broadband access where it was previously not available, and indirect as a result of alternative platforms being introduced by new entrants thus causing existing incumbents to rethink their position on regional infrastructure investment. This view of the impact of inter-platform competition is supported by Distaso et al, whose data analysis on 14 Western European countries (Austria, Belgium, Denmark, France, Finland, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom) emphasised that the role of stronger competition across technologies is the main driver in stimulating broadband adoption.

However, there is a counter argument put forward via Forfas in Ireland<sup>178</sup>, that in fact, some countries such as France and Norway, have experienced substantial growth in Broadband access in the absence of strong inter-platform competition, instead benefiting from competition within platforms (intra-platform competition). In France this has seen the percentage of the population covered by the broadband increase from 11% at the start of 2003 to 50% in January 2005.

### **Telecoms – impact of the existing infrastructure and capacity to improve it**

For a country to maximise the benefits of broadband and ensure high levels of penetration and diffusion, there is the associated requirement to invest in ever changing and more effective infrastructures. Unfortunately, for those countries and governments with limited financial power, it

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<sup>174</sup> Analysys Mason is an advisory body on telecoms, technology and media who work with operators, regulators and end users.

<sup>175</sup> Analysys Mason, 2010. Europe's Digital Deficit: revitalising the market in electronic communications.

<sup>176</sup> Assessing the impact of public sector procurement on competition Volume 2: Case Studies. Prepared for the Office of Fair Trading by econ.

<sup>177</sup> Pontikakis, D. and Collins, P., 2010. Exploring geographic variation in corporate broadband adoption; evidence from Irish small- and medium-sized enterprises (SMEs). Telecommunications Policy, 34, pp.144-161.

<sup>178</sup> Forfas, 2005. Benchmarking Ireland's Broadband Performance. Dublin: Forfas.

can be very difficult to improve and adapt the existing telecommunications infrastructure. In addition, location and spatial differences can act as barriers to the development of broadband technologies.

There is an argument<sup>179</sup> that the spread of technology of any kind, is contingent upon certain technological and infrastructural factors being present in the target nation, region or locality. In other words, existing telecommunications facilities may be crucial for understanding differences in the spread of the Internet. Phanindra et al, tested the hypothesis that 'countries with more developed telecommunication and technology infrastructures are more likely to have higher penetration rates'. They concluded, through subsequent empirical analysis of cross-sectional data from 100 countries, that while required technologies for third generation telecommunications (broadband) are readily available in most developed countries, their availability is extremely limited in less developed parts of the world. This is supported through the research of Criterion Economics (CE) who developed a number of country case studies<sup>180</sup> that illustrate how existing infrastructure can positively influence and facilitate broadband access and penetration rates.

According to Criterion Economics, the Netherlands and Sweden have comparable broadband infrastructures that have facilitated their widespread engagement and high penetration rates. Alongside Belgium and Denmark, Sweden is the leading EU market for broadband internet services with penetration rates back in 2003 already over 20%. Their population distribution is favourable to infrastructure roll out with more than 60% of households located in urban areas, where the user cost of installing fixed infrastructure is low, and 90% living within 4km of the main distribution frame operated by Telia, the incumbent broadband provider. The national government in Sweden has targeted high broadband penetration as a key policy goal and has enabled local municipalities to develop their own metropolitan fibre-optic networks through generous subsidies. This investment over time has provided an existing infrastructure that was well placed to benefit from broadband technologies and ensure high rates of penetration in both urban and rural areas. The Netherlands, too, is among the leading EU countries in terms of broadband penetration with platform competition facilitated by the near-universal reach of the country's existing cable network, which provides 90% of the population with cable television. This existing infrastructure has been further improved through significant investment by cable operators in network upgrades that can now supply two-way channels necessary to provide Broadband internet and telephony access.

In Sub-Saharan Africa there is a very different infrastructural context, but similarly to the value attached to it in Europe many countries view ICT as a foundation of long-term economic development<sup>181</sup>. The issue for the region is that there has been no comparable improvement in broadband connectivity and penetration. The primary contributor to this situation is the lack of high capacity backbone networks<sup>182</sup>. The region has very limited coverage of the fixed line access telephone network which has been used to provide broadband access in the rest of the world. The lack of infrastructure, thus significantly restricts the diffusion of broadband technologies.

One of the reasons for the lack of required infrastructure for second or third generation broadband in country's like those in Sub-Saharan Africa, is the cost of 'switching' or updating the existing infrastructure. This is a particular issue for developing countries, but also for those countries and regions that have invested heavily in previous generations of technology. As Bar et al argue, the

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<sup>179</sup> Eszter Hargittai, 1999.

<sup>180</sup> Competition in broadband provision and its implications for regulatory policy: A report to the Brussels Round Table, DotEcon and Criterion Economics.

<sup>181</sup> M.D.J. Williams (2009) Advancing the Development of Backbone Networks in Sub-Saharan Africa

<sup>182</sup> A backbone network or network backbone is a part of computer network infrastructure that interconnects various pieces of network, providing a path for the exchange of information between different LANs or sub-networks.

physical infrastructure or architecture of a given network/platform creates substantial switching costs. The more developed and ingrained the existing infrastructure is, the greater the associated cost to change it.

A similar infrastructure gap can exist within countries between rural and urban areas, with rural areas typically lagging in broadband infrastructure. As Grubestic<sup>183</sup> argues, this is a long-standing problem in the US, that stems from historical infrastructure weaknesses in rural areas and a lower population density to induce private providers to lay new infrastructure. Similar findings were made in the EU<sup>184</sup>, one particular example in Bulgaria, where DSL coverage within urban areas stood at 89% compared with just 20% in rural areas and in respect of Cable Modem, coverage was 100% in urban areas and only 30% in rural communities. In a recent experiment<sup>185</sup> used to depict the inadequacies of rural broadband connections in the UK, a race between ten USB memory stick laden Carrier Pigeons were released from a rural location. The pigeons were tasked with carrying the USB's 120km while a 300MB video file was downloaded. An hour and a quarter later, the pigeons had reached their destination, whilst over the same period only 24% of the 300MG file had been downloaded.

### **Education and broadband – is education a requisite of innovation adoption?**

Returning to the work of Phanindra et al, one of their testable hypotheses stated the following: *'Countries with higher educational standards and literacy rates are more likely to have higher penetration rates'*. They stated there are many reasons as to why this hypothesis should hold, the most obvious being that many of the resources and much of the information taken from the Worldwide Web are entirely text-based implying that literacy would be required to effectively access and benefit from the information. They go on to argue that another, perhaps less apparent reason, supporting the proposition made in the hypothesis, is that academic institutions play an essential role in adopting new technologies. Phanindra et al point out that schools were among the first institutions to heavily make use of the Internet and in doing so, have introduced young people to this media and information resource.

Everyone understands the impact that a positive educational experience has on individuals and the inherent role it plays in the shaping their future. It is within educational institutions that people often have their first experiences of technological innovations and the extent to which new technologies are engrained within educational experience is an important parameter and potential measure for the take-up and sustainability of a given technology. As Forfás argue, education is widely regarded as a key driver in broadband take-up.

The work of Todorova and Bokova<sup>186</sup> illustrates the renewed importance the Bulgarian Government has placed on educating its citizens in Information and Communications Technologies in an attempt to increase broadband penetration. Todorova and Bokova argue that in Bulgaria there are relatively low levels of ICT skills in the population. A 2006 survey found that two thirds of the population had no internet skills compared to the EU average of 40%. Of the population who do use Internet technology, 70% have never received formal computer skills education whilst the majority of people interviewed stated they were self-taught. In realising the need for higher IT skills and greater penetration of broadband technologies, the government implemented a series of skills development

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<sup>183</sup> Grubestic, T.H., 2006. A spatial taxonomy of broadband regions in the United States. *Information Economics and Policy*, 18(4), pp.423–448.

<sup>184</sup> Broadband Coverage in Europe: Final Report 2009 Survey. Idate Consulting and Research

<sup>185</sup> Experiment by Traver Davis, co-founder of business ISP Timico and serves on the board of ISPA (Internet Service Providers' Association).

<sup>186</sup> Todorova, D, Bokova, M, 2008. Access to Infrastructure. Bluelink Information Network Website, <http://www.bluelink.net>

projects, which included the largest Bulgarian training programme and access to ICT skills courses for young people with disabilities.

### **Exposure – how usage habits can play a role in innovation diffusion**

A study in Turkey<sup>187</sup>, sought to obtain views about intensity of Internet use, reasons for using the Internet and the impact of the Internet on student life. It found that males still dominate Internet usage in Turkey and that most of the respondents went online from home (50.1%), while 'other combinations' accounted for 32.4% of respondents. The most popular usage of the Internet was associated with e-mail, reading the latest news and sport, research for coursework and assignments and social networking activities. What these examples serve to illustrate is the range of uses students are finding for the Internet. The question to be answered, is how engagement with the Internet and broadband as part of educational experience, is influencing the extent of broadband diffusion and take-up?

As opinion leaders and the primary users of much of the latest technologies, young people, including graduates leaving Higher Education, have a high profile impact on the level of pervasiveness of broadband. In being exposed to such technologies at an earlier and earlier age, people are becoming more effective in their usage of such technologies and are seeing significant benefits to be obtained. Such levels of engagement are prompting providers, individuals and businesses to make continual improvements and develop products and services that make engagement with the internet more and more accessible. The increased usage of internet and broadband technologies among students and young people is leading to greater degree of take-up in society more generally. One of the societal groupings with the most significant barriers to internet and broadband usage is older people, who for many exposure did not occur until long into their careers or not until their retirement. However, usage of the internet among the older generations is increasing rapidly and is, to a large extent, related to young people, particularly family members, exposing them to the various technologies and teaching them how to make the most of the internet and broadband. Young people are contributing significantly to the 'silver surfer' phenomenon.

## **5.4 Case study: mobile telephone technologies**

Since the introduction of mobile phones in the late 1970s as a way for individuals to make phone calls without the limitations of a physical cable, the number of uses for mobile phones has continued to multiply. Short text messages were one of the first innovations in mobile phone technology, but more recently, mobile telephones have become devices that can be used to interact with the Internet, to make payments, to get directions, and to play games, to name a few of the uses for the latest generation of so-called smart phones.

Not only have the number of uses for mobile phones multiplied, but so have the number of markets. Setting up communication towers has proven cheaper than laying cable for telecommunications, which has expanded mobile phone usage by huge numbers. In 2000, the majority of people with mobile phone subscriptions were in the developed world, with a total of 719 million subscribers. By 2005, the number of subscriptions had more than doubled to 2.2 billion, with a slight majority being in the developing world. By 2010, one estimate puts almost three quarters of the nearly 5.3 billion subscribers in the developing world<sup>188</sup>. What started as a distinctly rich-world phenomenon has filtered to the developing world, with the uses of mobile phones multiplying in much the same way

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<sup>187</sup> Ruzgar, N.L., 2005. A research on the purpose of Internet usage and learning via Internet. The Turkish Online Journal of Educational Technology (TOJET), Volume 4, Issue 4.

<sup>188</sup> <http://www.itu.int/ITU-D/ict/statistics/index.html>

they did in the developed world. This also opens the important question of what are the real variables influencing uptake of this technology.

Below, we explain the reasons for lags in uptake, adoption or availability.

Before addressing the variables that are important for innovation uptake and lags, it is important to confront those that have little to no influence.

Early studies on the take-up of mobile phones show that one of the important variables is level of income (Leung & Wei, 1999; Rice & Katz, 2003); however, this correlation has become increasingly weak in the late 2000s. This can be seen in the fact that the developing-world is adopting mobile telephony very rapidly. With newer technologies, such as mobile internet, Scandinavian countries clearly show themselves adopting these technologies before other Member States in the European Union, even those at similar income levels. Other examples include Romania having more mobile internet subscriptions than Belgium and the Netherlands. In these same studies, education is seen as a critical factor, but as more and more of the developed world has begun to adopt mobile telephony, this assertion has also come into question.

Culture is a second factor often quoted as important for adoption of new technologies and is an issue addressed in other case studies for this report; however, in the case of mobile telephony, the issue of culture is a less important one. True, some have argued that culture feeds into the types of products adopted on the mobile phone. Levels of trust in technology, for example, could be barriers to m-banking as well as existing levels of banking. On another level, one study examined the widespread adoption of MMS in Japan because of the propensity of the Japanese to engage in photography more readily than in other countries (Haddon, 2005). Nonetheless, these studies rely on largely anecdotal type evidence and remain somewhat unconvincing, relying sometimes on national stereotypes as much as measurable fact. For this reason, culture is not covered as an important factor in innovation adoption for mobile telephony.

Adoption in the developing world is more than just “catching up”, but also has a different character. The developing world is doing more than just picking up basic mobile telephony while the developed world adopts newer uses, such as payment systems, internet usages, and mobile banking. Rather, mobile telephony adoption has been adapting to the individual character and needs of particular regions. For example, the mobile phone has become a tool to bring banking (so-called “m-banking”) to parts of the world where the level of development would make such services impossible. Banking services started when prepaid mobile airtime was used as an informal currency. Air time could be easily transferred between individuals, allowing people to exchange money in ways that the existing infrastructure did not allow. Within only a few years, service providers in countries like Kenya (M-Pesa), Zambia (Celpay and Gcash), and the Philippines have adopted m-banking products on a more official level, with tens of thousands of vendors supporting this new method of payment.<sup>189</sup> In two years from its introduction, M-Pesa gained over 6.5 million registered customers in Kenya in a country with a population of around 40 million people, exceeding by far all other financial services in the country combined. (Cammer&Sjöblom, 2009)<sup>190</sup>.

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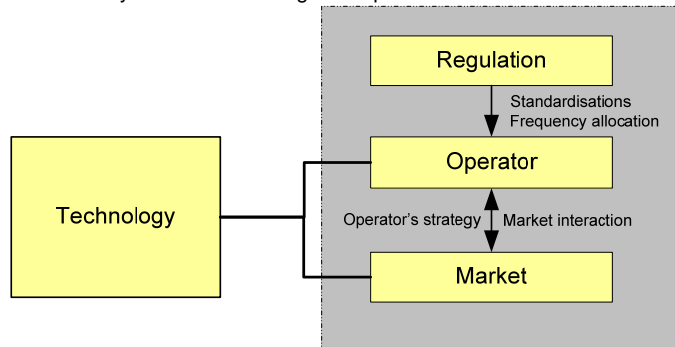
<sup>189</sup> [http://www.foreignpolicy.com/articles/2010/08/27/the\\_m\\_banking\\_revolution?page=full](http://www.foreignpolicy.com/articles/2010/08/27/the_m_banking_revolution?page=full)

<sup>190</sup> The literature provides no direct correlation between m-banking and adoption of mobile services. We have a clear jump in mobile phone usage during this period, and a huge number of customers adopting this service during the same time period. Given the current evidence, it is not possible to prove that m-banking is the cause of further mobile adoption, but one cannot ignore this possibility. Mobile adoption in Kenya starts to pick up in 2005, a time when the informal use of mobile phones as currency would have been rising, and after this period, for three years, growth of mobile phone subscriptions increased by more than 50 percent every year (ITU).

In these cases the ability for the technology to bridge a gap in other infrastructure and services has been a factor in rapid take-up of the technology.

Rather than income, education, or culture, three factors primarily influence the adoption of mobile telephony: technology (dealing with Infrastructure constraints), regulation (dealing with market competition, uncertainty, and expectations for the future), and consumer / industry relationships (dealing with consumer behaviour and market pricing mechanisms). These relationships are summarised in Figure 5.1.

Figure 5.5 Primary factors influencing take-up



Source: Adapted from Suryanegara & Miyazaki, 2010

Underlying all of these factors is the very important fact that adoption (and lags) depends on the *confidence* of both consumers and companies in the potential staying power of a new innovation. Here, standardisation and the widespread availability of products work to increase that confidence, and hence increase uptake. On the one hand, standardisation reduces the uncertainty of future payoffs, hence decreasing a potential entrant's reasons to delay a purchase or investment. (Koski&Kretschmer, 2005) At the same time, numerous studies have shown so-called "network effects", with wide product availability influencing uptake of new technologies. (Doganoglu&Grzybowski, 2007)

### Technology – the importance of meeting consumers practical needs at reasonable cost

Any product innovation involves some form of technological advancement, so it seems a truism to suggest that technology is a key element to mobile telephony adoption; nonetheless, mobile telephony has had to overcome two large technical obstacles before it could achieve widespread acceptance. On the one hand, in terms of transmission, limited bandwidth and high initial costs for the infrastructure limited participation in the market and also limited the appeal. On the other hand, only after handsets were miniaturised and battery technology improved were manufacturers able to design devices that consumers would be comfortable to carry around<sup>191</sup>.

One of the first technical obstacles was overcome through a switch from analogue transmission to digital transmission which allowed for three to four times as many customers to be served by the same amount of bandwidth. This was a critical driver of furthering the number of people that could be serviced (hence increasing the network effect) and also driving competition<sup>192</sup>. Costs also decreased rapidly, both from a transmission and switching perspective with wider installation of fibre optic cable and improvements in switch capacity<sup>193 194</sup>.

<sup>191</sup> Lacohee, et al, 2003

<sup>192</sup> Gruber & Verboven, 2001

<sup>193</sup> Gruber & Verboven, 2006

<sup>194</sup> James, 2008

The move to digital, second-generation (2G) and now 3G and 4G mobile telephony has enabled a wider number of services to be provided, such as short messaging services (SMS), conference calling, caller ID, voicemail, e-mail, and web browsing. These have enhanced the number of potential customers and users.

Technology is an important component in creating the conditions necessary for uptake. However, technology (and its uptake) rely more on regulatory and market conditions. Technological advancement in mobile telephony provided the opportunity, but regulation and the right market conditions needed to fall into place to drive adoption in particular jurisdictions. As the next two sections will show, Europe—and in particular the Scandinavian countries—have been early adopters of mobile telephony, partly because of the regulatory framework laid down by the European Union and the competitive landscape that this created.

### **Regulation – do uniform standards or fragmentation lead to lags?**

Governments can and have played a helpful role in avoiding harmful fragmentation of the market. When public bodies impose technical standards, it can increase confidence in the market regarding the staying power of a particular product and also helps to avoid detrimental “standards wars”, which limit roll-out of new products and increase consumer confusion. Battles over technical standards for video recorders (VHS versus Betamax), high-definition audio (DVD-Audio versus SACD) and high-definition video (HD DVD versus Blu-ray) have all hindered pickup of particular standards, as consumers wait for a single standard to emerge so that they avoid the risk of having their purchase become prematurely obsolete. In the last two cases, the battle over standards also severely affected profitability, with high definition audio never achieving consumer acceptance and the latter taking so long to be resolved, that newer ways of distributing video to consumers (via downloads) threatens to make the technology obsolete before it has fully gained acceptance.

Arguably, in the field of mobile phones, the imposition of standards has brought real benefit to the industry. Looking at uptake in Europe, the Scandinavian countries have been the first to adopt the use of mobile phones, and not coincidentally, they were the first to achieve a unified standard that allowed for roaming across Finland, Sweden, Norway, Denmark and Iceland since 1981-82 with the Nordic Mobile Telephone standard<sup>195</sup>. The European Union as a whole followed suit afterwards, with a resulting Directive, calling for all Member States to reserve the 900 MHz band for future development in mobile telephony. By 1987, the group signed a memorandum of understanding, agreeing to deploy GSM on a standard frequency, after which, providers quickly fell into line<sup>196</sup>. It is true that uptake did not immediately follow the adoption of these standards, but arguably this was extremely important groundwork that would eventually lead to the higher adoption rates seen across the EU-15. These standards expanded the potential market for the product, as it eliminated incompatibilities both between competitors and across borders<sup>197</sup>, a problem still faced, for example, in the United States, where two competing standards are used CDMA and GSM. This means that a phone bought and used with one provider can then be easily used with another, which also increased the network effect<sup>198</sup>.

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<sup>195</sup> Dunnewijk & Hultén, (2006)

<sup>196</sup> Salant & Waverman, (2003)

<sup>197</sup> Dunnewijk & Staffan Hultén, (2007)

<sup>198</sup> Whether these imposed standards should remain is up for debate. Lee, Chan-Olmsted, and Kim (2009) argue that mobile telephony, which has reached a mature stage with fewer competitors, does not necessarily benefit new innovations (and their adoption). It should also be noted that just because imposed standards benefited the industry and uptake in this case, this does not necessarily apply to all cases.

The United States provides a useful counter example for how diversified standards and other public policy concerns can cause innovation lags. While the United States held an initial lead, with American companies being important for the development of the technology, from the late 1980s, the U.S. was slow to pick up mobile telephony. King and West<sup>199</sup> (2002) argue that American AT&T—the undisputed market leader in the American market for telecommunications up until the 1970s—represented an important hindrance to the speed of uptake of mobile technologies in the United States. The authors argue that AT&T had been caught up with its old government mandate of providing telephone service to the entire country, creating a “competency trap” in which working toward new forms of telephone service more difficult. The issue was not that AT&T did not recognise the importance of the technology to a certain demographic, but they did not recognise the vast importance of the technology and how it could disrupt their existing infrastructure.

By the 1980s, the United States had decided to liberalise the telecommunications industry, breaking up AT&T and introducing competition into the market. Rather than mandating a single standard for the country, the United States left the issue of co-ordination completely in the hands of private industry. The only role that the government played was to ensure that any standards adopted would not interfere with other standards already using the allocated spectrum. Initially, the break-up of AT&T and liberalization of the market led to severe fragmentation, with subscribers unable to use their phones outside of their local area. Special numbers would need to be dialed and extremely high roaming charges would apply. When moving to second-generation mobile telephony, the United States continued to move in a different direction to Europe and much of the rest of the world, adopting two standards—CDMA and NA-TDMA. Mergers and acquisitions reduced the number of companies, but there were still 733 separate services areas<sup>200</sup>. At the same time, while European and Asia had adopted GSM, CDMA became the more important of the two standards in the United States, bringing North American into the minority in terms of market size and leaving them behind Europe in terms of mobile telephony.

### **Market structure – competition and the interaction of operators and regulators**

Adoption of standards is one side of the equation; on the other is how regulation and the introduction of competition have helped to drive adoption of mobile telephony. The introduction of digital technology, as mentioned earlier, increased the number of customers that could be reached by increasing bandwidth, but it also allowed governments to grant more licenses for this increased, though still limited, bandwidth. This increased competition, and as shown by many studies, helped drive adoption<sup>201 202</sup>. Central and Eastern Europe, for example, a region which only really began to pick up the technology in earnest in the late 1990s, shows this clear correlation between levels of competition and adoption rates. As markets in this region passed from monopoly to duopoly (and beyond), diffusion of the technology accelerated<sup>203</sup>.

Competition and regulation in mobile telephony currently work hand-in-hand, however, there is little evidence to suggest that liberalisation of markets to open competition provides a direct and immediate impact on mobile telephony uptake. Sweden, as an early adopter, is an instructive example. Much like the United States, Sweden found itself at the forefront of developing mobile

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<sup>199</sup> King & West (2002)

<sup>200</sup> Goodman, (1988)

<sup>201</sup> Gruber, (2000)

<sup>202</sup> Rouvinen, (2006)

<sup>203</sup> Gruber, (2000) - It should be noted here that some debate does exist on the importance of competition. Koski and Kretschmer (2005) argue that competition is not the driving force of adoption, *per se*, but rather that competition helps drive down prices, which then drives diffusion of the technology. They argue that other policy instruments that lower prices would be equally instrumental in supporting adoption of mobile telephony.

telephony, developing the first automatic mobile system in the 1950s. From this beginning until the late 1970s, Swedish Telecom received monopoly rights to operate within the necessary spectrum to offer mobile services. The market opened slowly, with a number of regulations allowing for a slow and gradual introduction of competition. First, in 1971, mobile telephone suppliers were allowed to market their products directly to consumers. It took ten years before the competition in the network operator market arrived, when operator Comvik was allowed to enter the national market (though a number of regional competitors had already been allowed before this)<sup>204</sup>. However, even at this stage, Swedish Telecom still held a key advantage in the market, having been made responsible for allocating the necessary frequencies to the market<sup>205</sup>. It took until 1991 for frequency management to be separated from Swedish Telecom, to be placed under the authority of the National Post & Telecom Agency. At about the time when Comvik began to become established—and also a time when mobile telephony began to accelerate in Sweden—the company began to introduce roaming and improved coverage<sup>206</sup>. The network effect, which competition helped to bring about in this instance, helped to drive further adoption of mobile telephony.

At the same time, other market structures affect take-up of new innovations, such as the existence of competing technologies. Looking at mobile telephony adoption in the developing world, for example, one of the reasons why this technology has been quicker to spread in the developing world is simply because it did not have to displace an existing technology to achieve acceptance, in addition to the lowered costs of rolling out mobile infrastructure versus a new landline infrastructure. Some studies have shown a correlation between higher levels of landline penetration with slower acceptance of mobile telephony<sup>207</sup>. This type of “substitution effect” for mobile telephony is up for much debate within the academic literature. Gruber and Verboven<sup>208</sup> find that mobile telephony was hindered by the extensive use of fixed-line telephony. Other studies have pointed out that this substitution effect is much lower; however, these studies tend to be limited to a developed-world context. Kauffman and Techatassanasoontorn<sup>209</sup> report, for instance, that early studies show that mobile phone usage complemented landline usage, but that “increasing evidence” showed that this correlation was proving to be false (partly because the coverage of these studies has been increasing to all parts of the world, as uptake increases globally).

Here, for the developed world, the point is two-fold. On one level, especially in the early days of the technology, consumers with existing landline telephones would need to be convinced of the value taking a service they already receive and only changing it slightly. At the same time, this initial resistance means that companies are less likely to pick up the technology. In jurisdictions such as the United States, where existing telecommunications companies, such as AT&T, were the ones pushing the new technology, this would be particularly true. In this case, telecommunication companies would potentially be cannibalizing their own customers to fund new services.

Finally, given the importance of “network effects” in terms of uptake, the role of the relationship between the consumer and operators is an important one. On one level, companies need to accept and provide the infrastructure for the basic operation of the system. The cost of rolling out each subsequent generation of mobile telephony technology represents a significant expense, in which

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<sup>204</sup> It should be noted here that mobile handset providers were skeptical about opening up the market, with Ericsson CEO arguing against increased players in the market. Trade unions also supported the monopoly.

<sup>205</sup> The same dynamic still takes place today in telecommunications and Internet technology. The Canadian market for Internet providers is, for example, dominated by only a few players that own the infrastructure. The government mandates that these providers lease their infrastructure to smaller players, which allows for a further injection of competition into the market.

<sup>206</sup> Mölleryd, 1999

<sup>207</sup> Samanta, Woods, and Ghanbari, 2010

<sup>208</sup> Gruber and Verboven (2001)

<sup>209</sup> Kauffman and Techatassanasoontorn (2009)

companies need to believe that they will achieve a return on investment. This requires consumers to accept that an incoming technology will both provide tangible benefit and will (eventually) achieve a widespread acceptance. At the same time, as a technology takes hold, other companies and consumers may discover other uses for the technology, which further encourages expansion of networks and potentially improvements and innovations. Adoption (and lags) depends on the *confidence* of both consumers and companies in the potential staying power of a new innovation.

This symbiotic nature of this confidence problem befalls many large-scale efforts and its influence can be articulated as follows: businesses do not want to take-up innovations until they have some confidence that a market exists; at the same time, consumers that are not early adopters – generally only two percent of the population – may be unwilling to purchase an innovative product until they are convinced that it will accept broad acceptance, hence keeping the potential market small. Only companies with a particular risk profile will be willing to introduce product into this kind of an environment, able to financially survive until a certain “tipping point” is reached in the market, and adoption can take place. Given the huge expenses involved in building a network, one can perhaps understand the need – during the infancy of the technology, when benefits and potential profits were less clear – to ensure providers near monopoly conditions to increase confidence for business to provide the basic service.

## 5.5 Case study: energy efficiency technologies

For producers and consumers, an increase in their energy efficiency enables them to do more for less, this gain can be captured in overall cost savings or increased activities. For firms this is an essential element of competitiveness and therefore it is likely that the most competitive and successful firms direct innovation efforts to improve the energy efficiency products and processes. For consumers it can be an important expenditure item and by cutting costs or increasing services is related to quality of life. Given the resource and environmental implications of most energy production and use, understanding the adoption of energy efficient products and processes is important.

Yet our initial review of literature and evidence suggests that the most energy efficient products and processes are not always immediately adopted, even if there are clear and demonstrable financial benefits. Exploring the reasons that some efficient products and processes fail to be widely adopted and that others are but with uneven or time-lagged diffusion is highly relevant to the study objectives. This section specifically explores energy efficient lightbulbs and boilers in this context.

Below, we explain the reasons for lags in uptake, adoption or availability.

This section first explores general factors that can lead to innovation adoption lags for energy efficient products and processes. It then also briefly explores some factors specifically relevant to consumers and producers. There are similarities and differences between the innovation adoption process of these groups. An important difference in the context of energy use is that residential consumers are in general 'satisfiers', meaning that as long as they are happy and satisfied, they do not engage in risky actions that could potentially make them better off. This can be in stark contrast to firms reasoning, as they will try to streamline their production processes and minimize costs in a continuous attempt to gain an edge over their competition. If managers do not engage in this kind of behaviour, they risk the business going into decline or bankruptcy, and then losing their jobs. These demands usually produce different approaches between consumers and producers. An interesting facet of this difference is that the managers will also be residential consumers, therefore decision making can transfer from one to the other, for example resulting in companies taking on the 'satisfied' approach and neglecting energy use, particularly if it is only a minor cost item.

## Technology and knowledge diffusion – does it actually work and is this known?

The first innovative products that come onto the market to replace a less efficient predecessor are often subject to growing pains. This can be a particular issue when the new products are not perfect substitutes for the original products, this is often found in a lack of durability or functionality in comparison to existing products. The lag in compact fluorescent lightbulb (CFL) technology adoption is a good example of this. The standard lightbulb was fully developed, reliable and had an established function and reputation among users. The first CFLs that came on the market in the 1980s, were heavy, weighing 500 grams each (a normal bulb only 50 grams), expensive, took time to reach their full brightness and the light from the bulbs was felt to be 'cold'<sup>210</sup>. The CFLs often also required replacement of the light fitting to accommodate their different plugs and shapes. These characteristics did not endear the product to consumers on the basis of both cost and functionality and resulted in the emergence of a negative perception of the technology that slowed adoption and still lingers among consumers today.

This point is important, that the perception acquired by products in their first years often sticks with them and proves difficult to change and can be a major barrier to adoption. A barrier that is difficult to overcome even when the product or process is developed to a point where it meets or more than meets all consumer demands – the initial reputation sticks<sup>211</sup>. Ball et al<sup>212</sup> distinguished two stages in the consumer decision process. The consumer first considers the product, and judges it on its merits, then they decide whether to buy it or not. The merits should offer benefits to the consumer and a convincing story that these exist, that the innovative product is either better, cheaper or more exciting than the existing products. At the first stage mass marketing can be one of the most effective methods to enable people to consider a new product, and is essential in conveying information on the increased energy efficiency of products and processes. This is relevant to the extent that studies<sup>213214</sup> that have investigated the lack of adoption of innovative, more energy efficient products, found that consumers simply lacked information. For example over 50% of consumers surveyed in one study<sup>215</sup> answered either a lack of awareness of the existence of energy savings products, or the advantages of them and the level of cost savings this would result in, were reasons they were not adopted.

For the second stage however, the ultimate buying decision, the innovation adoption model developed by Mansfield<sup>216</sup> suggests that interpersonal marketing is more effective than mass-marketing. The theory proposes that at first only a few people adopt the innovation, and that they are slowly, and at increasing speed, followed by the rest. The first few people form a critical mass that initiates mouth-to-mouth interpersonal marketing by sharing their experiences. On this basis it is therefore critical for innovation diffusion that the initial experiences are positive, the evidence suggests that for CFLs it wasn't<sup>217</sup> and this held up overall adoption of the technology. Later

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210 Menanteau, P., & Lefebvre, H. (1999). Competing technologies and the diffusion of innovations: the emergence of energy-efficient lamps in the residential sector. *Research Policy*, 29, 375–389.

211 Mahaparta, K., Gustavsson, L., & Madlener, R. (2007) Bioenergy Innovations: The Case of Wood Pellet Systems in Sweden. *Technology Analysis & Strategic Management*, 19, 99-125.

212 Ball, R., Cullen, R., & Gan, C. (1999) The diffusion of energy efficiency innovations among residential energy consumers. *New Zealand Economic Papers*, 33, 115-135

213 Di Maria, C., Ferreira, S., & Lazarova, E. (2010) Shedding light on the light bulb Puzzle: the role of attitudes and Perceptions in the adoption of Energy efficient light bulbs. *Scottish Journal of Political Economy*, 57, 48-67.

214 Mills, B. F., & Schleich, J. (2010) Why don't households see the light? Explaining the diffusion of compact fluorescent lamps. *Resource and Energy Economics*, 32, 363–378.

215 Di Maria, C. et al (2010)

216 Mansfield, E (1961): Technical change and the rate of innovation. *Econometrica*, 29, (4).

217 Di Maria et al (2010)

evidence from the tire industry<sup>218</sup> suggests that Michelin had learnt from this and adopted an approach to launch their new C3M process product to a lower end of the market than they planned for eventually, so that any issues in quality or production could be dealt with. When the product was then moved to compete at its intended level, at the high end of the market, it had the necessary levels of quality but also with reduced costs.

Entrepreneurship can also play an important role in this lag factor, with firms attempting to launch an innovation needing the correct mix of technical and business/marketing skills to avoid these problems with first consumers. They need a strong awareness and understanding of what the market is demanding and could demand. It is also useful to ensure that lead customers can provide feedback that can be used to improve the product, the approach of Michelin above, or beta testing and other trials can be highly useful in this regard.

Compatibility can also be a major issue in lags in the adoption of innovation and is an important condition for fast diffusion<sup>219</sup>. In the beginning this was a major factor for CFLs, the size and weight of the first bulbs often did not allow them to fit into existing light sockets and totally new fittings were required. This further added to the initial cost of switching to CFLs, the bulbs were already more expensive, but requiring replacement of the whole light fitting increased the cost difference between standard bulbs even further. It is no coincidence that as CFLs were adapted to standard light fittings, reduced in size and weight and became available in a greater variety of shapes, that they began to have greater appeal and diffused more widely.

A similar example is found in the boiler sector and analysis of the switch to wood-pellet boilers in Sweden<sup>220</sup>. These are regarded as an alternative to standard non-condensing boilers, that have lower environmental impact and take advantage of a low cost and locally abundant fuel. To install a pellet boiler though, in many cases, requires a complete reinstallation of pipes and burner to make them compatible. The additional investment and hassle, resulted in low adoption rates by residential consumers. However, for larger electricity generating installations, their infrastructure was already compatible, and consequently pellet boilers experienced a faster diffusion in this sector. This demonstrates that compatibility with existing equipment is an important condition for fast diffusion of a new technology.

The issues faced for the first CFLs stemmed primarily from technological problems, the product was more efficient and the output was similar to standard bulbs, but it was not a perfect substitute. It took several years before these technological drawbacks of CFLs were addressed, to bring them to a point of being much closer substitutes for standard bulbs. When CFLs began to reach this point the rate of their adoption began to pick up. The fact that innovations are usually not perfect substitutes for the original products is a major reason for the slow adoption of the innovation.

A further issue facing energy efficiency innovations is one of information. The way that energy use is billed rarely allows for specific items and their contributions to be distinguished. Added to this is the fact that energy bills are highly influenced by various factors like the weather, the behaviour of the household members and the price of energy, it becomes highly difficult to distinguish the impact of adopting energy efficient products or processes. This is particularly true for the residential sector but can also be relevant for producers. Set against this information gap is the clear and unambiguous difference in initial cost that typically exists between standard products and those that are more energy efficient. This has a substantial impact on how consumers perceive energy

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218 Brusoni et al (2006)

219 Ball, R., et al. (1999)

220 Mahaparta et al (2007)

efficient products and processes, they can see the initial cost with certainty but may not understand the scale of energy use of the standard products or trust the savings claimed by efficient products even when they are occurring<sup>221</sup>.

### **Risk aversion – why risk change when current technology works?**

Risk is a universal factor in use of technology and processes. From using technologies or processes over time the user begins to understand and to trust them and a certainty emerges around the costs and risks. When considering a decision to switch to a new technology or process, a variety of factors beyond purely cost and benefit come into play that may hinder change. These are understood as risk aversion and can powerfully alter the decision dynamics, this is obviously therefore an important factor in innovation adoption.

From a purely financial perspective installing more energy efficient equipment is often the rational thing to do, as, while the initial capital investment may be higher than less efficient products, the reduction in energy consumption can often more than compensate for this, bringing significant overall net benefit. It is also understood that, in general, people do not like to take risks. Prospect theory, developed by Tversky and Kahneman<sup>222</sup>, provided an explanation as to why this is the case. The theory explains that people often have a stronger aversion to potential losses, than they have an attraction to potential gains – “losses loom larger than gains”. Therefore, ending up with an innovative product that does not function as hoped is given more weight in making a decision than the potential gains of ending up with a good product that will improve their energy efficiency. This can be an important influencing factor in a purchasing decision and impact on innovation adoption and diffusion. This is also closely linked to information gaps in relation to energy efficient technologies, if the potential gain is not understood, then certainly the loss (initial cost) will loom larger.

Uncertainty on future energy price trends may also impact on decision making. Energy prices are volatile, as with many other commodities, and can rapidly peak and then dissipate, as experienced in the various energy crises in the 70s and 80s and the Oil price spike of 2008. This variance in prices brings uncertainty as to what the actual savings or benefits of the efficient product or process will be. A decision may be postponed on the basis that a fall in energy prices makes it possible for the investment to not deliver net savings<sup>223</sup>. This can also be closely related to general loss aversion as explained by prospect theory.

Income plays an important role in innovation adoption, this is particularly relevant to energy efficiency as the technology or process is usually more complex and therefore a premium is charged for this. For those with low incomes this can be a particular factor, as they will tend to purchase the item with the lowest up-front cost. Even in the context of CFLs, whose costs are now relatively low, and much closer to that of standard bulbs, this has been found to be an issue<sup>224 225</sup>.

Taking this view on the costs and benefits further, a variety of work has been carried out to attempt to quantify the size of the return required to overcome the risk aversion and other factors that affect

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221 Ball et al (1999)

222 Tversky, A, & Kahneman, D. (1979) Prospect Theory: an Analysis of Decision Under Risk. *Econometrica* Vol 47, no.2, pp. 263-292

223 Hasset, K. A. and G. E. Metcalf (1993), 'Energy Conservation Investment: Do Consumers Discount the Future Correctly?', *Energy Policy* 21(6), 710–716.

224 Di Maria, C., et al (2010)

225 Mills, B. F. et al. (2010)

adoption decisions. Working on a net present value (NPV) the evidence<sup>226 227</sup> shows that consumers demand high returns on their investments, in the region of effective NPVs of 25% to 300% higher than their initial outlay. Specifically in the Dutch farming sector the present value of the savings of the investment needed, on average, to be 76% higher than the initial cost of the investment for the energy efficient technology to be adopted<sup>228</sup>. This clearly demonstrates how sizeable a barrier risk aversion is in decisions to adopt energy efficient technologies.

### **Consumer behaviour – the principal-agent problem**

In respect of consumer behaviour the nature of energy efficiency technology and processes, as being more expensive initially but accruing net savings over the longer term, is particularly prone to the classic principal-agent problem. This problem can result when the decision maker only bears the costs of the original decision but does not receive the full benefits of any savings. Classic examples in the energy efficiency context are found in relation to residential energy efficiency and landlords and tenants. The problem can manifest in various ways depending on the rules of the tenancy agreement, for example where tenants are not responsible for the energy bills, there is little incentive for them to save energy. In this case the tenants may be reluctant to cooperate with the landlord in installing energy efficient equipment, given the disruption it may cause and the suspicion rents may be increased accordingly to pay for them. The opposite problem can exist when roles and responsibilities are reversed, in this case the tenants may have trouble negotiating with the landlord to pay more for energy efficient equipment rather than pick the cheapest option, but where most direct benefits of the decision will go only to the tenant. Negotiating these points can be difficult and delay the adoption of energy efficient technologies<sup>229</sup>. Similar situations can exist between architects/construction workers and the building owner, where design and technology choices have sometimes been found to be made to minimise trouble to the former, at the expense of the latter and energy efficiency<sup>230</sup>.

### **Producer behaviour – keeping options open, is first-mover advantage enough?**

There are other factors, in addition to the general factors discussed above, that also impact on producers innovation adoption decisions. The investment decision for firms in a new innovation is typically focused on cost reduction, with firms particularly inclined to reduce their highest costs. The proportion that energy costs make up of total costs will have a bearing on how inclined a firm is to adopt energy efficiency innovations. Higher proportions typically translate to higher efficiency inclinations.

A factor that influences producers behaviour is that companies value the ability to wait with their investment decision, to keep their options open<sup>231</sup>, this is a more general human trait also<sup>232</sup>. The process leading to this can be understood in various ways. One reason is that when the company has decided to invest, it effectively “kills” any alternative investment options. Keeping alternative

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226 Gately, D. (1980). Individual discount rates and the purchase and utilization of energy using durables: comment. *Bell Journal of Economics*, 11, 373–4.

227 Hausman, J. (1979). Individual discount rates and the purchase and utilization of energy using durables. *The Bell Journal of Economics*, 10, 33–54

228 Diederer, P., Van Tongeren, F., & Van der Veen, H. (2003). Returns on Investments in Energy-saving Technologies Under Energy Price Uncertainty in Dutch Greenhouse Horticulture. *Environmental and Resource Economics*, 24, 379–394

229 Van Raaij, W F; Verhallen, T M M (1983a): A Behavioural Model of Residential Energy Use. *Journal of Economic Psychology*, 3, 39-63

230 Dieperink, C., Brand, I., & Vermeulen, M. (2004). Diffusion of energy-saving innovations in industry and the built environment: Dutch studies as inputs for a more integrated analytical framework. *Energy Policy*, 32, 773-784

231 Diederer, P. et al (2003)

232 Ariely, D. (2008). *Predictably irrational*. HarperCollins, 2nd ed., London, UK.

options open is closely related to information uncertainty, if a firm is uncertain of the new investment, there is a preference to wait so that the company can assemble more information. The conclusion to be drawn is that the stronger the uncertainty regarding the costs and benefits of the investment, the more attractive it is for companies to delay a decision, and continue to maintain or invest in the old equipment.

Part of the advantage of innovation adoption is understood to be cost savings over competitors, first-mover advantage, though this may not always be long-lived. A study<sup>233</sup> into the reaction time for firms in the adoption of innovations in the US found that for products 70% of the first adopting firms rivals know and understand the characteristics within 1 year, and for processes around 60% within 18 months, illustrating the short time over which a first-mover advantage may exist. Understanding this diffusion process affects firms strategic thinking, in so far as firms may prefer to minimize innovation competition in the market, while they maintain or improve their position in other more cost-effective ways. As noted above, when this is not the case and a firm starts to invest in energy efficient products or processes, competitors will also react to catch-up<sup>234</sup>. The results of this can be that any advantage gained from first movement is short-lived and that the market returns to a similar position as was originally found. Given that the additional initial investment cost required for energy efficient products or processes may place firms at a financial disadvantage in the short term, these factors can form a powerful deterrent to innovation investments.

The balance between the costs and benefits is vital to the decision to adopt an innovation, for firms this is a factor of the difference between the value of their existing systems and the investment cost and projected savings of the new systems. Existing systems have an advantage in this regard as the costs of utilizing them tend to decrease for a period of time as firms learn more and more about how to optimise their use. This can close the gap between the cost advantages of the new and existing technology to a point where this learning becomes a significant factor in investment decisions. It may be more advantageous to continue investing in the existing technologies. Intangible assets can also be more emotive or political issues. Writing off previous, possibly expensive training, or making a previous decision obsolete, can be hard to justify financially and those involved in previous decisions may continue to champion them, forming a political block to the decision making process.

The age of the equipment, its tangible balance sheet value and accrued depreciation also all play important roles in the cost-benefit equation of investment decisions. It would be a costly endeavour to regularly replace new equipment because a more efficient machine is now available. Evidence suggests that companies will only invest in new equipment when the value of the current equipment has depreciated enough or when the need for more production capacity is strong enough<sup>235</sup>.

These arguments help explain why the adoption of energy efficient innovation by firms may be relatively slow and lag the technological frontier. Though evidence proposed in other research<sup>236</sup> suggests that companies that invest most heavily in energy efficiency innovations to their products and processes achieve higher sales and are more successful on average. The size of this advantage was in the order of 15% additional sales per employee. This suggests that successful

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<sup>233</sup> Mansfield, E. (1985) How rapidly does new industrial technology leak out? *Journal of Industrial Economics*, 34, no.2.

<sup>234</sup> Mulder, P., De Groot, H. L. F., & Hofkes, M. W. (2003). Explaining slow diffusion of energy-saving technologies; a vintage model with returns to diversity and learning-by-using. *Resource and Energy Economics*, 25, 105–126.

<sup>235</sup> Dieperink et al (2004)

<sup>236</sup> Rennings, K., & Rammer, C. (2009). Increasing Energy and Resource Efficiency through Innovation: An Explorative Analysis Using Innovation Survey Data. *Czech Journal of Economics and Finance*, 59, 442-459.

firms better understand the link between higher energy efficiency and competitiveness, though it should be remembered that there are also many other factors necessary for success.

## 5.6 Case study: Audio and Visual technology

Innovation in the field of audio and video technology has led to a radical shift in all aspects for the broadcast and consumption of multimedia, with huge changes in both product and process, the move from analogue to digital among the most significant.

This shift to digital technology has led to a reshaping of all aspects of the value chain for the industry, stretching right down to consumers. The invention of digital storage and playback did not, *per se*, entail a reshaping of the industry. However, as computers and the Internet merged with music and video creation and playback, it opened up possibilities for consumers to use content in ways that had not previously been envisioned. What was originally viewed as an incremental innovation driven by industry quickly spiralled into a consumer-driven series of radical innovations, which forced industry to adopt innovations, as consumer copying changed the validity of a business model that called for full control over content. Copying content was not a new phenomenon, and in fact, had been legalised in most Western jurisdictions for private use. What was new was the ability to reshape that content, to play it back on any number of devices, and perhaps most importantly, to make that content accessible to any number of strangers in a broader content-sharing community.

Audio and video technology has seen a rather dramatic difference in terms of innovation uptake, notably where different parts of the industry may be driving or resisting innovation in turn. The case study focus however, is on the manufacturers and *buyers* of the devices. For the most part, these manufacturers were the segments of the industry driving innovation. Divorced from concerns over content protection—or, in the case of some manufacturers, actively looking to co-opt and extract value from content providers (as in the case of Apple)—manufacturers were looking to provide new products that would allow consumers to work with digital content in new ways, and consumers were looking for new ways to share and listen to content.

The focus of this chapter will be on two technologies for audio and video, which came to the fore at different points of the interaction between content providers and manufacturers. DVDs represented an incremental change and improved on an old model of film distribution, improving sound and video reproduction via a new medium. Portable medial players, however, represented a radical shift for the industry, where consumers drove industry through their aggressive uptake of digital music, which the industry fought to prevent.

Below, we explain the reasons for lags in uptake, adoption or availability.

### **DVD players – the role of complementary goods and standards**

Work by Hall and Khan<sup>237</sup> stressed that the key determinate of technology uptake is that the benefits received by the user are larger than the costs of uptake. In terms of DVD players, this would imply that users must consider the utility derived from using their DVD appliance to be greater than the costs of buying it. To estimate the costs and benefits of adopting a DVD appliance, one must note that a DVD player is a network good in a sense that the utility derived from owning the player is severely limited if the user does not have access to DVD discs<sup>238</sup>. When complementary goods, such as DVD discs, are not easily available or their price is relatively high,

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<sup>237</sup> Hall and Khan (2003)

<sup>238</sup> *Ibid.*

fewer people will buy a DVD player and the ones who do, are able to make less use of their purchase<sup>239</sup>. Hall and Khan refer to this as “a hardware-software example” where increase in software availability positively influences the sales of the hardware. However, this relationship goes both ways, as in some cases software producers are not interested in supplying their products unless the country has reached a large enough hardware installed base<sup>240 241</sup>. This may cause significant bottlenecks for innovation uptake. Overall, consumer's purchasing decision is based on the price and availability of both DVD appliances and complementary goods, such as DVD discs<sup>242 243</sup>. It should be noted that the price and availability of both DVD players and their complementary goods may depend on how well a country is connected on global markets and on its market size and quality. In the quantitative analysis (see chapter 3.) one could not find a clear relationship between price and ownership of DVD appliances. However, the analysis did not include the availability of DVD appliance nor did it include price and availability information for complementary goods.

Another significant factor determining technology uptake is the presence of product standards and confidence of consumers and companies on the permanence of the new product. The DVD market can be characterized by continuous development, which has both positive and negative effects on product uptake. On one hand, product development means that the consumers are able to buy higher quality products, which potentially increases the utility consumers are able to derive from the product and gives them an additional incentive for adopting it. On the other hand, product development can simultaneously take multiple directions, which may cause confusion among consumers<sup>244</sup>. This was the case with DVD appliances.

In 2002, DVD appliance industry came to crossroads where some producers, led by Sony, announced to start developing a new high-definition Blu-ray DVD discs, where as other producers, led by Toshiba, started producing a similar, yet technically different disc called HD DVD<sup>245</sup>. Both forms of the new DVD disc offered significant improvements in terms of memory size and picture quality, yet they were not compatible with the old DVD players and both DVD disc types required a specific DVD player compatible with either Blu-ray or HD DVD disc. The format war did not only include the DVD appliance producers but also other related industries, such as movie studios and computer producers, who had to choose which type of DVD discs and appliances to support. A number of studies conclude that format wars cause consumers to postpone their purchasing decision in order to wait for dominant standards to appear<sup>246 247 248</sup>. This is partly due to the uncertainty regarding the future use of the type of appliance the consumer chooses to buy and partly due to the more limited use of the appliance given that for example the availability of certain movies depended on the format that the movie studio has decided to support<sup>249</sup>. Where as in some situations governments have chosen to interfere the market by deciding the dominant standard, this did not happen in the DVD market. Instead, the format war ended in 2008 when Toshiba announced that it would no longer produce HD DVDs. One of the main reasons for this

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<sup>239</sup> Karaca-Mandic, (2003)

<sup>240</sup> Ibid.

<sup>241</sup> Dranove and Gandal, 2000

<sup>242</sup> Hall and Khan, 2003

<sup>243</sup> Chris and Slowak, 2009

<sup>244</sup> Spark, 2009

<sup>245</sup> Ibid.

<sup>246</sup> Christ and Slowak, 2009

<sup>247</sup> Spark, 2009

<sup>248</sup> Dranove and Gandal, 2003

<sup>249</sup> Christ and Slowak, 2009

announcement was that Blu-ray DVDs were gaining significant popularity since several producers of complementary goods decided to support Blu-ray DVDs in 2006<sup>250</sup>.

In terms of DVD appliance uptake, format war took place at a critical time. While consumers were postponing their purchasing decisions regarding DVD appliances, a number of alternative products gained popularity. Within EU countries both computers<sup>251</sup> and internet<sup>252</sup> access became more widely available during the format war, which enabled people to substitute DVD players by computers with inbuilt DVD drives and by using internet to download and watch films<sup>253</sup>. Although Internet can be a substitute for DVD players, Dranove and Gandal<sup>254</sup> point out that it may also serve as an information source for consumers looking to buy a DVD player. The authors further argue that it is not necessary for competition to physically exist in order for technology adoption to slow down. A mere preannouncement of intentions of developing a new and better product will slow the adoption process. This was the case when the initial DVD format was challenged by DIVX format in the late 90's. As DIVX promised a number of qualities that outperformed the current DVD format, the growth of DVD uptake slowed down in anticipation of the new product. However, DIVX failed to launch in time which gave DVD format time to gain dominant market position.

New technology uptake may also be slowed down by the presence of older technology, which is still a fair substitute for the new technology<sup>255</sup>. In the case of DVD appliances, consumers were able to postpone their decision to buy either Blu-ray or HD DVD appliances as they had the option of using older DVD appliances that supported the older DVD disc format. Similarly, when looking at the early days of DVD appliances, the uptake may have been slowed down by the presence of VCR players. The presence of older substitute technologies is likely to have stronger effect on new technology uptake in the developing countries, as low income consumers may not be easily convinced to purchase a product that adds little new value to their

### **Portable media players – consumers selecting standards and Apple's first mover advantage**

While DVD players have represented an important development in terms of digitising content, the true impact of digital content and how consumers would interact with it did not come to the fore until the advent of media players that would play content in a format not originally offered by content providers. This was a technology which began to see adoption before there were few legal means of purchasing content for the players that consumers had purchased.

Until recently, portable media players (PMP) were generally referred to as MP3 players for their ability to play the ubiquitous and free music format. Some manufacturers attempted to present alternative players that would prevent music from being copied between devices (and individuals). Sony spent years promoting their music format, ATRAC, in all of their media players, sometimes to the neglect of the MP3 standard. However, these attempts to present listeners with a "closed environment" were largely failures. PMPs that could not play the MP3 format were generally failures. In 2007, for example, Sony killed ATRAC and their accompanying eStore<sup>256</sup>.

One notable exception to the picture of open standards has been Apple, which has dominated the market for media players, and really driven adoption of portable media players by the general public

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<sup>250</sup> M'Chirgui et al, 2010

<sup>251</sup> [http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc\\_ci\\_cm\\_h&lang=en](http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_ci_cm_h&lang=en)

<sup>252</sup> <http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&language=en&pcode=tsiir040&plugin=1>

<sup>253</sup> Coplan, 2006

<sup>254</sup> Dranove and Gandal (2003)

<sup>255</sup> Hall and Khan, 2003

<sup>256</sup> Sony euthanizes Sony Connect., 2007

(iTunes was created by Apple in 2003, at the time when take-up of media players began to accelerate). Apple's entry into the market proved critical, because their focus on ease-of-use and an integrated experience proved critical in proving to consumers that, in terms of functionality, this product offered significant added value over old functionality.

Steve Jobs' ability to get content producers to agree to a low price for music also proved critical. Masterful marketing also played its role, with Apple able to generate positive press in a number of different formats. Currently, twelve percent of all tech articles are written about Apple, with Microsoft, by contrast, receiving only a 3 percent share<sup>257</sup>.

Part of Apple's success derives from innovative ideas both on a hardware and software level. Software here refers to not just the interface that drives the device—the touch-screen interface on the iPod Touch, derived from the iPhone, is considered by many to have fundamentally changed the industry. But the ease (and price) of purchasing music to fill those media players have also been critical. The Apple "ecosystem"—a target of the European Commission because it did not allow consumers to transfer music to competing devices—allowed Apple to almost single-handedly drive wide-spread adoption.

Understanding uptake of portable media players differs rather markedly from those of other products. In this category, a schism exists between Apple, which was able to present its own ecosystem and format (that was largely invisible to the user), and the rest of the industry, which in essence was forced into a role of adopting the ubiquitous standard of MP3, a standard which had already been set when people had begun exchanging music files on their personal computers. In essence, the standardisation battle had been settled when these devices began to be introduced to market, which made adoption more likely.

## 5.7 Case study: process innovations

When speaking of innovation, the innovations that first come to mind often entail improvements to a product. Companies in ICT, such as Apple and Google, have become famous for their ability to enhance the functionality of their products in a compelling way. While these product innovations are readily visible, the process innovations remain equally relevant. Process innovations are those innovations in which the way a product is produced changes rather than the product itself. Google, again, is a good example of a company where product and process innovation readily interact. One of the process innovations brought forward by Google was to allow its engineers to work one day a week (or 20 percent of their time) on projects outside of their job descriptions. Many new Google products have emerged from this system. Just as innovation lags exist with product innovations, so they exist with process innovations.

Below, we explain the reasons for innovation lags

### **Following the leader – first movers and followers**

In general, in a process known as mimetic isomorphism, companies follow the business practices of organisations that are considered to be a success. Nokia, in a speech to its employees in February 2011 regarding their falling business, identified two successful business models that have caused them to be left behind (and by extension, would be worth imitating).<sup>258</sup> On the top end of the market, they point to Apple and Google's creation of new ecosystems, where mobile telephones

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257 Marketing Apple: Secrets of the World's Best Marketing Machine: Apple Marketing generates the most news," 2010

258 <http://arstechnica.com/gadgets/news/2011/02/nokia-ceo-company-must-jump-from-burning-platform.ars>

sales are about more than just selling a product, but also about selling an environment in which one buys content and applications, has left Nokia's product looking wanting. At the lower end of the market, companies from the developing world are proving more nimble at developing new product at lower prices. Their business model—and their processes—need to change.

Products that are highly innovative require a more flexible value chain, one where manufacturers come and go on a frequent basis depending on the latest needs of the product. In particular, when a product is at the early stage of design, and no clear standard has been set, then any number of suppliers and manufacturers can come and go.

Process innovations are not only horizontal, but also vertical, with the notion of partnership coming to the fore. Companies no longer necessarily view relationships as one of selling product, rather, the idea of partnership has entered into the supplier-customer relationship. European steel companies, for instance, have built facilities in other parts of the world or developed strategic alliances worldwide to extend collaboration and meet the requirements of their customers in terms of services, quality, and prices (EU-Commission, ESTP, 2006). These organisations focus on high-quality tailor-made steel products in close cooperation with customers is an opportunity to differentiate and to compete with other means than price competition (Ecorys, Steel, 2008).

Production processes are another key area for innovation. In the glass industry, for example, new melting processes and improved processes to finish the glass product help enhance the finish. These new processes have also helped to reduce energy usage. (Ecorys, Gas, 2008). Automation, while an innovation that was created some time ago, continues to spread to newer industries.

Even when the balance between costs and benefits is favorable to companies, studies have shown that certain barriers to innovation can cause innovation lags. For example, a European Parliament's committee on Industry, Research and Energy: "Eco-innovation-putting the EU on the path to a resource and energy efficient economy<sup>259</sup>" (2009) identified some of the following barriers to innovation take-up.

Table 4 Barriers that potentially cause innovation lags

| Grouping    | Barrier   | Explanation  |
|-------------|---|--|
| Supply side | Technological and management capacity<br>Appropriation problem and Market characteristics | <p>Access to knowledge about new processes and products<br/>R&amp;D activities, financial resources and human capital<br/>Accumulation of human capital and available knowledge spills over. If the innovator is unable to capture all the social returns it generates, there are fewer tendencies to investment unless there is sufficient protection of the new generated knowledge.</p> <p>The research on the market characteristics and its relation to resource efficient innovation did not give a uniform picture. On one hand, in monopolies, the appropriation problem is overcome because firms fear less the imitation of their products or operations, thus they guarantee a higher social return of their investment. On the other hand, monopolies may not have an incentive to innovate. They monopolize the market any way.</p> |

259 The study selected three key sub-sectors: Housing- Deep renovation and Smart Metering, Mobility- Green electric cars and car sharing, Food and drink- Community supported agriculture (CSA) and Sustainable Sourcing of Retailers. The study uses three types of Eco-innovation: Product innovation, system innovation and process innovation. In that sense, it is identical to the typology used in this research, hence relevant to refer to its conclusions.

|  |   |  |
|--|---|--|
| Demand Side                            | Path dependencies   | “Innovation breeds innovation” (Baumol 2002 cited in Horback, J, et al 2007, p. 6) in one unit of production will be accompanied by changes in other units too. Inefficient production system and lack of knowledge may constitute a barrier towards resource efficiency |
|  | (Expected) market demand: state consumers and firms                         | The introduction of a new product or the same product with higher environmental standards is accompanied by higher prices without observable increased quality. Uncertainty surrounds the marketability and profitability of the product.                                |
| Institutional and political influences | Social Awareness, environmental consciousness                               | Lack of awareness and consumer responsiveness will determine market demand and will affect negatively companies investment decisions for resource efficiency innovation  |
|  | Environmental policy (incentive based instruments or regulatory approaches) | Negative effects characterizing environmental problems are external to companies, regulations may force firms to realize environmental benefits through regulations (Porter and Van der Linde 1995, cited in Horbach, J. et al, ibid, p.7)                               |
|  | Fiscal systems<br>Institutional structure                                   | Pricing of eco-innovative goods and services<br>The existence of pressure groups such as industries and trade associations and the extended knowledge network may affect positively or negatively resource efficiency measures.  |

Source: adapted from European Parliament 2008, p. 26

### Sunk costs and market competition

Sunk costs are another important contributor to innovation lags because the more that a company needs to invest to adopt and optimise delivery of a product or service, and the tighter that margins are within that industry, the less likely that they will want to spend on changing internal processes. The tire industry is one such example. Innovation in the tire industry is not one that is necessarily sought out, but one where disruptive forces need to reach a high critical mass before managers to adopt new production methods. Automation and robotics were one of the intervening factors that forced change upon the industry, as companies in Germany and Japan managed to achieve such drastic cost savings, that other companies were obliged to follow this trend or face bankruptcy<sup>260</sup>.

This is in sharp contrast to an industry such as ICT, generally acknowledged to be dynamic, where product and process innovations are more common. Even in ICT though, it should be acknowledged that while incremental innovation can be quite common, radical innovations—such as the introduction of the Apple iPhone—are much less common, fraught as they are with the same types of sunk cost problems facing others, such as the tire industry mentioned earlier. Computer chipmaker Intel, for example, in October 2010 announced that they will build a new R&D wafer “fab” in the west coast of the United States and upgrade another facility at a cost of between U\$6-8 billion.<sup>261</sup> While Intel may produce new chips annually, adding significant speed and functionality. Nonetheless, while chips may get thinner, production processes do not normally change so radically that facilities become completely unusable.

While cost factors are important to explain process innovation adoption, cultural and managerial factors also play a role. Some authors look at organisations to judge whether they form an “innovation-supportive culture”, with authors focussing on the role of managerial flexibility in

<sup>260</sup> Brusoni&Sgalari, 2007

<sup>261</sup> <http://www.eetimes.com/electronics-news/4209734/Intel-confirms-new-Oregon-R-D-fab>

supporting innovation<sup>262,263</sup>. The size of a firm may also be a determining factor, with larger firms more likely to invest. Capital intensive firms and firms with export activities are also found to be more likely to adopt innovation, both because an increased capital with which an organisation can risk and increased competition<sup>264</sup>.

Cultural factors and sunk costs can play off of each other. Returning to the example of Apple, and how they managed to essentially co-opt the music industry, speaks to a large extent of how large investments of time and energy lead to both financial and psychological barriers to change and innovation. The music industry, over several decades, developed a network of recording studios, manufacturing, and marketing to support the production, distribution, and sale of music. While product technology changed with the introduction of various mediums, such as the cassette tape or the compact disc, the processes behind the industry changed very little. Not only had enormous effort been expended in setting up this apparatus, with only a few players in the competition, but this dominance of the industry lasted for several decades.

Yet the sector to some extent planted the seeds of its own decline as the CD, a product innovation that would see the digitisation of analogue music, foreshadowed the radical process innovation that would be forced on the industry. The digitisation of music allowed for it to be much more easily copied and transferred and then the rise of the Internet and the ability to “rip” music to a file, which could then be transferred extremely easily. But rather than take this as an opportunity and attempt to adapt to this innovation, the industry chose to essentially ignore how this radical innovation would revolutionise their industry. Rather than throw away decades of thinking and facilities on how to produce and distribute their product, they chose to cling to older methods. This lag in thinking and the industry’s complete inability to stop widespread copying and distribution of their music, as consumers sought the convenience of digital media and found few outlets for its expression—essentially gave Apple an opportunity to radically shift processes in the industry. Apple seized a large share of the market and the sector has struggled to regain the ground lost as CD sales have declined significantly.

## 5.8 Case study: evidence from the CIS – eco-innovation motivations

The CIS survey in 2008 included an additional, optional module relating to firms decisions and motivations in relation to carrying out eco-innovation activities and adopting innovative technologies that could have resource efficient impacts. This provides valuable insight into the broader reasons for lags in process and product innovation uptake by producers in the context of eco-innovation. It helps explain why some firms innovate faster or more than others, and how this relates to the important issues of energy and resource efficiency.

The results of the survey give an insight into the balance between product and process and innovations in firms, with the analysis grouping firms responses by their member state and how this fell into a broad innovation performance grouping<sup>265</sup>. These groupings, somewhat mirror the consumer groupings identified in chapter 2, with member states generally classed as innovation leaders, followers, moderate innovators and catching-up countries. The general finding is that leading countries focus more heavily on product innovation in comparison to catching-up countries, which focus more heavily on process innovation. An implication of this being that less innovative

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<sup>262</sup> Khazanchi et al, 2007

<sup>263</sup> Reichstein and Salter, 2006

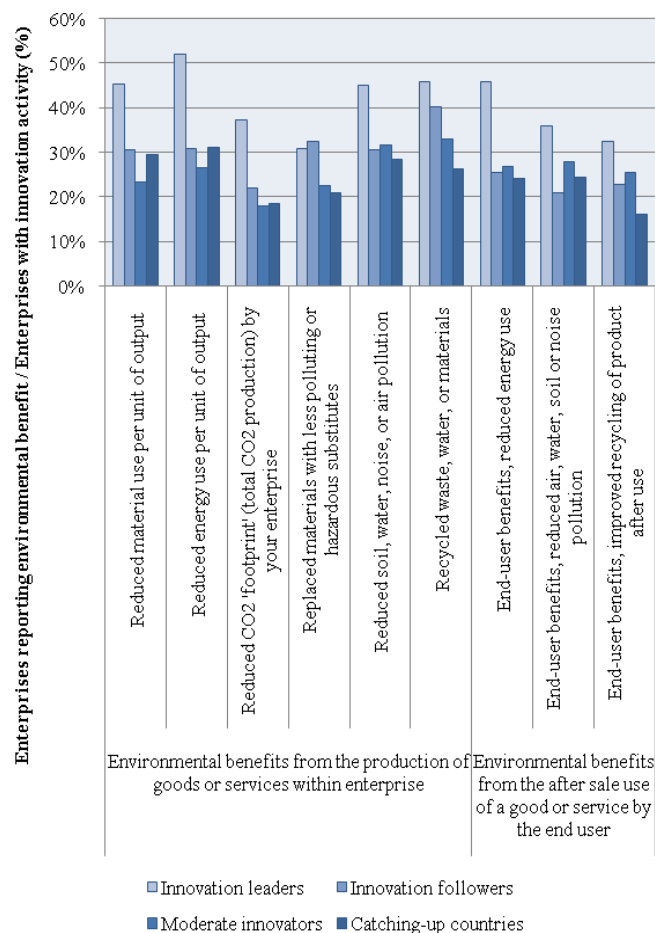
<sup>264</sup> Martínez-Ros, 1999

<sup>265</sup> Innovation leaders: DK, UK, DE, FI, SE; Innovation Followers: SL, CY, EE, NL, FR, IE, BL, LU, AT; Moderate Innovators: LT, PL, HU, SK, MT, IT, EL, ES, PT, CZ; Catching-up Countries: BG, LV, RO.

countries have to invest first in process before being able to develop products, this could be a factor in lags in product innovation adoption in some countries.

The CIS survey directly focused on innovative firms that experienced environmental benefits from the adoption of innovations. The results are presented in Figure 5.6 detailing the types of environmental benefits experienced by enterprises and how these vary across countries by their innovation grouping. The primary findings from this, illustrate that enterprises in the innovation leading group countries, report more environmental benefits than other country groups. For the other groups (innovation followers to catching-up countries), the proportion of innovating firms reporting environmental benefits is lower and broadly similar across the groups, except in the case of recycled waste, water or material where there appears to be a clearer link between innovation type and environmental benefit. In this case, it should be considered that recycling is connected to country characteristics and framework conditions and that countries with higher innovation capacities typically have better recycling infrastructures. The overall pattern in this case is that the impacts of innovation behaviour of firms can be linked, at least broadly, to their innovation performance, though the causation is not clear in which way the effect works. This can be informative for lags.

Figure 5.6 Environmental benefits (% enterprises reporting an environmental benefit), 2008



Source: CIS 2008 (IDEA Consult)

The CIS survey also goes further to explore what motivates enterprises to pursue and adopt innovations that have associated environmental benefits, exploring the role of various factors. The results to this question are presented in Figure 5.7 and are illustrative, though some caution should

be applied to their interpretation as they provide information on motivations for introducing an environmental innovation and not on companies' actual eco-innovation behaviour.

The clearest motivation, common across almost all countries, is found through existing regulation and taxes, and, to a lesser extent, future expectations regarding these. This is interesting in that it shows the direct role of policy in providing the strongest reason for most firms to adopt eco-innovations. In most countries voluntary codes and agreements also play an important role, this is particularly the case in Portugal, Hungary, Luxembourg and the Baltic States.

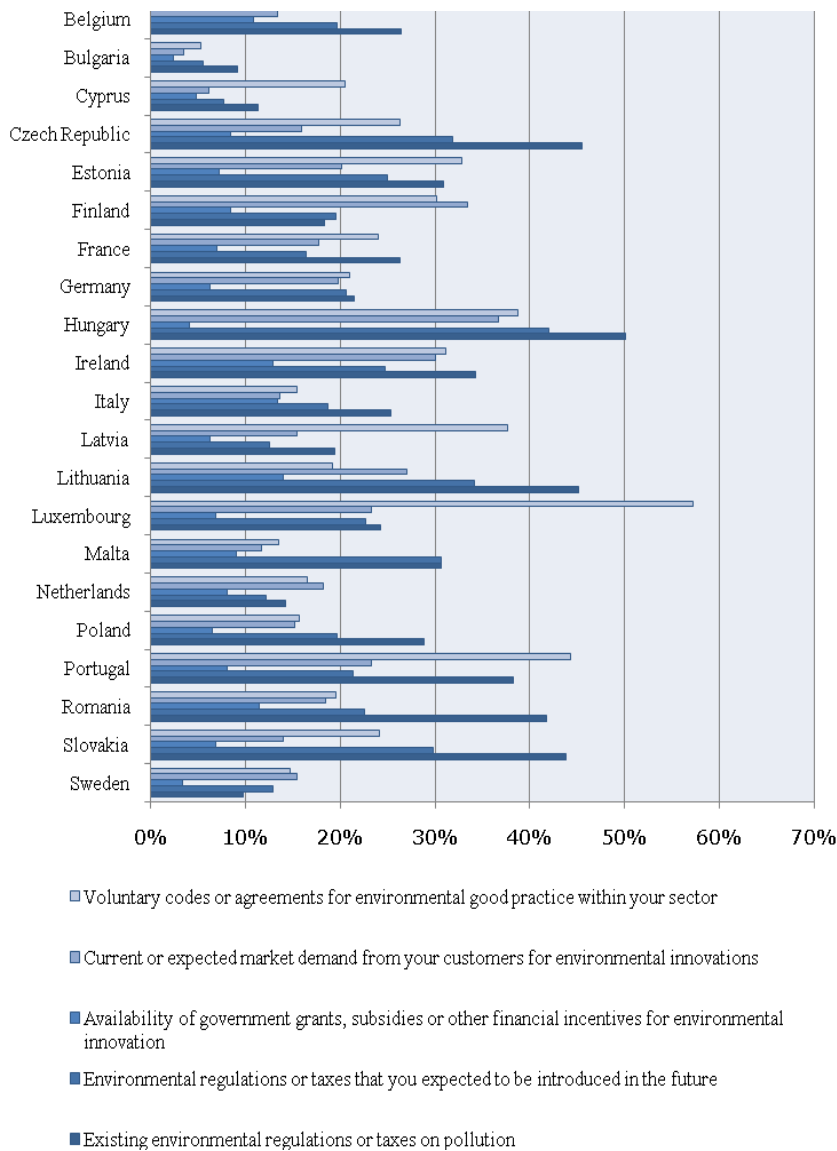
The role of market demand has been stressed in many areas of this report. It is interesting therefore to see that the results show that in many countries, it is not yet a clear motivation for innovation adoption. There are countries - Finland, the Netherlands and Sweden – in which market demand is viewed as the no.1 motivation for innovation adoption, this points towards a positive correlation between the innovation grouping / framework conditions in a country and the role that market demand plays in innovation development and adoption. This is interesting, in that way that it points to lags in business responsiveness to demand in countries with weaker innovation performance. Yet the role of uncertainty in decision making is also believed to be a strong factor in this, with evidence from a recent Eurobarometer survey<sup>266</sup> finding that around two thirds of managers said that uncertain market demand was a barrier to a faster uptake of eco-innovation in their company.

One final interesting finding from the survey is that grants, subsidies and financial incentives were in every case the weakest motivation for introducing an environmental innovation, in most cases less than 10% of companies found this a factor. This points to grants playing a very limited role in triggering environmental innovation. Two reasons were put forward to explain this finding, firstly that the available grants do not provide enough a big enough incentive to invest in eco-innovation; and/or secondly, that companies are unable to easily access these grants. This has implications for policy responses to promote greater innovation and faster business responses to economic challenges, particularly in the areas of the environment and resource efficiency.

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<sup>266</sup> The Gallup Organization (forthcoming), "Attitude of European entrepreneurs towards eco-innovation", Flash Eurobarometer 315, pp. 6.

Figure 5.7 Motivation for introducing an environmental innovation (% enterprises with innovation activity), 2008  
 – Industry (without construction)



Source: CIS 2008 (IDEA Consult)

### 5.9 What causes lags - do actual explanations match those predicted?

The six cases of lags in innovation represent many different challenges in terms of demand, drivers, regulation, technology and market structure. This is reflected to some extent in the reasons used to explain the lags in each case. Across the six cases though there are a number of common threads that align with the seven principle reasons for lags put forward previously. There are also a few explanations that are unique to the challenges of the individual case and that are not directly captured within the seven principle reasons. To conclude we summarise the evidence across the cases for the seven principle reasons as explanatory factors, and also summarise other reasons that may also be pertinent to lags and in what circumstances.

### 5.9.1 *The role of existing infrastructure and practices in influencing future choices*

This was identified as an important factor in lags across nearly all of the case studies, representing on technological, industrial, organisational and habitual levels a path dependency or 'lock-in' to doing things in a certain way.

In the automotive sector it was explained that there is a strong level of path-dependency that has stifled development of alternative vehicle technologies. Historical decisions, market structures, levels of risk to return in R&D and the interdependency of auto-industries and services have all contributed to providing advantages to the existing petrol engine vehicles. To achieve similar savings and learning in the scaling up of production for alternative vehicles is likely to require significant investment and potentially short term losses. The cost of developing new models and the financial power of existing market players has effectively also created a 'lock-out' of new entrants. Lock-in of consumer practices and expectations of vehicles performance to be compatible with current practice has also been an important barrier to the take-up of alternative vehicle technologies.

For broadband development and take-up this path dependency has been both a help and hindrance, with the quality of the existing telecoms infrastructure an important factor in enabling take-up. In some countries (Sweden, the Netherlands) an existing high quality and wide infrastructure allowed for easier and cheaper provision of broadband, enabling higher take-up. In other countries, particularly developing countries, the lack of an existing telecoms infrastructure makes roll-out of broadband much more difficult and expensive, with knock-on effects on take-up. This is often also the case within countries as part of an urban-rural divide.

In lags in the take-up of energy efficient technologies various forms of path dependency were evident. Compatibility was a problem with the early efficient light-bulb technologies, they did not fit with existing fittings. The technology had to develop to a point where it was compatible with the existing infrastructure before barriers to take-up could be overcome, the development path therefore dependent on what had gone before. For firms, and also for consumers and other organisations and groupings, it was shown that lock-in to previous decisions can also affect innovation adoption decisions. On a simple financial basis there is the need to reconcile investments with expenditure and depreciation, continuously adopting more efficient products and processes is rarely feasible. Less tangible concerns can also form barriers to innovation adoption, these include the value of learning and optimisation on the existing technology being lost and the political implications of decisions.

The financial factor in influencing future choices was also identified in respect of process industries. Sunk costs in processes is an important factor in the decision to adopt an innovation, particularly when margins in an industry are tight. High sunk costs in capital equipment and associated training and management can act as a significant deterrent to new investment, particularly when the innovation is radical and risks are higher. This can lead to lags.

The range of situations in which the existing infrastructure and practices have been a major influence on innovation take-up, provides clear evidence that this can be an instrumental barrier to innovation adoption. Yet, there were also examples of the potential for it being beneficial, for example in broadband where a strong existing telecoms infrastructure provided a base for rapid broadband diffusion. Similar, positive effects are proposed in Brazil and the US in relation to biofuels, where existing infrastructure and commitments may act as a catalyst to drive moves towards 2<sup>nd</sup> generation biofuels.

Breaking what is perceived by policymakers as negative 'lock-in' is a significant challenge, more so when the time-frames and planning horizons for major infrastructure projects are considered. The supporting regulatory and planning environments in themselves provide a locked-in lag to infrastructure change. This is evident from the time taken for an infrastructure project to get from inception, through planning procedures and to construction and operation. The energy sector provides examples of how this can be a serious factor, the scale of change required in many member states is massive, particularly in meeting renewable energy targets, but for example in the wind energy sector the administrative procedures vary from less than 23 months average in one member state (Belgium), to more than 76 months average in another (Spain), taking nearly three times as long<sup>267</sup>. This is perhaps an example at the high end of the scale but is illustrative of the importance of the issue, particularly when large scale infrastructure change is required. It is also instructive of the role of regulation and standards, further explored in 5.9.7.

The automotive sector offers some insight into how broad lock-in may be broken out of and the types of actions that could be supported by policy makers wishing to initiate changes such as this. These insights include harnessing developments in other sectors, as auto manufacturers have begun to in respect of battery technologies (from home electronics and mobile communications). The other is through the potential rewards and demonstrated success from first movers, with the audio and process examples of Apple providing an example of the potential for success through being a first mover and challenging existing practices. This contrasts with the auto sector where only a few firms have shown willing to risk innovation in alternative vehicles, Toyota, Honda and now GM and Nissan among them. Their first successes demonstrate the potential to others and can drive the whole industry in the same direction, increasing the chance that lock-in could be broken. Ways to support first movers, such as exclusivity type arrangements may be an interesting avenue to explore further, with the pharmaceutical industry offering learning potential.

### 5.9.2 *How our expectations of the future influence what we choose to do now*

Future expectations can play an important role in adoption decisions, this was found to be the case specifically in the context of energy efficient technologies and process innovations. At the general level uncertainty about the future makes choosing between options more problematic. It was demonstrated that consumers and firms have a preference for keeping options open, even when this can lead to financial losses. The reasons for this were closely related to the known implications of the current option and uncertainty regarding other options with this becoming further clouded looking into the future and, for example, the future direction of energy or resource prices, which can radically change the costs and benefits of an investment decision. In audio and visual technology this uncertainty was demonstrated in respect of standards, and uncertainty among consumers when competing standards exist, as shown for HD DVD and Blu-ray. The example of energy efficient technologies also provided evidence that the importance of energy as a current cost component and expectations of how this may or may not change in future is an important factor in decisions to invest and adopt energy efficient products. Decisions are made on the basis of expected cost savings, their relative importance and also how they compare with other competing investment options such as marketing spend, that may deliver greater returns.

Very closely related to this is risk aversion, which is another major factor. With an inherent wish to avoid risk a common and natural trait. The evidence showed that in general loss aversion is a major factor, that people are likely to put more weight on avoiding losses than risking for potential gain. This is complicated by the uncertainties surrounding future price expectations and the information

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<sup>267</sup> EWEA (2010) Wind Barriers: Administrative and grid access barriers to wind power

deficiencies that can exist. Attempts to quantify the scale of this effect found that this aversion meant that the financial returns of an energy efficiency investment must be considerable to induce adoption, with net present values in the range of 25%-300% higher than costs. This is also particularly an issue among low-income groups and is related to time-preference and short term thinking. Obviously the high demands this makes of innovative technologies, in demonstrating cost advantages over existing technologies, slows their adoption and diffusion.

In respect of mobile telecoms this was articulated as a confidence problem, where a symbiotic relationship exists between consumers and firms. Business needs to have a future expectation of a market to take-up an innovation, while the majority of consumers need to be convinced that an innovation will be broadly accepted and that they won't be left with an incompatible or obsolete product or service. When there is uncertainty on either side this restricts the space for innovation adoption which can slow or stall the adoption process.

There was a lack of clear evidence of these effects in the other cases studies though it would be logical to assume that this could be highly relevant to innovations that improve the efficiency of which scarce resources are used, such as alternative vehicle technologies. If an expectation of a continuing future upward trend in fuel prices was widely perceived then downside uncertainty in alternative vehicle technology innovation adoption decisions would be reduced. This could spur take-up and also provide signalling to producers of consumer's future demands, leading to increased investment in innovations to reduce fuel costs. The extent to which these types of trends are known and understood is an important factor in the role of future expectations, therefore this is closely related to consumer knowledge and awareness and to educational standards.

### *5.9.3 How our consumption habits and choices are shaped by those around us*

The evidence from the case studies suggests that our consumption choices and habits are strongly shaped by those around us. In the automotive sector one of the explanations for the lag in adoption of alternative vehicle technologies was identified as consumer perception. Firstly, in that petrol engine vehicles are a long term consumption habit and beyond this, they are the definition of automobiles in consumers minds. Establishing alternative vehicles in this perception is difficult and is reliant on the technology being able to fulfil expectations, an important theme revisited later in this section. The examples in the case studies reflect times where this has not been the case, for example the first electric vehicles, and this has subsequently had a negative impact on innovation adoption.

In the adoption of broadband the interconnected nature of consumers habits and choices was found to be positive factor in addressing innovation lags. The habits of younger people in internet usage, habits often formed during education, were found to be an important factor in stimulating take-up of broadband across different age-groups. Within families the interaction of young and old has served to raise awareness and diffuse the habits for internet usage, driving wider take-up of broadband.

At later stages of innovation take-up, following early adopters, a certain critical mass can be reached that accelerates innovation take-up and further innovation. In mobile telephony this was demonstrated as growth in users developed, so a growth in the uses for mobile phones was also found, from video and photo technology through to banking and other services. Similar effects were also noted more recently in the context of firms and the choices of first movers, with more charismatic or successful companies being imitated by others, their choices influencing wider choices. Similar network type effects were also noted in audio and visual technologies and process innovation, specifically in the diffusion of digital music, driven at first by consumers acting illegally but the sheer volume of use diffusing the innovation to the point that producers, which had been

lagging consumer choice had no choice but to adopt the new innovation. This is also highly relevant in the context of competing standards, where people will, where possible, attempt to choose the standard that the majority follow.

A positive example of the role of others shaping consumption choices was found in the automotive sector and the adoption of Hybrid Electric Vehicles (HEVs). These managed to avoid gaining a negative perception based on performance and although apparently reliant on early adopters happy to pay a premium for the environmental qualities of the vehicles, have established themselves in the market. The reasons to explain the willingness to pay this premium are interesting to the extent that the early adopters may also have invested in them as a status symbol, with the pro-societal values of HEVs acting as a display of status, evident in their publicised purchase by celebrities.

#### *5.9.4 How knowledge diffusion and awareness can shape decisions*

The automotive sector provided a powerful example of how knowledge diffusion can lead to lags in take-up. The failure of the earliest electric vehicles, when the technology performed poorly in comparison to standard vehicles, established a negative perception of them and the knowledge of this diffused to the wider population. This first knowledge of the product has since tainted the development of electric vehicles. Similar experiences were found in energy efficient technologies, such as energy efficient lightbulbs, with the evidence suggesting that the innovations need to be, as far as possible, perfect substitutes for existing products or processes. Problems in quality and functionality or the need to replace other items for compatibility reasons can both lead to negative experiences for consumers, which can then quickly become accepted knowledge. Consumer experience at the initial innovation adoption stage is therefore crucial, because of the role of word-of-mouth in diffusion, and how negative experience can lead to diffusion of a negative knowledge and awareness of the innovation which then is difficult to shake.

In the case of broadband technologies knowledge diffusion was found to occur within families and other groupings with a diffusion across age groups, from young to old. The knowledge and awareness gained by young people in an educational setting and through social interaction, was able to diffuse to create an understanding and demand for broadband technology from a wider consumer group. Harnessing these types of diffusion patterns can be a useful way to overcome lags in innovation take-up.

In the case of energy efficient technologies knowledge and awareness were found to be crucial issues in innovation adoption. Consumer surveys indicated that in many cases there was a lack of awareness of the existence of the innovative technologies in the first place, making it impossible to make an adoption decision. This can be a significant hurdle, particularly for items that are taken for granted in our daily lives. When an awareness of the technology was present the problem of fully understanding the benefits and advantages becomes an issue. In relation to energy efficient technologies this was understood to be a significant factor in lags in innovation take-up and was due to an information deficit, part of which was structural. With the way energy is typically used and paid for it is highly difficult for users to understand exactly how much existing technologies use and therefore their cost. Knowing that an energy efficient bulb is, for example, 40% more energy efficient, is one thing, but for the consumer it is very difficult to translate this into a potential monetary saving as it is not clear how much a particular appliance or fitting is using. This knowledge gap was shown to lead to lags as the uncertainty surrounding the costs and benefits makes it easier to put off any decision.

### 5.9.5 *The important role played by skills, education and educational systems*

Education is an important factor in understanding, which in turn shapes decision making processes. Mathematical and financial skills are important to accurately weigh the financial implications of a decision and highly relevant in the case of energy efficiency technologies, where the trade off between short term cost for long term benefits was found to be a factor in adoption lags. For energy efficient technologies a potential gap in understanding was identified where decisions did not match with optimal decisions on an NPV basis, with benefits from investments needing to be in the range of 25-300% more than costs to induce adoption. That it takes so much more to induce innovation adoption points towards a failure in this process, as noted previously information deficits, knowledge, awareness, uncertainty and risk aversion are all likely factors, but the ability to understand and interpret the information that is available can also be an issue.

Educational institutions and systems can also play a role in attitudes toward and diffusion of innovation. In the case of broadband technology this was identified as an important factor in take-up. Higher education institutions in particular, pioneered the use of the internet and associated technologies, many students gained their first exposure to the technology there, building both skills in internet use and also learning its value to lead residential consumer demand.

Little specific evidence was found for the role of education as a factor in innovation lags across the other case studies, indicating it may only a specific factor in a limited number of situations. Yet through its general role in enabling individuals to make informed decisions, education remains an important factor in all innovation take-up.

### 5.9.6 *The role of market and organisational structures in influencing decisions*

Market structures, particularly in relation to competition and organisation, can play a significant role in innovation take-up decisions. These factors are closely connected to the policy and regulatory environment and the role that plays in setting market rules and conditions. Evidence from across the case studies finds these factors as being important in every case.

In the automotive sector the market situation was found to be influenced particularly by the history of development, with the major market players already well established and the possibilities for new entrants restricted given the costs involved. A further aspect of the market is the nature of proprietary technologies, in that there are lags between firms in the sector, such as Toyota and Honda pioneering HEVs while other firms lagged behind. That these firms developed the technology and intellectual property first confers on them an advantage. What was evident is that other firms did not immediately follow their lead, waiting to see if the technology would be successful. Following the demonstrated success the other firms have now also begun to invest and launch models with hybrid drive-trains.

This illustrated two important factors, firstly that there can be a tendency among firms to 'let the market decide', which in the case of new innovations where demand is unknown, is tantamount to not doing anything. Secondly it illustrated the dilemma that firms face when taking the gamble to lead in innovation to try and secure a first mover advantage. For Toyota and Honda it is understood that their HEV models were initially sold at a loss, while the technology first gained acceptance. Now they are both leaders in the market and are taking advantage of being first movers as others struggle to catch-up.

First mover advantage was identified across all the sectors, but it was not always clear if the benefits outweighed the initial costs, the main conclusions were that first mover advantage could

secure significant market share, particularly in the short term. Just how short-term is an important factor to consider, the evidence from energy efficient technologies suggested this could be on average as short as 12 months for product innovations and 18 months for process innovations. In the longer term other players caught up and the market often returned to a similar state to that found originally. These factors obviously have a strong bearing on the strategic innovation planning and decisions of firms, acting to deter innovation and leading to a general lag in development. Yet evidence from energy efficient products and processes showed that firms that do focus on the development and adoption of innovation are, in general, 15% more successful than those that do less, on an additional sales per employee basis. Evidence from bio-technology and drugs development suggests that an exclusivity period for innovations can incentivise investment in innovation.

In the context of broadband technology most countries started from a position of a state-owned telecoms monopoly. The rate of adoption of broadband technology were shown to be closely related to the extent that there was open competition between providers, with markets with level-playing fields that were more open, supporting more rapid penetration of broadband. South Korea was the most successful example of this but also an interesting case where majority control of the sector was still retained. Where competition and the regulators were weak and the incumbent monopoly operators were allowed to control the roll-out of infrastructure lags in broadband adoption clearly emerged. Competition between firms in the sector and also technology platforms that exist were both viewed as beneficial forms of competition to stimulate take-up.

Very similar evidence was presented in the context of mobile phone technologies, with adoption rates related closely to the level of competition in the market. In both cases competitive markets required access to the infrastructure that serviced demand, whether the telecoms exchanges or frequencies, adoption of the technology lagged when control over these was left with one firm. In respect of mobile phone technologies inter-technology competition was also identified as a factor in adoption rates. In the developed world where a competing fixed-line telephone infrastructure existed take-up of mobile phones was slower than the rates now seen in the developing world where this infrastructure was much weaker or didn't exist. This is also relevant if the same firm is marketing both technologies, as incentives for firms to promote the switch and consumers to accept it are not always clear. On the other hand, if an innovation has no real competition very rapid adoption can take place as is happening in the developing world.

#### *5.9.7 How policy makers can hinder as well as assist the take-up of innovations*

The role that policy and regulation plays in innovation take-up is important, as by setting the rules and standards for the market to meet, in addition to being a major market player, policymakers can have a powerful influence. The case studies provide a variety of examples of where policy and regulatory intervention has played an important role in both assisting and hindering the adoption of new technologies.

In the automotive sector evidence was presented from Brazil, and to a lesser extent the US, that regulatory support for the biofuels sector was one of the vital factors in the sectors growth and development. In respect of regulatory tools the automotive sector provided insight into the relative merits of standards and taxes. A standards based approach in America in the form of Clean Air legislation was believed to be a major factor in the introduction and widespread adoption of catalytic converters, which were not adopted in other countries until similar regulatory mandates were applied. Yet in respect of fuel efficiency, the US standards based approach through CAFE, has not had the same impact on improving fuel efficiency as the tax based approach applied in the EU.

Whether the two policies can work effectively in combination remains to be seen, though recent automotive emissions standards legislation in the EU will allow an insight into this in the future.

In the context of broadband technologies the active promotion and support of the innovation, through an appropriate legislative and regulatory environment, was shown to be an important factor in diffusion. In Russia where regulatory power is weak and property rights, particularly intellectual property rights, were not protected adequately then lags in innovation take-up were evident, this contrasted with experiences in the neighbouring Baltic states where policy and regulation were more supportive and strongly enforced. It was also shown in South Korea that decisive policy intervention to actively create and promote the right conditions for an innovation can lead to rapid innovation adoption.

For mobile phones the role of regulation in setting standards was identified as an important factor in the relative speed with which the technology is adopted. Establishment of agreed standards on frequencies, roaming and other technical issues was achieved at an early stage in Scandinavia and then the EU, this provided an excellent base for the technology and take-up was able to increase rapidly when the market expanded. In contrast in the US, competing standards emerged, and liberalisation of markets led to fragmentation in the sector. The result of this was problems in compatibility between handsets and the cost of usage when travelling outside local areas or the US. These contributed to lags in adoption of the technology leaving the US behind Europe in terms of mobile telephones. Similar problems in the fragmentation of standards leading to lags in adoption were observed in audio and visual technologies and the divide between HD-DVDs and Blu-ray.

In the context of energy efficient technologies regulatory standards were found to be a crucial driver of innovation. Regulatory measures in Europe have slowly pushed up adoption of low energy lightbulbs, while the lack of such measures has been a factor in lags in take-up in North America and Oceania. In the case of boiler technologies a regulatory requirement in the UK for high efficiency boilers has driven the take-up of innovative technologies, transforming the UK from a country that lagged in take-up to among those with the highest levels of adoption.

#### *5.9.8 Other reasons for lags in innovation adoption – technology, principal-agent & geography*

In addition to the factors that fit with the seven principle reasons for lags identified previously the case studies also drew out a number of other reasons that contribute to lags in innovation adoption.

The most common additional reason was centred on technology readiness, whether the characteristics of the innovation were able to satisfy consumer and producer needs. A lack of readiness in these respects was identified as a prime factor for lags in the adoption of alternative fuels and vehicles. In the case of electric vehicles the technology is not yet able to match the performance of standard petrol vehicles at competitive cost levels, though recent innovations are closing this gap. In respect of biofuels the technology is also problematic and not appropriate to all situations, the conditions for success with the current technology need to be close to the Brazilian model, with a suitable crop, such as sugar cane, produced at large scale and with significant initial investment and regulatory support to start an industry. This can then make biofuels relatively cost-competitive with standard fuels. Generous support for biofuels but an unsuited crop, has succeeded in creating a market and industry in the US but not to the same extent and there is intense debate on the costs and benefits.

A similar problem was found in relation to energy efficient technologies, particularly in the case of lightbulbs, where initial lags in adoption were caused in part by the technology not meeting consumers' practical needs. This has been touched upon as part of existing infrastructure and

practices, consumer expectations and perception, and these are connected factors. An innovative product needs to be at least as practical and functional as existing technologies. In addition to this it also needs to offer some level of positive NPV or other benefits over and above what is offered by existing products.

A factor in lags specific to certain situations is the principal-agent problem. This was identified as particularly relevant in the context of energy efficient technologies but can also have implications for any decisions where a similar separation of decision maker and beneficiary exists. Where this is the case and the decision to adopt a product or process is made by someone that does not benefit it, then the result is often that the least cost or least effort option is chosen to satisfy the needs of the decision maker, while better options are passed over. This slows innovation adoption and is a particular issue for decisions with externalities, such as energy and resource use decisions.

The role of geography and income in innovation lags was not addressed deeply by the case studies. Much of the data focussed on explanations of lags based on just the developed world or made the direct distinction between developed and developing. Regional and geographical variations were picked up to some extent, that East Asia for example has significantly different standard lighting technologies, that North America has different fuel tax regimes or that Scandinavia was able to develop mobile phones more quickly. Yet the evidence could just as easily show neighbouring countries with significantly different approaches to a facet of innovation adoption, such as regulatory approaches to broadband in Russia and neighbouring countries. Culture and shared history can play an important role in these types of geographical factors, giving potential for spill-over effects, this is related to existing infrastructure and practices. Income was picked up as important factor in relation to energy efficiency where low incomes become a barrier to take-up of innovations that are more expensive in the short term, this is a problem when access to capital to invest for the long term is limited. There was also evidence though from the example of mobile phones that income levels were not that important to innovation diffusion, with low-income countries recording some of the highest adoption and penetration rates. Managerial culture was also identified as a factor in process innovation, this could potentially be a wider ranging factor also but was not explored in much depth in the case study examples.

## 6 Implications for policy

Identifying the major causes of lags in innovation uptake is important, but needs further understanding if it has to lead to an appropriate policy response. This understanding needs to address how the various causes interact with each other in the wider innovation and socio-economic system, what this means in the context of the structural changes demanded by environmental pressures and finally, how policy itself, beyond what was explored in chapter 5, can be a factor in determining lags and the ability to influence them.

### 6.1 Analysing how the identified causes of lags interact with each other

It is clear from the case studies (cf. chapter 5) that more than one of the identified causes of lags was at work in each case, and often all causes were at work to varying extents. It is also clear that each of the causes is interrelated, for example, our expectations of the future will be shaped by our educational background and that of those around us. In turn, our education will also shape our ability and inclination to seek out information and understand complex processes, this will impact on all our decisions, again with respect to future expectations, and also in our work lives where it can serve to influence the way organisations function and evolve. For policy makers, this serves to influence their choices and tendencies, the extent to which they may focus and challenge the status quo and existing infrastructure. Additionally, as noted with automotives, existing infrastructure shapes our lives and our thinking and this also shapes our decisions and expectations. These types of links could continue to be drawn in relation to the other causes, putting together a web of effects and interdependencies between them.

One of the most interesting inter-relationships as part of this system, and particularly in the context of the findings of this research, is the link between firms waiting for market demand signals from consumers on one-hand, as in the automotive case study. On the other hand, a significant share of consumers wait for innovations to become more widely adopted and established before they themselves adopt, as network effects become stronger as in the mobile and broadband case studies. This can represent something of an impasse, requiring either first movers among firms or greater awareness and positive knowledge diffusion among consumers, the barriers to which were demonstrated in previous chapters. It is important to understand this particular interplay as part of the wider system.

To attempt to analyse the various links and effects independently would be a significant challenge and although it may provide a basis for policy response in certain areas, the actual results of the action would not be clear given the behavioural and social nature of many of the effects and how changes in one could have unexpected effects on another. Taking a systems approach can be more instructive in providing insight into how the causes link together and what factors should be the focus of a policy response. This research though, only provides limited space, given the scope of the study and other constraints, to discuss how systems interact in theory and how this then may be applicable in practice to the causes of lags in innovation and in-turn economic responses.

Among the systems analysis techniques defined is complex-evolutionary systems thinking, which has been derived from the work by Schumpeter into innovation theory. It is based on the radical uncertainty associated with innovation and how the majority of innovations fail as part of a complex evolutionary selection process. Each of the causes of innovation lags identified in this study forms a

strand of the overall complex picture. They underpin one of the base assumptions, that belief systems and cultural infrastructure play a key role in innovation and innovation adoption. Systems thinking, in this sense, enables focus on the dynamics and drivers of change.

Work in this area by Dodgson et al<sup>268</sup> concludes that in respect of innovation it is highly useful to adopt this type of approach. In relation to lags this is relevant through the theory's assumption that the dynamism of economies is dependent on the ability to adapt and evolve innovation systems. This mode of thinking can help identify and understand how the various causes link together, but also accepts that the causes, often results of market failure, are natural to the system and that addressing one problem, may result in progress but then also re-emphasise another problem or create a new one.

The scale of systems thinking, and how it relates to various governance levels is important in this evolutionary context. The role of the regions, in how they can have different and distinct characteristics can also have an impact on the relevance of specific lags and how they interact with each other. The limited work on this at national level, feeds through to even less evidence at regional level. One of the newest strands of thinking in this area is based around 'regional resilience', which has become more prevalent in recent years in the US and beyond in the context of major economic shocks and events such as September 11<sup>th</sup> 2001, Hurricane Katrina and the financial crisis to name but a few.

That regions respond differently is important in relating back to the over-arching research objective in understanding how EU economy's may lag in their responses. In this respect it may be possible to consider innovation the long term driver of economic change, but one-off shocks also have an impact. The resilience of regions to respond to these shocks and deal with the changes is dependent on a variety of existing factors, in an innovation sense these will relate back to the extent to which each of the causes of lags are a factor in the region, i.e. relative education levels, quality and type of infrastructure, knowledge diffusion networks, market characteristics and importantly the role of policy makers. Work in the UK<sup>269</sup> has analysed some of the regional impacts of the financial crisis, highlighting that the regions worst affected (North East, West Midlands and Yorkshire & Humber) were those weakest on labour market indicators, while the major financial centre in London, proved much more resilient to the shock. The same paper highlights the role of regional leadership and moving the economy towards being more flexible and adaptable but engaging with the existing regional situation, i.e. harnessing the strengths of existing vertical supply chains and also working to utilise these strengths horizontally, to other sectors, to increase resilience.

Overall, a more holistic view needs to be taken, with policymakers maintaining policy interventions to address the market failures but also working to enable the market mechanisms to work with and complement the interventions. The purpose is then to support a system that is adaptable and flexible and that can overcome some of the systematic and structural lock-in that led to the causes of lags in the first place. This is particularly important in the context of eco-innovations, such as those relating to resource efficiency, where it is often necessary for multiple policy tools to work to support an innovation. Supporting market development for the innovative product and also potentially increasingly limiting or regulating non eco-innovative products to level the playing field. Achieving this, so that the system which shapes innovation adoption decisions can evolve, so that it shapes decisions to face the challenges of the move to a sustainable and more resource efficient economy, is a major challenge for the years ahead.

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<sup>268</sup> Dodgson, M., Hughes, A., Foster, J., and Metcalfe, J.S., (2010) Systems thinking, market failure, and the development of innovation policy: The case of Australia.

<sup>269</sup> Dawley, S., Pike, A., and Tomaney, J. (2010) Towards the resilient region – discussion paper for OneNorthEast

## 6.2 Implications in the face of structural changes

The environmental challenges posed by economic activity have become increasingly relevant as the global economy has continued to grow. Sustainable development has evolved into an overarching principle and policy objective for most countries as ecological limits have begun to be pushed, resource scarcity has become increasingly important and understanding of human impacts on climate increasingly known. The need for sustainable development can be framed as a result of an overall system failure of the current economic and policy model. The move towards sustainable development as a guiding principle is a recognition of this failure, but the transition required to make it an economic and policy reality represents, in most aspects, a need for significant structural change. A need to transition from the current system to a new sustainable system, with resource use one of the critical components of this.

The current system has been successful in delivering incremental innovations in respect of environmental performance and resource efficiency but the scale of the environmental and resource efficiency challenge is thought, by most, to demand more radical change. The current system has failed to deliver this, both in terms of innovation outputs and also wide scale adoption of these radical innovations, when they are available. The causes identified in chapter 5 highlighted the major problems faced in the adoption of radical innovations with resource efficiency objectives, rooted in both technological and behavioural factors, that are locked into the current system. Of the examples where a more radical eco-innovation has begun to be adopted the role of policy, in the form of regulation, has been crucial. The regulatory environment, either through standards, or administrative structures fixed in guidelines, plays a highly important role. This is vital when knowledge, awareness and understanding is too abstract or uncertain, such that the price mechanism and cost v benefit calculations by consumers, do not lead to adoption decisions, energy efficient products provided a clear example of this problem and the progress made through regulation in favour of more efficient light bulbs.

One of the first points that can be made in respect of these objectives, is that the evidence shows that consumers in general have little preference for products which have the social benefits associated with improved resource efficiency, they are primarily interested in their own private benefits, in the cost, performance and quality of the product. At the same time for a small section of consumers, tentatively estimated at around 5% of all consumers, altruism does function as a private benefit, as was shown in chapter 5 and Hybrids as status symbols. To enact structural change it will be necessary to adequately inform and incentivise the great majority of non-altruistic consumers to bridge this gap, for the innovation to be ready, known, and for the externalities of less resource efficient products to be factored into their prices, to provide a level playing field or one that directly favours the more efficient product, if the societal need is strong enough. This is needed to tackle the double externality problem raised in chapter 4.

A further relevant point from the causes is the role of risk and uncertainty. While adoption of an incremental innovation poses a risk to firms or consumers, adoption of a radical innovation, multiplies the risk and uncertainty involved. This is highly problematic when there is a need for adoption of these more radical technologies. This is particularly the case for firms and especially those in highly competitive sectors, as there is considerable uncertainty that adopting a radical innovation will prove beneficial, while there is much greater certainty that any weakness or failure will be exploited by competitors. Again this problem provides a potential role for policy, to help share the risk and stimulate adoption.

Work by Nill and Kemp in the area of sustainable innovation<sup>270</sup>, analyses the role of policy from a 'windows' perspective. This is developed from the point where a systematic style lock-in of behaviour, technology and infrastructure exists, but where there is a need, such as in the case of sustainability and resource efficiency, to break out of this. Windows refers to the windows of opportunity for this break out to happen, with opportunities being presented by internal and external factors such as major events, technological change or attitude shifts, to name but a few. These factors can lead to the current system becoming more unstable, presenting a window for change. Nill and Kemp propose that policy should work in 3 ways:

1. Window preparation;
2. Window creation; and
3. Window utilisation.

Where the current system remains stable, then window preparation is a suitable policy approach. This firstly involves demonstrating technical feasibility of concepts, and then with this to encourage development of further promising solutions. Window creation is the next phase, this becomes important particularly in times where strong social or political pressure exists. With pressure to act quickly the simplest solution for policymakers is to try quick fixes, which rarely get to the structural change needed. It is necessary to balance these necessary immediate actions with a more long term view to generate awareness and support for the required structural changes that can then be taken advantage of when the technologies are available. This relates to the final stage, window utilisation, where competitive technical solutions exist and the policy strategy and objectives then need to be orientated to facilitating the transition to the new technologies or structure. It is important here that policy works with market mechanisms as far as possible, an element of this is balancing the desire to promote the first solution above others for speedier progress towards goals, in effect 'picking a winner', against the benefits from a greater diversity of solutions, which may be superior to the first solution. A matrix of the policy responses in these varying circumstances is reproduced below in figure 5.8.

Figure 5.8 Taxonomy of techno-economic dynamics and related policy objectives.

| Status of the techno-economic system                      | Status of technological alternatives   | Kind of technological competition | Policy strategies and objectives  |
|---|--|-----------------------------------|---|
| Stable<br>(Still) stable                                  | Only theoretical alternatives exist<br>Promising solutions                                 | Not applicable<br>Only new-vs-new | Demonstration of technical feasibility<br>"Window preparation": diversity and development |
| Stable (but strong social pressure for quick path change) | Promising solutions  | Not applicable                    | "Window creation": handling of political pressure   |
| Unstable (window)   | At least one solution is competitive   | Old-vs-new and new-vs-new         | "Window utilisation": making transition easier and avoiding rush selection                |
| Unstable (window)   | Only one alternative solution is competitive, but other promising solutions for the future | Mainly old-vs-new                 | "Window utilisation": making transition easier  |
| Unstable (window)   | Several alternative solutions are competitive  | Mainly new-vs-new                 | "Window utilisation": avoiding rush selection   |
| Stable  | Transition takes place   | Not applicable                    | Restoring selection function of markets   |

Source: Zundel et al. (2005b, p. 329), adapted.

Source: Nills & Kemp (2009)

Among the policies approaches suggested are softening of competition rules to encourage shared research between private firms in areas where eco-innovation is needed but the market conditions are not conducive to it. The benefit of this would arise from a pooling of resources for innovation activity and also that by spreading the risk firms would be more likely to invest in the more fundamental research required in early stages. It is likely at later stages that firms would agree to pursue the innovation on their own as it reaches commercialisation and natural business needs

<sup>270</sup> Nill, J. & Kemp, R., (2009) Evolutionary approaches for sustainable innovation policies: from Niche to Paradigm?. Research Policy 38, pp. 668-680.

take precedent. One downside of this approach is the reductive effect on competition and the potential it could lead to collusive behaviour that works against the overall policy objectives or spreads to the wider market.

A further area for policy support is related to the window creation and utilisation steps outlined above and is based on the assumption that eco-innovations – those that improve resource efficiency – are not self-enforcing on the market<sup>271</sup>. They need market support of some kind as the typically the playing field is already skewed to the existing technologies through direct support such as subsidies or through a general lock-in. There is significant evidence regarding the need to specific market and regulatory support for eco-innovations and transition and niche market approaches<sup>272</sup> put forward for supporting this process.

These policies have a more general innovation and supply side focus, though can both be relevant for addressing lags in diffusion and adoption. Similar to the rest of the study, the literature on demand-side policy responses to reduce lags in adoption is much more limited.

One area of specific request for policy action is in the area of access to finance. This was recognised as a significant contributor to lags among the market and organisational structures. Work by Bleischwitz<sup>273</sup> has focused on the role of access to finance for entrepreneurs and its importance. A role for policy is found in a co-evolutionary respect, while continuing to provide innovators with direct support it is also necessary for policy to play a role in ensuring the correct framework conditions and strategic goals are present to deliver greater certainty for finance and market development. This is particularly relevant following the financial crisis.

### 6.3 Slow response rate of policy itself

In considering the appropriateness of policy responses, based on the identified causes relevant to a situation and considering the system effects and potential window of opportunity for change, it is important to remember that policy itself is an area of lags and uncertainties. This was touched upon in section 5.9.7 in how policy may sometimes hinder in adoption and up-take of innovations, but that was focused on the particular choice of policy to meet objectives and influence behaviour. It also needs to be recognised that the process of policymaking can cause lags itself, indeed, it can be typical for EU policies to take anywhere between 2 – 7 years to be transposed to national legislation and implemented..

The previous section highlighted the role of policy in breaking out of the current system, in doing this it is necessary to change the existing policy frame. Moving from the status quo can be difficult, with significant political risks and uncertainties involved and also a sense of inertia, the 'if it isn't broken, why fix it?' mentality. The political system itself is not always geared towards making long term commitments and objectives of the type required to enable the structural change envisaged in a move to a resource efficient economy. The political cycle in most cases dictating a shorter-term horizon for most decisions and policies.

One of the results of this shorter term horizon is that policies are often time-bound and carried out as initiatives. While sometimes providing necessary stimulation or action over a short time-frame they also run the danger of only temporarily alleviating the issue. When the funding or interest is

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<sup>271</sup> Rennings, K., (2000) Redefining innovation – eco-innovation research and the contribution from ecological economics

<sup>272</sup> See Rennings (2000) and Nills & Kemp (2009) for further information on these

<sup>273</sup> Bleischwitz, R., (2004) Governance of sustainable development: co-evolution of corporate and political strategies. International Journal of Sustainable Development, Vol. 7, No.1

ended the cause of the problem returns with the policy having had little structural impact upon it. The time and resources used in the meantime potentially putting back the time when a long-term policy measure can be implemented. A particular risk of this is that a poorly implemented short-term initiative may taint the overall concept, although the concept itself may be highly relevant and appropriate to the situation. This will then make further attempts to use the concept more difficult.

There are various steps at which a policy concept can also experience delays, and also where the idea can be adapted or modified so that it doesn't necessarily meet the original objectives. The time taken for a policy to flow through the system imposes a lag on the process. This can also be the case in turning a strategy into implementation actions, with commitments and goals known in advance but then only slow response in terms of implementation. The evidence suggests that this could be the case with the EU 20-20-20 climate package goals for 20% of energy from renewable sources targeted by 2020. Although announced in 2009, member states have required time to formulate their approaches and plan for how to meet these goals in their National Renewable Energy Action Plans (NREAPs), submitted in 2010. Mobilising support for measures at national level takes time and progress towards the goals appears to be lagging behind target. Yet when measures are put in place it is expected that progress will accelerate, in the meantime a lag is evident. This is unavoidable in modern bureaucratic systems, with the need to follow administrative and legal procedures, with similar findings on delays made in section 5.9.1 in relation to planning approval and wind energy. Policy lags can also be exacerbated by the fact that in many countries innovation policy and environmental (including resource efficiency) policy are both considered and handled separately between industrial and environmental departments, with varying, but generally low levels of integration between the two<sup>274</sup>.

At the same time, it has also been acknowledged<sup>275</sup> that policy can be ahead of other fields such as academia. When it takes a more visionary and long-term approach, unrestricted by the technical or other barriers that are faced, policy strategies and goals can provide an evolutionary framework that influences behaviour and adoption decisions. This can help to avoid lags and is particularly relevant to firms investment decisions, giving greater certainty to what the over-arching destination is meant to be and how it is hoped to get there.

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<sup>274</sup> OECD – Eco-innovation in Industry: enabling green growth - Forthcoming

<sup>275</sup> Nill & Kemp (2009)

## 7 Conclusions

This study sets out to explore when and why economies are slow in their take-up of beneficial innovations. It has drawn on existing evidence as to where lags can be discerned and the reasons typically given for this.

The focus of the work has been on the take-up of innovations, that is the act of adoption and consumption. This proves to be a relatively novel approach, despite on first sight to be a matter of common sense. One of the most significant findings is the lack of exploration of this matter. There is a limited literature which deals with lags in innovation take-up explicitly, and data sources are equally sparse. As Chapter 2 illustrates, attempts to measure innovation are dominated by indicators relating to the production of new goods and services, with considerations of consumption and take-up much more limited. Some useful approaches are beginning to emerge however, which do seem to suggest that there are differences in the readiness of European consumers to embrace innovative products and services, both between EU economies and in comparison with non-EU economies.

From the prevailing measures, it would appear that there is something of an assumption that if a 'beneficial' innovation should be available, then it will be automatically taken up. An assumption that our review of the literature suggests, is dangerously misplaced. Yet, this fallacy continues. The recent Communication on a Resource Efficient Europe<sup>276</sup>, seems to maintain the belief that simply through the provision of better information, consumers will take-up resource efficient goods and services (p.7) and that empowering consumers will lead to more resource-efficient consumption patterns. A reading of the literature suggests that this may not be the case unless other factors are also present.

The available evidence from literature and cases, suggests that lags do exist in the take-up and adoption of innovations. These are visible at two levels. Firstly, between countries, or economies, over time and, secondly, between the availability of an innovation and its widespread adoption. Both types of lags were clearly present in the data set out in Chapter 3. However, it is also clear from the evidence that these lags do not conform to consistent patterns. It is not necessarily the case that some economies are consistently slower to adopt innovations than others. Even in associated technology fields patterns of adoption and take-up between economies can vary quite strongly. Swift adoption of one innovation may occur at the same time as another is being taken up relatively slowly.

A simple analysis of the data quickly dispels the notion that lags in the take-up of innovations is due to wealth and income effects. This can undoubtedly play a role, particularly at an early stage in the introduction of an innovative good or service when prices may be high, as the literature indicates for mobile phones, but is rarely the defining reason. Our analysis of the literature suggests that the reasons behind lags in take-up are complex, variable and often inter-related.

Analysis of the theoretical understanding of why lags in the take-up of innovations occur suggests seven broad reasons, which each include a number of subsidiary themes. This is reinforced by an

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<sup>276</sup> European Commission (2011) A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy  
COM(2011) 21 final Brussels, 26.1.2011

examination of the take-up of particular cases of innovation, with some additional reasons also suggested from this work.

The role of existing infrastructure and practices in influencing future choices has emerged as a major factor in why some economies lag behind in the adoption and take-up of particular innovations. The evidence of this is all around us in the case of our physical infrastructures, the past investment decisions by firms – their sunk costs – and embedded institutions and routines of decision-making.

Our expectations of the future also influence what we choose to do now. On the whole, we are naturally risk averse and we value ownership of a good now more highly than our ability to pay for it in the future. Whether such cultural markers vary significantly between economies within Europe is not clear from the literature, but there is some evidence that cross-cultural differences do exist when comparing the European economy as a whole to other economies.

We have also been found to be selfish in our consumption patterns rather than altruistic. Lags in the take-up of innovations seem to occur when we, as consumers or producers, fail to see a benefit to ourselves. To be taken-up an innovation needs to display benefits over other products, being better, cheaper, or more exciting, for example, it needs to be both be this and have a story to convince potential buyers. That benefits might accrue to others, who we do not know, does not appear to be a powerful influence on our consumption choices, except where conscious efforts are made to influence our behaviour – such as in the case of the Fairtrade movement as one example.

Significantly, our consumption habits and choices are shaped by those around us. There is now extensive evidence that the take-up of innovative goods and services is dependent upon the extent to which our peers, neighbours, families and friends take-up these goods and services. Lags in take-up occur, where this process is slow to occur for any reason. The stress placed on Quarterly Financial Reporting by the investment community is increasingly held up as one example of how decisions are influenced by the expectations of others.

The spread of knowledge and awareness can also shape decisions, both in terms of consumers being aware of the availability of a particular innovation, but also in terms of the information cascade referred to in the previous paragraph. Knowledge is not ubiquitous and this lack of awareness can impede the take-up of particular innovations. The means by which knowledge and awareness spreads can also influence patterns of take-up and lead to lags in some economies compared to others. There is also good evidence as to how marketing agencies seek to influence these patterns, and our perceptions, of the take-up and ‘acceptability’ of particular goods and services in order to increase the speed of take-up and sales. The role of entrepreneurship in ensuring knowledge diffusion, by matching technical and business/marketing skills to get positive initial feedback, is also important.

Consumers have also proven to be very conservative, only adopting new products once they are assured that they are at least as good as the alternatives available. Poor initial performance can also bias consumption decisions for a long period. This notion of technical ‘readiness’ has proven important across several diverse sectors. As consumers tend to act within discrete markets, their decisions can be based on local perceptions of the ‘readiness’ of particular alternative options.

Available skills, education and educational systems have all been found to play a role in the speed with which particular innovations are adopted. This can be due to inertia in the skills set, the use of some educational systems to promote familiarity with particular technologies or the fact that levels

of education appear to have a bearing on the willingness of consumers to take-up new goods and services.

Both market and organisational structures have emerged as powerful reasons for lags in the take-up of innovations. Organisational structures can both encourage and inhibit the take-up of innovations, and organizational cultures also act in similar ways – we provided examples from both Japan and Finland but they can be found everywhere. Overall, open competitive markets appear to be more conducive to the take-up of innovations. Where competition is limited delays in the introduction of innovations, such as in the case of vehicle technologies, can occur, or can account for lags in take-up between economies – such as has been found in broadband technologies. However, the picture is complicated where there are significant costs related to the introduction, and so take-up, of particular innovations.

There are challenges here for policy makers, but also opportunities. Some of the reasons identified are extremely hard to influence, particularly in the short-term. However, recognizing their influence is the first stage in developing smarter policy approaches, policy approaches which work with prevailing trends rather than against, whilst trying to break out of the constraints of past investment decisions and the shackles of future expectations.

The review of the literature demonstrates that the choices of policy makers – whether they are deliberate or not - can hinder as well as assist the take-up of innovations. Regulations, standards and incentives have all acted to speed up the take-up of some innovations and slow down others. Policy should be targeted where possible at reducing the double externalities of resource efficiency improvements, supporting new products and ensuring that externalities of inefficient products are increasingly internalised. In summary, where policy making is slow to recognize new opportunities, or conflicts in objectives, so lags in innovation can occur.

#### *Some final thoughts on lags and resource efficiency*

The principle is whether lags affect the take up of resource efficiency innovations more than other innovations. Also should we perhaps differentiate between lags in the take-up of particular innovations in general and lags in the take-up of those innovations in one country compared to another.

1. Raising awareness is not enough. Even with strong levels of awareness behaviour, it may not change. Regulation seems to be an important driver for eco-innovation!
2. One approach will not fit all cases. It is not the case that some countries/economies lag behind others consistently. Policies need to be smarter than this and consider how the various parts of the system apply in each area. Core principles to encourage are economic flexibility and adaptability.
3. Infrastructure constraints are real and make some lags unavoidable. This means that alternative solutions to common goals are needed. There is strength in diversity.
4. Market structures, skills and education are important but are longer terms issues. Actions here are unlikely to have an impact on Europe 2020 goals – but our understanding of their effect might (back to smarter policies).
5. Developing a stronger understanding of consumers' willingness to adopt innovative goods and services is valuable and deserves more attention – particularly in fields of resource efficiency (again aggregate measures are likely to be too coarse).

6. Generating consumption momentum seems to be the key. Consumers react to the behaviour of others (their friends, family and neighbours). Techniques for generating such snowball effects may be underutilised (including the ways messages are framed).

7. Opportunities should be taken to build consumer momentum – through preparing, creating and utilising windows of opportunity for beneficial and resource efficient innovations. This needs to include ensuring consumer certainty as to future value/returns/benefits, the reliability and utility of the products on offer (compared to alternatives).

8. Short-term thinking and risk aversion is unlikely to change - but a better understanding of this may assist in the design of more effective policies. In the case of businesses is there scope for changing accounting standards/practices? For policy an increasing focus on material flow innovation?

9. If producers are to take up new innovations then they need knowledge (awareness and capability), capacity, access to finance and confidence in the future savings/return. Evidence suggests that when all this is in place many do react, but when any single element is missing then lags in take up occur.

10. Be realistic about the time taken for change – some lags are in-built and the policy process itself has lags – but use the experience of swift adopters to generate momentum for change in economies which are lagging.

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