SECTORAL INNOVATION WATCH
SYNTHESIS REPORT

What is the right strategy for more innovation in Europe? Drivers and challenges for innovation performance at the sector level.

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Europe INNOVA is an initiative for innovation professionals supported by the European Commission under the sixth framework programme. The fundamental objectives of this initiative fall in line with the policy direction set out within the FP6 priority of ‘structuring the European research area’. In acting as the focal point for innovation networking in Europe, Europe INNOVA aspires to inform, assist, mobilise and network the key stakeholders in the field of entrepreneurial innovation, including company managers, policymakers, cluster managers, investors and relevant associations. Additional information on Europe INNOVA is available on the Internet (www.europa-innova.org).

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<td>Community Innovation Survey</td>
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<td>EIS</td>
<td>European Innovation Scoreboard</td>
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<td>GDP</td>
<td>Gross national product</td>
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<td>ICT</td>
<td>Information and communication technologies</td>
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<td>HRST</td>
<td>Human resources for science and technology</td>
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<td>LMI</td>
<td>Lead Market Initiative</td>
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<td>MNC</td>
<td>Multinational Corporation</td>
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<td>NIS</td>
<td>National Innovation System</td>
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<td>OECD</td>
<td>Organisation for Economic Cooperation and Development</td>
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<td>RCA</td>
<td>Revealed comparative advantage</td>
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<td>R&amp;D</td>
<td>Research and development</td>
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<td>S&amp;E</td>
<td>Science and Engineering</td>
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<td>SIS</td>
<td>Sectoral Innovation System</td>
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<td>SIW</td>
<td>Sectoral Innovation Watch project</td>
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<td>SME</td>
<td>Small and medium enterprise</td>
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<td>SYSTEMATIC</td>
<td>Acronym of the consortium involved in the SIW project from</td>
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<td></td>
<td>November 2005 to May 2008</td>
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<td>TFP</td>
<td>Total factor productivity (in OECD publications often called multi factor productivity MFP)</td>
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Innovation Watch - SYSTEMATIC

Detailed insights into sectoral innovation performance are essential for the development of effective innovation policy at regional, national and European levels. The Sectoral Innovation Watch project researches the factors and institutions impacting innovation performance and analyses the framework conditions for 8 selected sectors and 3 horizontal topics: Biotechnology, Food/Drink, Machinery/Equipment, Textiles, Chemicals, ICT/Electrical/Optical, Space and Aeronautics, Automotive, Eco-innovation and gazelles (fast growing SMEs). The aim of Sectoral Innovation Watch is to provide policy-makers and stakeholders with a comprehensive, holistic understanding of both sectoral innovation performance and challenges across the EU25.

Sectoral Innovation Watch SYSTEMATIC has produced a number of outputs throughout its period of activity from November 2005 till May 2008. This report summarises the main findings of the project. It is complemented by in-depth reports for each sector, delivering policy mapping and analysis on innovation performance, leading innovators, innovation challenges, national sectoral profiles, barriers and drivers of innovation and the innovation environment; a number of reports covering cross cutting topics will complete the palette of deliverables for this initiative. The finalized work package reports and background papers are published on the Europe Innova website (www.europe-innova.org).

Innovation Watch – SYSTEMATIC – was a joint activity of LABEIN, Logotech, NIFU-STEP, SPRU, Technopolis, UNU-MERIT, WIFO and ZEW coordinated since fall 2007 by Michael Böheim, Andreas Reinstaller and Kristin Smeral (WIFO). Between November 2005 and November 2007 the project was coordinated by Hannes Leo and Kristin Smeral, WIFO.

For further information and feedback on the project contact Andreas Reinstaller, andreas.reinstaller@wifo.ac.at.
Executive summary

The aim of the Sectoral Innovation Watch (SIW) SYSTEMATIC project was to analyse the factors and institutions impacting innovation performance, and the structural background of innovation potential in the nine SYSTEMATIC selected sectors of food/drink, machinery/equipment, textile, chemicals, ICT, space and aeronautics, automotive — and in three horizontal topics: biotechnology, eco-innovation, and “gazelles” (fast growing SME’s). Special reports have been generated for each of these sectors. The main focus of the report is identifying drivers and barriers in innovation that are relevant across sectors.

Using sector data, firm level data as well as case studies on enterprises that are innovation leaders, this project has produced evidence on how sectors differ in their innovation behaviour and on how the industrial structure of an economy affects its innovation performance. It delivers insights into why innovation performance differs across sectors, and identifies challenges. Finally, the project has also investigated how Sectoral Innovation Systems and National Innovation Systems influence each other. The findings should help to develop a differentiated perspective and inform discussions on the strategy outlined in the Lisbon agenda that assigns high priority to innovation and structural change in high-tech industries.

Why the sector perspective is important

The focus of innovation policy across countries and also at the EU level is on promoting research, education, and business start-ups in order to foster national competitiveness. These are mainly horizontal measures addressing a number of industries and do not focus on any particular industry. A considerable part of these measures also target R&D activities. However, firms pursue different strategies to acquire knowledge that is necessary to develop new or improved products and processes. A descriptive evaluation of firm level data has shown that industries differ considerably in their modes of innovation. In some industries firms that produce technology, i.e. firms that carry out R&D either continuously or intermittently, are more prevalent. This is, for instance, true for the ICT sector, the automotive industry or the chemical industry. The total share of innovators in these industries is also above average, as is their economic performance. Technology users, i.e. firms that use, adapt and modify existing technologies, in turn, are in sectors such as food, textiles or the energy industry. These firms are more likely to look beyond technological opportunities, and the total number of innovators among them is low.

The share of innovators in the population of surveyed firms as well as the distribution of technology producers and technology users also varies greatly across countries. The data suggest that this depends on the sector structure of a country but they also suggest that this depends on its state of economic development. Countries that have an industrial structure that is biased towards technology intensive sectors, such as Sweden or Finland, have a higher share of technology producers in their total population of innovating firms, whereas countries where the industrial structure is biased towards medium or low technology intensity sectors the share of (innovative) technology users is high. Examples are France or Austria. The number of innovators in the population and the relative frequency of technology users and producers also varies considerably across countries depending on the stage of economic development of each country. The data show that firms in economically less advanced member states are less likely to be innovators than firms in countries with more developed economies such as Germany or Sweden, and if they are innovators they are more
likely to be technology users. This is an unambiguous outcome of many studies carried out in the SIW project using a number of different approaches and data sources.

As technology users are also predominantly non-R&D innovators, this evidence suggests that countries with a high share of technology users will find it more difficult to increase the aggregate share of R&D expenditures of their economies. This puts the 3% Barcelona target of the Lisbon agenda into perspective. Those countries that were far below the Lisbon target in the year 2000 also projected the largest increases in R&D spending in their National Reform Plans. However, most of these countries are either countries catching up or countries with an industrial structure where industries with a low or medium emphasis on technology dominate. Realistic targets need to take into account the industrial structure of each country. A policy is likely to fail if it sets targets that are too high for an industrial structure where sectors with low R&D intensity predominate or, conversely, it will turn out to be ineffective if targets are set too low in an industrial structure that has a large share of firms that are technology producers. This report argues that it is important to understand the factors underlying the great variation in innovation behaviours across sectors but also across countries. The sector perspective essential to understanding the different opportunities and challenges EU member states face in their efforts to improve their innovation potential.

Drivers of innovation

The SIW project has analysed a large number of factors that affect and drive innovation in each of the chosen sectors and across sectors. The studies carried out in this project have focused on the role of financial constraints, human resources and skills, knowledge creation and diffusion, cooperation between firms and informal networks, demand factors, competition, innovation culture, and aspects of regulation and taxes in the innovation process in each of the evaluated industries. Furthermore, the research in the SIW project has identified the central determinants of the performance of fast growing firms that are sometimes referred to as “gazelles”. It has also proposed a new classification of industries that is based on the characteristics of entrepreneurship and a broad concept of innovation that transcends the conventional R&D-based classifications. Finally, the project has produced evidence on how innovation performance can best be measured in each of the sectors under investigation in this project. This executive summary will focus on the most important driving factors of innovation.

Knowledge creation and knowledge acquisition

Firms innovate in a variety of ways. They may engage in intensive in-house research activities aiming at the creation of new products or processes, or they may rely more heavily on external knowledge and imitative research projects. Firms can acquire external knowledge through formal collaborations with other firms or university research labs, informal knowledge transfer, or embodied technology transfer through the acquisition of machinery and equipment. Each of these activities may still require some R&D investments. However, in this case the aim is not to create new knowledge but to enable firms to absorb external knowledge and technologies. These aspects have been explored systematically in the SIW project.

The results show that in many sectors non-R&D related activities are important drivers for innovation. Knowledge acquisition from external sources is of particular importance in sectors with large shares of technology users, whereas R&D activities are important in sectors where firms that are technology producers prevail. Technology users are found in all firm size classes, countries and industries. If compared to R&D performing firms, or technology producers, they
are on average smaller, and are predominantly active in sectors with low technological intensity (such as a large part of the service industries, or traditional industrial sectors such as textiles) and are also more likely to focus on process innovations. Technology users may be highly innovative in terms of the turnover they generate through the introduction of new products. In this case innovation is driven by the acquisition of external knowledge. Formal cooperation agreements, licenses, commissioned research, or informal exchanges with suppliers or competitors, act as (weak) substitutes for in-house R&D. In addition, innovation expenditures related to personnel training and activities related to market introduction of innovation are all crucial factors for the firm’s innovative success. Yet, the results also show that across all types of firms, R&D investment remains the most important factor for innovation success.

Market and technological opportunities also differ systematically depending on the state of economic development of the country in which firms are located. For firms based in countries that are at a distance from the world technological frontier, technology transfer and non-R&D related innovation activities are extremely important to promote innovation. This is true for technology intensive sectors as well as for sectors with less technological intensity. On the other hand, for firms located in countries on or close to the technological frontier, intensive innovation activity is a driver of competitiveness. In order to maintain a competitive edge firms need to invest in R&D, acquire and adapt new technologies, and develop other capabilities that ensure continuing innovation. Under these circumstances competition becomes a crucial driver for innovation. Indeed, one of the results of the project has shown that if leaders in technology production compete with less-advanced producers, they tend to reduce their R&D investment and rely more on third party technologies. On the other hand, if these firms engage in competition with peer firms, they are motivated to increase their own R&D efforts. This is compatible with findings reported later on the relationship between R&D investment and the intensity of competition.

Characteristics of a National Innovation System other than the level of economic development influence innovation performance, i.e. there is a significant correlation of national policies and sectoral innovation performance. The SIW project has studied the impact on sectoral R&D investment of R&D subsidies, government R&D expenditures, IPR protection, monetary stability, freedom of trade, regulations on credit, labour and business, the percentage of domestic credit that goes to the private sector, and foreign direct investment as percentage of GDP. The results show that the impact and the magnitude of these factors varies greatly across industries and countries. In fact, most variables can have either a positive or a negative influence depending on the sector. For the energy sector, the ICT industries and the aerospace industry public R&D subsidies have a positive effect, whereas R&D spending by the government seems to crowd out R&D investment in the textile, chemical and ICT industries. The variables involving free market access seem to have a positive effect in the energy and food sectors, while they have a detrimental effect on ICT and aerospace companies. Hence there is a broad spectrum of specific national sector responses to national policies that have an effect on innovation performance. These results suggest adjusting the national and regional innovation policy mix to accommodate factors specific to sectors.

The evidence presented so far has shown that a number of non-R&D related factors play a crucial role in the innovation process. However, traditional sector classifications, as they are used for instance by the OECD, use R&D intensity as the principal ranking criterion. This is all the more remarkable given that the Oslo Manual presents a much broader definition of innovation. Based on this wider view the SIW project has proposed a new innovation taxonomy. Derived from the CIS-3 micro data it organises firms according to different types of entrepreneurship
and the characteristics of the technological and learning environment within which they operate. As a result the classification of many industries changes, as is shown in the table below.

The most striking change in classification affects the textile industry. Under R&D based classifications it typically ranks as a low-tech sector because the R&D intensity in this industry is low. However, in the SYSTEMATIC taxonomy it is a medium-high tech industry. One reason for this is that the taxonomy takes into account that textile firms invest frequently in process innovations. Statistical analysis confirms that there is a positive association between a higher rank in the new classification and the added growth of value as well as total factor productivity growth. This is important as it is the basis for a better understanding of the relationship between economic performance and innovation. It shows that innovation does not depend on R&D alone, but is influenced by a larger number of factors such as entrepreneurship or the knowledge base of an industry and the related technological opportunities. Applying these insights should help develop better-targeted innovation support measures.

**Human capital**

Recent research has emphasized that the level and composition of skills (or human capital/ resources) in an economy also has an important bearing on differences in levels and growth of productivity across OECD countries. A study carried out in the SIW project shows that engineering and science skills contribute directly to international competitiveness and productivity since a better-educated workforce not only augments the efficiency of labour, but also raises the capacity of firms to more easily integrate new technologies and ideas. The ability of a country to adopt state-of-the art innovations is an important source of economic growth. In other words, the returns to higher education will be higher for countries farther away from the technological frontier due to the greater importance of technology transfer and absorptive capacities. The better the skills of the workforce of a country not on the technological frontier, the better are its capabilities to imitate technologies developed elsewhere. On the other hand, in countries that are on or close to the technological frontier accumulated knowledge and experience are a precondition for sustained innovation performance and growth. For economically more advanced countries this evidence makes a strong case for life-long learning. But these results also indicate that advancing closer to the technological frontier implies a gradual building up of capabilities. Consequently convergence in innovation performance across EU member states will be slow and gradual.

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<td>Low tech (Medium-low tech*)</td>
<td>Medium-high tech</td>
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Concerning the make-up of skills, the results show that it is the complementary and the balanced mix of skilled labour that is important, not just high-end formal skills. Therefore, vocational training seems to be as important as good institutions of higher learning. The distinction between pure educational skills defined by educational attainment and occupational skills defined by accumulated experience in the workforce is therefore important. The latter consistently turns out to be more important than the former. However, different sectors have different needs with respect to skills and education. The effect of human assets on innovation and productivity is positive in all investigated sectors, but the magnitude of the effect varies. The overall findings, however, show that sectors employing a large share of high or medium skilled workers manifest higher productivity growth while a high share of low skilled workers in a sector effects a negative influence on productivity growth. Furthermore, skills are important for the speed of approaching the technology frontier.

Financial resources

Limitations are unavoidable in financing innovation and force allocating scarce resources to those projects that promise the highest returns. Financing-related policy measures serve as a way to compensate for the reluctance of firms to invest enough resources to maximise social returns. The expected reward has to outweigh the risk in order for an innovation investment to be made. If the expected reward falls below a threshold set by the management, or if an innovation project has to compete with an alternative, two factors will contribute to underinvestment: (i) many innovation projects suffer from an unfavourable ratio between earnings and costs due to low appropriability of innovation returns; (ii) banks are reluctant to finance firms’ innovative activities, resulting in a low supply of loans for innovation financing because of the asymmetric risk distribution between the lender and the borrower. Furthermore in many innovation projects the investment is mostly in intangible assets that cannot be used as collateral. Hence, the more a firm engages in the creation of new knowledge instead of adopting new technologies embodied in new capital goods, the higher is the associated risk and the more difficult it is to find external funding.

Firms in sectors with a high number of R&D performing firms but with a relatively low investment ratio in tangible assets will have greater difficulty to obtain credit for their innovation expenditures as they offer less collateral than firms in sectors with a higher investment ratio. This is the case for research-intense industries where tangible assets play a subordinate role in the production process. For instance, firms in the biotech sector have a much higher risk exposure than firms in the energy sector. Similarly, by analysing the relationship between R&D investment and the operating surplus gives an indication of how well firms can finance their innovation expenditures through equity funding. The higher the operating surplus the better firms should be able to finance their innovation expenditures out of the cash flow. The results from the SIW project show that the financing of innovation projects constitutes a particular challenge for small and medium-sized enterprises, but especially for fast growing firms. Moreover, highly innovative companies and industries with high R&D-intensity levels have more problems than industries that have a low R&D intensity. Economic risk and lack of capital hit cutting-edge technology firms the hardest. Financial support should therefore be targeted at these groups of companies.

Competition

Competition is based on the interplay between the creation of novelty and imitation, i.e. between exploration and exploitation of opportunity. Entrepreneurship and competition strategies relate to profit in general and hence reflect patterns of technology, customer tastes and the nature of price competition in the market. For
instance, technologically advanced firms that compete mostly with less advanced firms, have an incentive to reduce their risky R&D investments, as they are easily able to keep a competitive advantage over their rivals without incurring the cost of R&D investments. On the other hand, if they compete with firms with similar technological capabilities, they have an incentive to invest more in R&D, as this is a means to explore new opportunities and market niches and therefore set themselves apart from their competitors in such a way that customers are willing to pay a higher price. The prospect for creative entrepreneurs to gain higher profits acts therefore as an important incentive to invest into R&D and other innovation activities. However, if these profits dissipate too quickly because of easy access of imitators to the market, incentives to engage in risky research are dampened.

The SIW project has studied the relationship between competition and R&D investment across sectors and within each of the sectors evaluated in this project. The results show that there is an inverted U-shape relationship between competition and R&D across countries and sectors. This means that firms have little incentive to invest in R&D if they are not stimulated by competition, whereby too much competition discourages investments into R&D activities, as the likelihood of diminishing returns on their efforts increases. However, the effect of competition on innovation declines when a country lags behind other more advanced countries. This means that in less advanced countries more competition could actually harm R&D spending. This implies that more competition might not initially be good for less advanced countries. However, as they pass productivity thresholds competition would become a more important factor in stimulating innovation. This means that in less advanced countries competition policy should not be too rigid, and temporarily allow less competition among fewer companies.

Drivers of fast growing firms

Firm growth is affected by a large number of factors, such as technology, the micro- and macroeconomic environment including regulation, institutional factors at regional or sectoral level, and – most prominently – firm-specific determinants. Contrary to common belief the analysis carried out in the SIW project of fast growing firms, or gazelles, shows that they are not limited to industries with a high technological intensity such as the ICT or the biotech sector, but that fast growing firms are present in all industries albeit more prevalent in high-tech industries. There are also systematic differences across sectors and regions. Indeed, a gazelle count reveals a significantly higher number of gazelles in the new member states of the European Union than in other EU countries. The results also provide a clear indication that there is a statistically significant difference amongst the country groups with regard to innovation. Statistical analyses show that in the more advanced economies of the European Union (continental and northern countries) fast growing firms are mostly of the creative entrepreneurship type and they also have a significantly larger share of turnover from product innovations. For gazelles in the southern European countries and the new member states innovation is much less important. In these countries the growth potential of fast growing SME’s rests mostly in the exploitation of comparative advantages due to lower costs. This result clearly confirms that gazelles are different across country groups. Innovation is more important for fast growing SME’s in countries near the technological frontier.

Challenges

The three top challenges facing all industries studied in the SIW project face are related to human capital, the support of knowledge creation, diffusion and technology transfer, and financial constraints. Other aspects like regulation,
innovation culture, competition or demand factors play a significant role in some sectors: however, the analysis also reveals that these issues are very sector specific and hence not of equal importance to all industries. The challenge represented by the lack of well-qualified human capital affects almost all sectors and is likely to turn into a major constraint for the innovation capabilities and as a consequence the competitiveness as well as the long-term growth potential of the EU member states.

Knowledge creation and knowledge transfer

EU policy initiatives as well as market mechanisms have not been able to encourage enough R&D activity to reach the higher levels of R&D-expenditures across the EU as envisaged by the Lisbon agenda. The market failure associated with insufficient production of knowledge has not been overcome. EU manufacturing largely remains specialized in medium-tech sectors and has not taken advantage of the fast growth of certain high-tech sectors. A much smaller share of corporate R&D investment in the EU is carried out by firms in high-tech sectors as is the case in the US. Furthermore, R&D productivity continues to be lower in Europe than in the US or Japan, even though results from the SIW project show that a gradual convergence in R&D productivity is taking place and technology gaps are decreasing. Here the lack of a highly qualified work force may negatively affect this process in the near future. There is the danger that firms will increasingly relocate their research activities to countries where conditions concerning human resources and scientific infrastructure are better.

The challenge of increasing R&D and the technological intensity of EU industries is important: results from the SIW project show that across sectors firms foresee technological capacities, strategic planning, specialist knowledge and skills, management capacities/leadership, customer involvement in R&D and innovation activities, as well as different types of partnerships as key drivers of innovation in the future. In order to meet these needs innovation investments have to be accelerated. Fostering R&D spending but also supporting knowledge and technology transfer therefore remain a top priority. However, the results from this project reveal that a differentiated strategy is needed across EU member states. As this report has shown, there are considerable differences across sectors that have to be taken into account when developing innovation policies. For some countries that are lagging behind or are beginning to make headway, technology transfer remains an extremely important means of innovation and technological development. R&D activities in these countries also fulfil the aim to increase absorptive capacities needed to adopt and adapt new technologies more effectively. The policy priorities in these countries must therefore lie in strengthening absorptive capacities and the acquisition of technology. For countries that are approaching or already on the technological frontier the main thrust should be to foster growth and competitiveness instead of R&D. Here the focus of innovation policies should lie on fostering creative research and knowledge production as well as entrepreneurial activities to transform the discoveries resulting from the research phase into innovations.

Human resources

The main drivers of innovation identified in this project require highly skilled technical and non-technical personnel. Evidence collected in the SIW project suggests that there is a present and projected future undersupply of a well-trained work force. The problem is quantity as much as it is quality. There are clear differences in the problems different sectors face. For technology intensive sectors the problem is that they are not able to hire enough top level science and engineering graduates or attract the best-qualified engineers, scientists and specialists from abroad to their industry. Sectors with low technology intensity instead have to cope with different, but two closely related problems: even though
the overall demand for highly skilled employees is comparatively low in these industries, they still loose highly skilled employees to technology intensive industries, and they are a-priori also not so attractive for potential employees. These problems are particularly severe for new and fast growing firms that cannot rely on a long-standing reputation to attract people with top level qualifications and skills.

The human resource problem is significant as a barrier for growth, but also as a factor to attract and keep knowledge intensive businesses in Europe, because if companies cannot find enough people with the right skills in Europe, they will look elsewhere to invest. The problem has even wider implications, however. The advent of strong competition from emerging economies, and the quickly growing competencies of firms in these countries require achieving greater competitiveness here through product innovation and increased productivity. This goal can only be met through more research and a well-qualified workforce. If this is not possible firms will have to either relocate or engage in less expensive innovation.

**Financial constraints**

The decision to invest in innovation depends on the initial incentive to allocate resources for innovation, the capacity to dispose of all non-financial resources needed to carry out the innovation activity (such as human resources) and the capacity to raise the necessary financial means to realise the project. If returns on R&D investment dissipate too quickly due to imitation, lowered expectations of inventions may distort incentives to invest. As a consequence, capital markets may not provide enough financial means to carry out innovation projects because of questionable information on their possible futures.

Especially for firms carrying out high-risk research, for young and small start-up firms and for firms facing extraordinary growth opportunities the lack of financial resources constitutes a serious problem due to the murkiness of the associated market potential or the lack of tangible assets that may be used as collateral for loans. Results from the SIW project show that the lack of venture capital, especially for the seed financing stage is therefore a major problem for many small ICT and biotech firms as well as for fast growing SME’s. These firms in most cases have to rely on personal funds of the founders in the seed-financing stage. New financial instruments tailored to the needs of emerging firms remain underdeveloped in most EU countries.

For established firms and firms in more mature industries the finance-related under-investment in innovation activities is normally no longer hampered by the lack of financial resources but by the limited expected profitability of innovation projects in relation to the costs of R&D and other innovation expenditures. Instruments other than risk capital are therefore necessary to stimulate more innovation. The rationale for policy intervention here is to compensate for social returns being higher than private returns. Many EU member states apply tax credit schemes and direct research subsidies as instruments to limit this gap. However, a review of existing policy measures across member states suggests that resources remain very fragmented and are very likely to operate at sub-critical levels and lack transparency and coordination. Furthermore, beyond traditional tax credit schemes and research subsidies, the instrument of public procurement is used only rarely. This could be important especially for the development and diffusion of eco-innovations, but also for life-science innovations.

**Conclusions**

Drawing on the evidence on drivers and challenges of innovation across sectors and countries, the central message of this report is that the European Union needs
a differentiated policy approach to achieve its goal to become the most innovative economic area in the world:

- Firstly, policy makers must take into account that innovation is driven by a large number of factors that are different in each industry. Policies and innovation support initiatives should not focus on R&D activities alone. R&D knowledge creation is not in all cases the most important driver of innovation. Some very innovative industries rely heavily on technology transfer and the use of new technologies developed in upstream industries. Knowledge diffusion, vertical technological cooperation and non-R&D related activities are important drivers of innovation in industries such as the textile sector.

- Secondly, innovation behaviour in industries differs greatly depending on the economy of an individual country. Firms in advanced countries are more likely to rely on R&D based innovation modes, where the role of R&D is to create new technologies and products. Firms in less advanced countries are more likely to rely on technological transfer and non-R&D related modes of innovation than firms in the same sector in technologically advanced countries. Policies to support innovation in specific industries should therefore take into account the state of the individual economy.

- Thirdly, the industrial structure of an economy has a strong effect on its overall innovation capability. A policy is likely to fail if the targets it sets are not appropriate with respect to the sector structure of a country. Innovation policies should therefore take into account the national specialisation profile.

- Finally, future horizontal policy measures, i.e. policy initiatives affecting a larger number of industries in a number of complementary policy areas, should focus on the shortage of skills and financial constraints in order to promote innovation activities and especially the development of new knowledge and ideas. Policy makers should be particularly aware that the three challenges above and the related policy domains are highly interdependent. The problems cannot be tackled in isolation. However, as these challenges vary greatly across countries and industries, a sector perspective in the development of policies to support innovation in Europe may be necessary to achieve the EU's stated goals.
Chapter 1
Introduction

At the European Council in Lisbon in 2000, the Heads of State and Government set themselves the common goal that the European Union should become “the most competitive and dynamic knowledge-based economy in the world, capable of sustained economic growth with more and better jobs and greater social cohesion” (see Commission 2002). The support of innovation is one of the core ingredients of what is now known as the ‘Lisbon Strategy’. However, the implementation of this goal has proven to be difficult because the member states of the European Union differ in their level of economic development, in their industrial specialisation patterns and, as a consequence, also in their need for innovation to drive their current and future well-being. Clearly, a differentiated policy approach is needed to support innovation in Europe. Detailed investigation of sectoral innovation performance is therefore essential for the development of effective policy measures to support innovation and economic growth at the regional, national and European levels. This requires studies of innovation performance and its determinants at the level of individual industries. The aim of the Sectoral Innovation Watch project was to provide policy-makers and stakeholders with essential knowledge of the factors driving sectoral innovation performance and the challenges these sectors face across the EU25. This report presents the main findings and recommendations of the SIW project.

1.1 Background

Many studies and benchmarking exercises have provided evidence that the European economy is not as competitive as the United States and Japan. For instance, OECD data presented in Figure 1 show that most European countries and the EU average is lagging behind the US economy in terms of GDP per capita and in labour productivity by about 30%. Thus economic theory suggests that Europeans are on average less wealthy because they are less productive. An influential study by O’Mahoney and van Ark (2003) has shown that the productivity gap in the European economy is related to the slower diffusion of information and communication technologies in manufacturing, slower productivity growth in services and a weaker integration of knowledge intensive business services and manufacturing. From this perspective the difference in economic performance is caused primarily by the sluggish diffusion of new technologies.

However, other indicators such as the Global Competitiveness Index of the World Economic Forum or the European Innovation Scoreboard suggest that the reasons for the lower economic performance may be related to institutional and structural deficits that negatively affect the competitiveness of the European countries. Many studies substantiate this view. They argue that the European economy has been losing ground to the US because prevailing conditions in most European countries are not favourable to innovation-based growth: there is a lack of competition and entrepreneurship, member states do not invest enough in higher education, credit markets do not provide sufficient funding for growing enterprises, and pro-cyclical fiscal policies widely practiced in Europe are detrimental to growth (Sapir et al 2003, Bartelsman and van Ark 2004, Aghion and Howitt 2005a). The Summary Innovation Indicator of the European Innovation Scoreboard shown in Figure 2 captures many of these aspects. The figure shows that the European Union lags behind the United States and Japan in innovation performance, even though some European countries score higher than the two
Figure 1: Percentage GDP and labour productivity gap per capita compared to US.

Note: Both indicators are expressed in 2006 purchasing power parities (PPPs); EU19 is an aggregate covering countries that are members of both the European Union and the OECD. These are the EU15 countries plus Czech Republic, Hungary, Poland and Slovak Republic. The OECD statistics do not include the remaining six EU member states. Source: OECD 2008, Economic Policy Reforms: Going for Growth, 2008 Edition, p. 16. Adaptations by WIFO.

Figure 2: European Innovation Scoreboard 2007 – Summary Innovation Index.

Note: The Summary Innovation Index is calculated using the most recent statistics from Eurostat and other international data sources. Source: Commission of the European Communities (2008).
benchmark-countries. Much of the observed difference in innovation performance with respect to the US and Japan is explained by a lagging EU performance in indicators for scientific output, such as tertiary education or triadic patents (Commission 2006c, p. 30, Commission 2008). This diagnosis is further backed up by the finding that the US and Japan are attracting more international R&D expenditure than the EU. The USA are also more successful in attracting top researchers and highly skilled staff (Commission 2005, p. 5). Apparently, conditions that nurture the generation of new knowledge and highly innovative industries and play a crucial role in innovation-based growth are more favourable in the US and Japan than in Europe.

This aggregate evidence makes a case for policies to boost European competitiveness through business expenditures on R&D and innovation. However, it is not just the prevailing conditions at the levels of regions, member states or the EU that matter but also the industrial design of European economies. In recent publications the European Commission has suggested that the specialisation of EU manufacturing in medium-tech sectors may act as a potential barrier to sustained competitiveness through innovation. Companies belonging to high R&D intensity sectors perform only 36% of corporate R&D investment in Europe. Compared to the 67% for the US this reflects the weaker position of European companies in these sectors. (Commission 2007b; Commission 2007d).

Another study on driving factors and challenges for the European industry commissioned by the European Commission also confirms these concerns (see Montalvo et al 2007). It argues that the specialization of European manufacturing may put the European economy at a disadvantage in facing future challenges such as rapid technical change or strong competition from emerging economies such as China, Brazil or India. Both factors are likely to put pressure on non-skilled employment causing either wages to fall or unemployment to rise in this segment of the labour market. The authors suggest that the only feasible alternative to such a race to the bottom is to stimulate competitiveness through product innovation and faster productivity growth. However, in their view, economic policy should encourage product innovation in high-tech sectors and in those sectors characterized by higher income and demand elasticity, and less promote cost-cutting through process innovation. Seen from this perspective product innovation driven by R&D spending in high-tech industries is the best path to sustained competitiveness able to guarantee high wages, more and better jobs, and growth.

While one cannot deny that industries investing a relatively large share of turnover in internal R&D are mostly growth industries and that there is more technological opportunity in these sectors, the issue is whether these industries should be the main focus of innovation policy. R&D is vital for many innovation activities of firms and the competitiveness of an industry and a country; however, there seems to be no single industrial structure conducive to growth and the creation of more and better jobs. Growth is dependent on sectors; where some sectors expand others contract, and where output growth in some sectors is driven more by productivity improvements, others depend more heavily on demand developments (see Harberger 1998, Smith 1999, Hözl and Reinsteller 2007). In this process the expanding sectors need not necessarily be high-tech sectors. Indeed, the recent EU report on industrial structure suggests that countries can compensate growth disadvantages resulting from a specific specialisation profile by promoting higher competitiveness in selected sectors (see Commission 2007a, p.55). The Schumpeterian notion that growth is mainly driven by radical innovations and structural change, therefore, may not explain growth in any general sense. Policy makers ought to be aware of the industrial structures from which growth derives in each country and how industries interact with the characteristics of national innovation systems.
From a micro-economic perspective the Community Innovation Survey (CIS) shows that less than half of the European innovators conduct intramural or in-house R&D (Commission 2008, p. 27). The innovation activities of these firms include the purchase of advanced machinery and computer hardware as well as marketing and organisational innovations specifically undertaken to implement new or significantly improved products or processes. It is interesting to note that the share of non-R&D innovators is also very high, indeed considerably higher, in Japanese manufacturing and services than in most European countries (OECD 2007a, p.98). This evidence relativises the common belief that firms should invest more into R&D to become more innovative. Some industries are innovative but do little R&D as their own innovation activities rely on innovations developed in other industries, while others rely heavily on their own research activities. It is an aspect that deserves further discussion and research. If a large part of innovation activities in many industries is not R&D driven, then the failure to differentiate between non-R&D and R&D innovators will reduce the effectiveness of public policies to stimulate innovation. This requires a deeper understanding of innovation at the sector level. These considerations motivated the research in the Sectoral Innovation Watch (SIW) project.

The principal questions underlying the entire SIW project are closely related to the aims of the Lisbon agenda that assigns innovation and structural change towards high-tech industries high priority:

1. “What is the right strategy to stimulate more innovation in Europe from a sector perspective?” or “Is a high-tech strategy the right recipe for European competitiveness?”

2. “Is there a need to stimulate innovation at the sector level through sector specific innovation policy measures?”

These are bold questions that cannot be answered easily. To address them

• we need to understand how innovation takes place in sectors and how the industrial structure of an economy affects innovation performance.

• we need to understand which factors drive innovation in each sector, and

• we need to understand how potential barriers to innovation and other challenges differ across sectors.

The principal aim of the project therefore has been to establish the differing sources and degree of innovation performance across sectors. The project should identify innovation barriers and drivers as well as challenges at the sector level and shed light on how sectoral and National Innovation Systems interact. This report summarises the main findings.

1.2 Outlook on this report

The Sectoral Innovation Watch (SIW) project has analysed the factors and institutions impacting on innovation performance, and the prevailing conditions across eight selected sectors and three horizontal topics: the sectors that have been studied are summarised in Table 1. The Sectoral Innovation Watch project has produced a Sector Report for each of these sectors, where all the findings of the project specific to a sector have been summarised. This synthesis report therefore will not discuss drivers and challenges for innovation for each sector in depth, but highlight only the most relevant aspects found in the analysis. The reader interested in detailed sector specific findings is referred to the Sector Reports (see also the list in the Appendix of this paper on page 152).

1 Concerning the horizontal topics but also to some extent the sectors, there are some data constraints that might limit the analysis. In some cases, the analyses deviate from that definition including data of other sectors (e.g. NACE 35 instead of only NACE 35.2) or excluding some sectors of interest (ICT might include only the manufacturing sectors, but not NACE 72). If those cases deviations are highlighted.

2 The Sector Reports can be downloaded on the Europe-Innova website, http://www.europe-innova.org (Innovation Watch -> Sector Reports).
It is evident from Table 1 that most of the SYSTEMATIC sectors are aggregates of traditional NACE sectors. The table also shows that for most of the horizontal topics no statistical classifications exist. This meant that data were often not available to analyse these sectors statistically. That it was difficult to find relevant official data for the biotechnology and the eco-innovation sector despite their importance indicates that the traditional sector classifications as they are used in official statistics are increasingly obsolete. This is a significant data issue that needs to be addressed by statistical offices.

A problem of the analysis in this report was in many instances data that made it difficult to rely on one single statistical unit. Due to the different data sources the statistical units were not identical in all analyses carried out in this project. Sometimes the units are NACE sectors or aggregates thereof as reported in Table 1. Other times, when micro-data are used the unit of analysis is a firm in a specific country, whereas in some of the case studies presented in this report, the unit is the transnational corporation. That the reader must be aware that at times the perspective changes and that results obtained using different statistical units are not always comparable or complementary. Whenever it is possible such changes in perspective will be clearly stated.

In order to improve the quality of the statistical results and their interpretation the project has also integrated innovation panels composed of sector specialists. These Europe Innova innovation panels discussed preliminary findings of the Sectoral Innovation Watch (SIW) project and helped to formulate the final policy recommendations for each sector. The panellists thereby provided important feedback that has been used to enhance the quality of the results presented here. Most of their suggestions for improvement have been taken into account in this report, particularly in the Sector Reports.

Following the discussion in the previous section this synthesis report is organised as follows. In Chapter 2, we will argue why the sector perspective matters for the analysis of innovation and the development of innovation policies. It will also provide evidence that the national innovation performance is strongly influenced by the industrial structure of a country, and that on the other hand, the innovation performance of industries is also related to the state of economic development of a country.

Table 1: Sectors analysed in the Europe Innova – Innovation Watch SYSTEMATIC project.

<table>
<thead>
<tr>
<th>SYSTEMATIC sector</th>
<th>NACE Code</th>
<th>CIS data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food / Drink</td>
<td>NACE 15+16</td>
<td>Available</td>
</tr>
<tr>
<td>Textile</td>
<td>NACE 17+18</td>
<td>Available</td>
</tr>
<tr>
<td>Energy Production</td>
<td>NACE 10+11+12+23+40</td>
<td>Available</td>
</tr>
<tr>
<td>Chemicals</td>
<td>NACE 24</td>
<td>Available</td>
</tr>
<tr>
<td>Machinery / Equipment</td>
<td>NACE 29</td>
<td>Available</td>
</tr>
<tr>
<td>ICT</td>
<td>NACE 30+31+32+33+72</td>
<td>Available</td>
</tr>
<tr>
<td>Automotive</td>
<td>NACE 34</td>
<td>Available</td>
</tr>
<tr>
<td>Space &amp; Aeronautics</td>
<td>NACE 35.3</td>
<td>not available</td>
</tr>
<tr>
<td>Eco-Innovators</td>
<td>Horizontal topic</td>
<td>of very limited use</td>
</tr>
<tr>
<td>Gazelles</td>
<td>Horizontal topic</td>
<td>of partial use</td>
</tr>
<tr>
<td>Biotechnology</td>
<td>Horizontal topic</td>
<td>not available</td>
</tr>
<tr>
<td>Energy</td>
<td>10-12, 23*</td>
<td>Low tech (Medium-low tech*)</td>
</tr>
</tbody>
</table>

Source: The SYSTEMATIC consortium.

More information about the innovation panels can be found by going to the “Innovation Panels” area of the Europe Innova web portal; http://www.europe-innova.org
Chapter 3 focuses on the main drivers of innovation. It attempts to organise the main findings of the research carried out in the SIW project into four overarching dimensions —factor markets for innovation, research and technology, markets and innovation, and innovation environment — for each of the SYSTEMATIC sectors. In this chapter we also present a new sectoral innovation taxonomy that allows us to classify sectors based on entrepreneurial characteristics and the general innovation intensity of their firms. All these results are condensed in a matrix that summarises the main innovation drivers for each sector. This is in Table 2. The results are discussed along main policy lines while a brief discussion of sector specifics concludes the discussion of each of the four main parameters. Four additional topics are examined in Chapter 3. Two sections present the findings of the SIW project on fast growing SME’s (Gazelles) and on eco-innovation. The concluding section discusses how best to measure sectoral innovation performance given that sectors strongly differ in their innovation behaviour.

Chapter 4 presents the main challenges for innovation. The results are again condensed in a matrix shown in Table 21. We call this matrix the “policy priorities matrix”. We then discuss three main horizontal challenges identified by the project and expound upon the key challenges for each sector.

Chapter 5 summarises the main findings and uses the findings of this project to discuss the principal questions of the project outlined in this chapter.
Chapter 2
Why the sector perspective matters to the analysis of innovation

2.1 How sectors differ and why it matters

The main focus of innovation policy across countries and also at the EU level is on promoting research, education, and business start-ups in order to foster national competitiveness. The large majority of these are horizontal measures addressing a number of industries or all industries and do not address any particular industry. Furthermore, a considerable part of these measures target R&D activities. However, firms pursue different strategies to acquire knowledge that is necessary to develop new or improved products and processes. This can happen either through intensive in-house research activities that aim at the creation of new knowledge or through the absorption of external knowledge which may happen through the purchase and adaptation of new technologies and new equipment, or through formal cooperation or informal interaction with partners who have knowledge that may be useful for innovative efforts. There is a great variation of behaviours and innovation strategies among individual firms within specific industries and we also find systematic and significant differences in innovation behaviour across industries. It is not surprising that horizontal policy measures vary in their impact on industries; some are rather effective and others have no significant effect.

There are major differences in the rate of technical change and the organisation of innovation activities across industries. In some industries technical change is happening at a fast pace, whereas in others it is slow and gradual, and in some industries innovation is carried out by a small number of actors whereas in others it is distributed across a wider population of firms (see Malerba 2007). This suggests however, that despite the high variation of innovation activities at the firm level, each sector shows specific patterns of behaviour despite this variation on the firm level reflecting differences in technological opportunity, appropriability and cumulativeness of knowledge. Differences in innovation activities of firms in specific industries are therefore not completely random. They show some commonalities giving rise to sectoral innovation modes. Given that patterns of technical change, innovation and economic performance are sector specific and very diverse across sectors some authors (e.g. Robson et al 1988, Breschi and Malerba in Edquist 1997, Malerba 2002, 2004) have called for a sectoral system of innovation approach in order to develop better-targeted innovation policies.

Sectoral patterns of innovation, however, are not independent of the national or supra-national situation. Hinloopen (2003), for instance, finds that the innovation environment of a country significantly affects the efficiency with which innovation efforts are transformed into new or improved products. Castellaci (2006) explains cross-country differences in innovation performance of sectors classified according to the well known Pavitt industry classification (Pavitt 1984) as being determined by differences in innovation policies and economic status. Technical change on the sectoral level, innovative behaviour and innovation output therefore merely evolve in sync with institutions and structural properties of a given country (Nelson 1994, Nelson and Sampat 2001, Nelson and Nelson 2002). The innovation behaviour of a specific industry therefore varies also across countries. National innovation performance depends on how characteristics of a national economy, such as its National Innovation System, fiscal policies, or labour market institutions interact with Sectoral Innovation Systems (SIS) and on the sector structure of the economy, i.e. its specialisation profile. Figure 3 gives an overview of the links between the firm level, the industry level and the country level, and how these have been analysed in this project.
Figure 3 summarises the main challenges researchers face when studying innovation at the sector level. In order to be able to organise the vast disparity in innovation behaviours we find on the firm level, we need to understand how differing types of innovation behaviour among individual firms determine the specific innovation mode of a sector. Secondly, we need to understand the nature of country-industry interaction effects, i.e. how the peculiar socio-economic situation of a country affects a specific innovation mode of an industry. Finally, we must understand whether the sectoral composition of an economy affects innovation and economic performance of a country. This illustrates why a sector perspective is important. It allows us to condense micro-level heterogeneity into more homogeneous behavioural types and it allows us to study how the performance of these types varies with national and supra-national policies and institutions.

Figure 3 identifies the **cumulativeness** of knowledge, its **appropriability**, and **opportunity conditions** as basic parameters affecting the behaviour of firms in an industry. These are core aspects of what in the literature has been called “technological regimes.” They define the particular knowledge and learning environment in which firms operate (see Malerba and Orsenigo 1995). Cumulativeness of knowledge refers to the extent to which a firm’s ability to create new knowledge depends on the stock of knowledge accumulated in the past. Appropriability conditions refer to the possibilities of firms to protect innovations from imitation and therefore to the possibility to extract profits from them. This depends on a number of factors, such as the complexity of a technology. Finally, opportunity conditions refer to the likelihood of producing an innovation for a given amount of money; they depend on the technologies used in an industry and on characteristics of demand. Much research has established that industry characteristics such as market structure, average firm size or the patterns of innovation expenditures are closely related to the factors in figure 3 (see Levin et al 1987, Klevorick et al. 1995). For instance, there is convincing evidence that in industries where opportunity is high and appropriability as well as cumulativeness are low innovations are usually introduced by start-up firms. These sectors are characterised by a process of “creative destruction” where many firms enter the industry and many others leave it. Consequently, market concentration is low and firms are small. The machinery industry is an example in case. If on the other hand, the knowledge base is proprietary and cumulative then

![Figure 3: The sectoral innovation model.](image-url)
sectors typically follow a pattern of “creative accumulation” where large firms dominate and industry concentration is high (see Breschi et al 2000). The automotive industry, for instance, matches these characteristics.

Whether industries may be characterised as driven by “creative destruction” or “creative accumulation” also depends on the ways firms try to exploit promising conditions. Firms can actively seek to exploit them through their own process or product innovations, or to explore opportunities through imitation, technology adoption or opportunities that are not related to technology. The first type of firm behaviour may be called “creative entrepreneurship” referring to firms that seek to be different from competitors by actively innovating through the creation of new technologies or products. These types of entrepreneurs are therefore innovation leaders. The second type of firm behaviour may be called “adaptive entrepreneurship”. This category encompasses firms that either try to close in on innovation leaders or to diversify through activities other than technological innovation. In Figure 5 entrepreneurship is therefore identified as a firm specific characteristic.

The patterns of entrepreneurial behaviour find their expression in the exploration strategies firms pursue. All things being equal richer technological opportunities make research activities potentially more profitable (see e.g. Pakes and Schankerman 1984, Nelson 1992, Nelson and Wolff 1997). “Creative entrepreneurs” are therefore more likely to be observed in industries with high technological opportunity where the creation of new technologies or products is R&D driven. In industries where technological opportunities are less bountiful, firms are more likely to pursue other opportunities and access critical knowledge in different ways than R&D. “adaptive entrepreneurs” are more frequent in these sectors. They are more likely to rely on technologies and knowledge that are not created inside the firm. Opportunity conditions and entrepreneurship are therefore closely related but patterns of entrepreneurial behaviour vary systematically across sectors. They give rise to modes of innovation that persist over time. This allows us to condense the disparity encountered at the firm level into a smaller number of salient types.

Figure 4 shows how innovation modes vary across sectors. It groups firms into four mutually exclusive innovation categories: i) strategic innovators,

**Figure 4: Distribution of innovation modes by sectors.**

![Figure 4: Distribution of innovation modes by sectors.](image-url)

Source: EUROSTAT CIS-3 micro data, Pooled sample of innovators. No data are available for the aerospace and biotechnology industries. UNU-Merit calculations. For details see Hollander (2007).
ii) intermittent innovators, iii) technology modifiers, and iv) technology adopters. For the sake of clarity, in later parts of this report we will combine the first two categories under the heading **technology producers**, and the latter two categories under the heading **technology users**. In this part of the report we will use the more detailed classification. These are specified as follows (for more details see Hollanders 2007):

**Technology producers**

- **Strategic innovators** have all introduced a product or process innovation that they have developed at least partly in-house, they perform R&D on a continuous basis, they have introduced at least one product that is new to their market, and they are active in national or international markets.

- **Intermittent innovators** develop innovations at least partly in-house and have introduced new-to-market innovations. But they are unlikely to develop innovations that diffuse to other firms. The class of intermittent innovators includes three sub-groups: 1) Firms that meet the identical requirements of the strategic innovators except that they only perform R&D on an occasional basis. 2) Continuous R&D performers, which are only active on local or regional markets. 3) Firms that do not perform R&D but which have introduced new-to-market innovations to a national or international market.

**Technology users**

- **Technology modifiers** have all developed an innovation at least partly in-house but none of them perform R&D. If they are active on national or international markets, they have not introduced a new-to-market innovation (otherwise they would be classified as an intermittent innovator). If they are active in local or regional markets, they may have introduced a new-to-market innovation and have slightly modified it for this market.

- **Technology adopters** depend on adopting innovations developed by other firms. These firms innovate through diffusion.

Across all countries and industries technology modifiers are the most frequent firm type observed. However, in industries that are classified as high- or medium-tech based on R&D intensities, such as the ICT sector, the automotive industry or the chemical industry, there is clearly a higher share of firms that are either strategic or intermittent innovators. This is a first indication that these sectors have more favourable opportunity conditions. It is also true that the total share of innovators in these industries is above average: In ICT 61% of the firms in the CIS-3 micro data are innovators, in chemicals it is 58%, in machinery 51% and in the automotive industry still 48%, whereas in the entire pooled CIS 3 micro data sample only 37% of firms are designated innovators (see Hollanders 2007, p. 6).

An analysis of the innovation performance of the different sectors shows that sectors with larger shares of strategic innovators and intermittent innovators also have the highest innovation performance. Technology modifiers and technology adopters in turn dominate low-tech sectors such as food, textiles or energy. Firms are more likely to pursue opportunities other than technological ones in these sectors. The total share of innovators is also low. In the energy sector 36% of firms are innovators. This is the same share as for the food industry. In the textile industry only 25% of the entire population are innovating firms. Figure 4 therefore shows that a sector perspective is useful to understand the differences in innovation behaviour across sectors. This in turn indicates that horizontal innovation policies may produce very different effects in each sector, especially if they target primarily R&D. It is therefore necessary that sectoral differences in innovation behaviour are properly accounted for during the development of innovation policies. Innovative firms do not necessarily invest in R&D, therefore, if the aim is to foster the innovation performance of European member states; supporting R&D on their own may not achieve this goal. This will be discussed in more detail in later parts of this report.
2.2 Differences in innovation performance across countries and how sectors matter: the link between sector structure and national innovation performance

The innovation model shown in Figure 3 maintains that each single industry contributes to national economic performance, or, in other words, that there is a link between the sector structure of an economy and its aggregate performance. This is an important aspect for policy, as it is a declared goal of the Lisbon Agenda to reach an average spending on R&D of three percent on average across all EU member states by 2010. This is a flexible goal and member states are free to set their own targets towards this collective goal. However, as van Pottelsbergh (2008), p. 4, argues, “the further away from the Lisbon target a country was, the bigger the increase projected in the national programme implementing the Lisbon agenda.” He continues that these targets “appear to represent wishful thinking rather than political momentum”. This suggests that realistic targets need to take into account the industry structure of each country. A policy is likely to fail if the targets it sets are too high for an industrial structure where sectors with low R&D intensity predominate or it will turn out to be uninteresting if they are set too low with respect to an industrial structure that has a large share of high-tech firms. This insight is important for innovation policy as changing the R&D intensity in some sectors is quite a different issue from supporting structural change towards sectors with a higher R&D intensity. This requires the policy maker to deploy different instruments depending on which of the two measures is necessary to implement innovation.

Leo, Reinstaller and Unterlass (2007) have carried out a statistical decomposition exercise on sectoral innovation indicators in order to analyse the link between sector structure and national innovation performance. In this approach observations of every specific sector are demeaned with the OECD average of that sector. This allows us to compare innovation indicators across countries and sectors. The result for business R&D is shown in Figure 5: the farther to the right the observations of a country are, the higher is the share of industries with a high R&D intensity in GDP. Conversely, for observations lying farther to the left of industries with a high R&D intensity there is also a lower share in GDP. On the other hand, observations that lie above the 45° line show countries where the average R&D intensity across all its industries is above the OECD average, i.e. in that country many industries spend more on R&D than what is spent the same sector in the OECD on average. The observation for Finland (FI), for instance, tells us that this country has a structure where R&D intensive industries contribute a large share to Finnish GDP. However, the R&D intensity in Finnish industries also lies above the industry average. If we look at the observation for Poland (PL) for instance, the reverse is true: this country has an industrial structure where sectors with low R&D intensity have a larger share in GDP. Furthermore Polish firms also spend less on average than firms in the same sectors in the OECD. Figure 5 therefore allows us to judge whether a country for any given industry structure is investing more or less than the OECD mean. Ireland (IE) for instance invests much less in R&D, whereas Sweden (SE) invests much more.

Figure 6 shows how R&D expenditures are concentrated in some sectors of the Finnish economy. It shows the cumulated deviations in R&D intensity from the OECD average in each industry in descending order. We will refer to these as structurally adjusted R&D intensities. The industry values sum up to the vertical deviation from the 45° line for the observation for Finland (FI) in Figure 5. Figure 6 indicates that the good aggregate result for Finland is due to a small number of sectors that have a particularly high R&D intensity and a dominance in Finnish manufacturing. Radio, television and communication equipment (NACE code 32) contributes most to the Finnish performance. The concentration of R&D spending
in Finland is high, but Leo, Reinstaller and Unterlass (2007) show this to be the case for most EU countries. Figure 5 and Figure 6 together show that aggregate innovation indicators such as R&D spending in the business sector vary greatly across countries because their industry structure is different. International comparison of R&D intensities therefore should take into account the particular sector structure in each country. On the other hand, the evidence presented here also shows that contributions to the above-average R&D intensity of a country may be due to just a handful of industries. This shows that the specialisation pattern is a very important factor in explaining aggregate innovation indicators.

2.3 Variation in sectoral patterns of innovation across countries

Section 2.1 established a link between firm types and sectoral innovation performance. This link provides a more accurate picture of innovation behaviour within firms and their markets. As such they improve the problem solving capacity of innovation policy, because by structuring knowledge about the innovation process in single industries they allow us to account for heterogeneity in supporting the development and use of more selective policy instruments. Later in this report we will present new sector taxonomies that reflect the complexity of the innovation process to a fuller extent (see Section 0). In Section 2.2 we have provided evidence of how national innovation indicators are influenced by the sector structure of the economy. Both sections demonstrate the importance of the sector perspective for innovation policy.

In combining the evidence from these two sections the question arises whether country performance is related only to structures in situations in which industries are dominated by technology modifiers or in situations where technology adopters dominate. Figure 3 suggests that the behaviour of industries is constrained by a number of specific regional, national and supranational factors. There are significant interactions between sectoral

Figure 5: Structurally adjusted R&D intensities.

Source: OECD ANBERD data, WIFO calculations. For details see Leo, Reinstaller and Unterlass 2007.
patterns of innovative activity and national innovation policies as well as national institutions and regulations that should be considered (see also Malerba 2002). This makes it clear that industries are likely to differ across countries.

Figure 4 shows how the innovation process varies across industries. Figure 7 on the other hand suggests that the innovation process may well be influenced by the economic and social realities as well as the institutional set up of National Innovation Systems. The numbers of innovators in the population and their separation into technology users and producers also vary considerably across countries. In the new member states and some southern European countries the number of non innovators and technology users is very high. This is first sketchy evidence that the state of a country’s economy affects the innovation process in each industry. This is the general conclusion in many studies carried out in the Sectoral Innovation Watch project using a number of different approaches and data sources. The reason for this is that opportunity conditions, technological capabilities, accumulated knowledge, appropriability conditions and also cost structures differ in less advanced countries from more advanced countries. As a consequence firms operating in the same industries pursue different innovation strategies across countries. This, of course, calls for different innovation policies and different innovation indicators to benchmark the innovation performance of countries as a function of the state of their economy. These aspects will be discussed in greater detail in the remainder of this report.

There is one more important aspect shown in Figure 7. It shows that if innovation performance of a country is measured on the basis of R&D alone, as in Figure 5 and Figure 6, other relevant forms of knowledge acquisition and technology are neglected, and as a consequence a broad range of innovation behaviour is ignored. This is another aspect which will be addressed in detail later.

Figure 6: Concentration of R&D expenditures in the Finnish business sector.

Source: OECD ANBERD data, WIFO calculations. For details see Leo, Reinstaller and Unterlass 2007.
Table 2: Innovation drivers

<table>
<thead>
<tr>
<th>Sectors</th>
<th>Policy dimensions</th>
<th>Sector classification</th>
<th>Markets factors for innovation</th>
<th>Research and technologies</th>
<th>Markets and innovation</th>
<th>innovation environment</th>
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<tr>
<td></td>
<td></td>
<td>Innovation intensity</td>
<td>Technology source</td>
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<tr>
<td>ICT</td>
<td>High</td>
<td>High</td>
<td>Tech. producers</td>
<td>Financial constraints</td>
<td>Human resources &amp; skills</td>
<td>Knowledge creation &amp; R&amp;D</td>
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<td>Machinery</td>
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<tr>
<td>Aerospace</td>
<td>Med-High</td>
<td>High</td>
<td>Tech. producers</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Chemical</td>
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<td></td>
<td>Techno. users</td>
<td>-</td>
<td>+</td>
<td>+</td>
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<td>Automotive</td>
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<td>Energy</td>
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<td>Textiles</td>
<td></td>
<td>Med-High</td>
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<td>Food/drink</td>
<td>Med-Low</td>
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<td>Eco-Innovators</td>
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<td>Gazelles</td>
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<tr>
<td>Biotech</td>
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</tbody>
</table>

Legend: green: highly significant; yellow: important; grey: no decisive evidence. The + - signs indicate expected causality, the shape of relationship, number in column "lead market potential": number of countries where sector has lead market potential in at least three of the five dimensions of the lead market analysis. 
Source: Analysis by WIFO
CHAPTER 3
Main drivers of innovation at the sector level and across sectors

The previous chapter of this report has shown why the sector perspective is important, and how aggregate innovation performance depends on industrial structure. Furthermore, it was argued that the nature of the innovation process in a sector differs across countries depending on the level of development of the economy in which the firms of an industry are located. Figure 3 assumes that sectoral innovation performance depends on a number of factors. Some are industry specific, such as opportunity conditions and the cumulativeness of knowledge; some are firm specific, such as entrepreneurial risk taking or the choice between different types of investment for innovation. Finally, some factors were shown to represent aspects of the national or supranational innovation environment that have an impact on the innovation performance of specific sectors. Examples are regulations, taxes or the general innovation culture. Table 2 gives an overview on the aspects that have been studied in the SIW project. Each row of the table represents the outcomes for one of the SYSTEMATIC sectors, whereas each column captures a broad field of economic and innovation policy. These are summarised under the headings “market factors in innovation”, “research and technologies”, “markets and innovation” and “innovation environment”.

The two aspects that have been combined under “market factors for innovation” relate to the importance of human resources and innovation funding. The next broad policy category summarises a number of factors affecting “research and technologies” in each sector. The research in the project focused on the investment and acquisition of knowledge as well as on the impact of different innovation strategies on innovation performance. The next broad policy field comprises factors related to the role of demand for innovation as well as on the effect of competition on innovation activities. These are under the heading “markets and innovation”. Finally, the columns under the heading “innovation environment” embrace characteristics of national policy and innovation culture that have an impact on innovation behaviour. The colour of a cell illustrates the importance of an innovation driver for a specific sector. A green field indicates that the factor is very important and statistically highly significant. A yellow field indicates important and significant factors. A grey field indicates that results are inconclusive or even contradictory. Finally, a white field indicates that our research has not produced significant results.

The SYSTEMATIC sectors listed in the second row of Table 2 are ordered according to the classifications in Chapter 2. Some general patterns of important drivers for, or obstacles to, innovation are immediately apparent. Human resources, R&D and financial constraints are important drivers or obstacles for innovation in the sectors classified as technology producers. For sectors that are classified as technology users, knowledge acquired through formal and informal networks but also through technology adoption are more important drivers of innovation. Financial constraints seem to be less of an obstacle to innovation in these industries. There are no systematic differences between technology users and producers when considering the impact of lead markets and user-producer linkages on innovation. Also the effects of competition show no clear pattern across the two broad classes of technology users and producers. This indicates that the markets in which the different industries operate are rather disparate and
users or customers have a rather important impact on innovation in each of them. This is also in line with findings of von Hippel (1988) and other authors.

### 3.1 Market factors in Innovation

The SIW project has focused mainly on two crucial factors that are important inputs into the innovation process: the funding of innovation and human capital. External finance plays an important role in the funding of innovation in many sectors. The lack of external finance is often identified as a key obstacle for innovation. Human capital and skills on the other hand are a key labour input for innovation activities. The lack of skills is equally often identified as a key obstacle to innovation. Finally, a third important input in the innovation process, new machinery and new technologies, is another factor whose role has been studied in this project. However, the discussion of embodied technical change for innovation is discussed in Section 3.2.

### Financial constraints

Table 2 shows that financial constraints are relevant for innovation in the sectors called technology producers. For technology users, financial constraints seem to be less of an obstacle to innovation in these industries. Industrial innovation is a form of entrepreneurial activity where risk is taken in the hopes of increasing value and profit. The expected reward has to outweigh the risk if an innovation investment to be made. If the expected reward falls below a threshold set by the management, or if an innovation project has to compete with alternative, potentially more profitable projects two factors are important: (i) many innovation projects suffer from an unfavourable ratio between earnings and costs due to a low appropriability of innovation returns; (ii) banks are reluctant to finance firms’ innovative activities, resulting in a low supply of loans for innovation financing due to the asymmetric risk distribution between the lender and the borrower. Furthermore in many innovation projects the investment is mostly in intangible assets that can’t be offered as a collateral. Hence, the more a firm engages in the creation of new knowledge rather than adopting new technologies embodied in new capital goods, the higher the associated risk is and the more difficult it will be to find external funding.

There are essentially two means to fund innovation activities: debt financing and equity financing. Debt financing is a means of financing that requires that some assets such as plants, machines, or land can be used as collateral. Equity financing does not require collateral but offers the investor some form of ownership in the innovation project. Internally generated funds with equity characteristics (cash flow financing) can come from different sources such as profits, sales, working capital, extended payment terms, or accounts receivable. To what extent a firm may be able to rely on one of the two instruments depends on the value of capital goods it can offer as collateral or the internal cash flow generated by the firm.

Cleff et al (2008) discuss important aspects involved in financing innovation. First, risk exposure and external finance is a challenge since financing innovation is very closely linked to the type of innovation in a sector. The larger a project, the higher the technological and market risk, the longer the project duration, and the lower the volume of available collateral Innovation, the more difficult financing will become (see Hall 2005). Low collateral in innovation projects occurs when the main investment is intangible, such as expenditure for R&D, skill formation and design. High risk exposure forces firms to rely more heavily on internal funds, whereby a high share of gross fixed capital formation (i.e. capital expenditure) in total innovation expenditure means that a high level of collateral is available for securing loans. Second, internal funds are generated through the cash flow that is approximately the sum of operating surpluses plus depreciation. A favourable ratio of output to cash flow facilitates financing innovation projects from internal...
funds. Third, private equity financing, i.e. the access to external equity goes through two main channels: selling company shares at stock markets, or acquiring investment from private equity companies. The former is not available for SME’s. Private equity is traditionally separated into two types of investment: venture capital and later stage investment. Venture capital is used to finance the start-up of new, typically technology-based firms as well as the expansion of fast growing companies. Later stage investment represents financial investment in companies that promise growing profits and is often associated with restructuring.

The two diagrams in Figure 8 illustrate some of these aspects. The left diagram plots the share of R&D performing firms in a sector against the investment share in that sector. This gives an indication of the risk profile of each sector in the plot. Firms in sectors with a high share of R&D performing firms but with relatively low investment ratio will have greater difficulty to debt finance their innovation expenditures as they can offer less collateral than firms in sectors with a higher investment ratio. Firms in the biotech sector, for instance, have a much higher risk exposure than firms in the energy sector. The right diagram plots R&D expenditures against the operating surplus in a sector. This gives an indication of how well firms can finance their innovation expenditures through equity funding. The higher the operating surplus the better firms should be able to finance their innovation spending with equity than, for instance, firms in the energy sector. This is reflected in Table 2. Biotechnology firms are generally technology producers, whereas energy firms are mostly technology users. Hence, the risk profile of the former is a-priori less favourable.

An evaluation of CIS firm level data carried out by Cleff et al (2008) has shown that the “lack of appropriate sources of finance” is the second most important obstacle to innovation activities in European companies. Firms also perceive high innovation costs and also excessive economic risk more important than other barriers and impediments to innovation.

- The realisation of innovations was hindered because firms reported that the innovation costs are too high. This barrier to innovation is a serious problem for almost 24 percent of the companies.
- The financial side of innovation constitutes another barrier to implementing innovations. Nearly 20 percent of the companies are affected by a lack of an appropriate source of finance.
- Economic risks and concerns about profits from innovation activities as a barrier accounts for about 16 percent of enterprises.

Regarding the financing of innovation, restrictions are unavoidable and serve as a means to allocate scarce resources to those projects that promise the highest returns. Financing-related policy measures serve as a means to compensate for the reluctance of firms to invest enough in innovation to maximise social returns. Financing innovation projects constitutes a particular challenge for small and medium-sized enterprises. Moreover, highly innovative companies and industries with high R&D-intensity levels have more difficulties than industries with low R&D intensity. Economic risk and lack of capital affect cutting-edge technology the most. Financial support should therefore be targeted at these groups of companies.

Human resources

This section presents results on the relationship between productivity, skills, and the catching up process at the industry level across countries. It is based on the contribution made by Crespi and Patel (2008b) to the SIW project. Table 2 shows that human resources and skills are highly important for innovation in all sectors studied in the SIW project. As the latest Trendchart report shows, there are
challenges related to the share of population with tertiary education. Youth education attainment levels are important long-term factors which can slow the shift to a knowledge economy, and the willingness of a population to adopt new innovative products or work-place organisational innovation. Amongst this group of indicators, the availability of sufficient S&E graduates is a key bottleneck for future knowledge-based developments in many EU Member States and candidate countries, as well as associated countries (Commission 2006c, p. 43). The results of the SIW project are in line with these findings.

A number of recent studies have emphasized that the level and composition of skills (or human capital / resources) in an economy also has an important bearing on differences in levels and growth of productivity across OECD countries. In an econometric study Crespi and Patel (2008b) show that engineering and science skills contribute directly to international competitiveness and productivity since a better-educated workforce augments the efficiency of labour, but also raises the absorptive capacity of firms to more easily integrate new technologies and ideas. The ability of a country to adopt innovations on the technological frontier is an important source of economic growth. In other words, the returns to higher education will be greater for less advanced countries due to the importance of technology transfer and absorptive capacities. The better the ability of the workforce of a less advanced country, the better are its capabilities to imitate technologies developed elsewhere. The level of skills is not restricted to tertiary or scientific education personnel: the intermediate level is also important. It is the complementary and balanced mix of skilled labour that is important, not just the quality of the high end of the formal skills.

However, different sectors have different needs with respect to skills and education. The effect of educated human capital on innovation and productivity is positive in all investigated sectors, but the magnitude of the effects varies. When evaluating the effects, the quality of skills is of central importance. The distinction between pure educational skills as reflected in levels of educational attainment and occupational skills as reflected in accumulated experience of the workforce is therefore important. The results obtained by Crespi and Patel (2008b) show that professional experience is an important complement to institutional learning. When looking at human resources that are specifically related to science

Figure 8: Financing constraints in the SYSTEMATIC industries.

and technology, the results for the pooled sample, i.e. the results attained across all countries and sectors, indicate that occupational skills are indeed more important for innovation than educational skills. Human Resources for Science and Technology (HRST) personnel as measured exclusively by educational attainment show a lower impact on Total Factor Productivity (TFP) growth than occupational skills based on accumulated experience. This holds for the food industry, the chemical sector and the machinery and equipment industry. Occupational skills are also important for catching up in the machinery, the automotive and the aerospace industries. Educational skills on the other hand show a significant impact on TFP in the chemical sector and in the ICT industry. Educational skills in general help to catch up in almost all sectors but the effect is statistically significant only in the automotive and aerospace industries. These results are summarised in Table 3.

There are major differences across sectors. Higher education (not necessarily in science and technology) positively affects TFP growth in three sectors: Machinery, ICT and Automotive. Surprisingly the higher education skill premium is not significant in the Chemicals sector. For the eight SYSTEMATIC sectors as a whole, occupational skills are much more important than pure educational skills. The interaction between technology transfer and skills associated with catching up is positive and statistically significant in the machinery, automotive and aerospace industries. In these sectors higher education skills affect productivity growth in the catching up process: this effect is therefore greater for less advanced countries (i.e. those with a large productivity gap).

To sum up, the findings of the research carried out in the SIW project support the argument that sectors employing a larger share of high or medium skilled workers exhibit higher productivity growth while a high share of low skilled workers in a sector exert a negative influence on productivity growth. Furthermore, skills matter for the speed of convergence on the technology frontier. A similar finding was reported in the latest European Competitiveness Report (Commission 2007c). Improving educational and occupational skills will have positive effects on innovation, but the magnitude of effects varies across sectors. Occupational training and long-term learning schemes are highly important for innovation performance. In short, sectors are important because of the great disparity amongst them in the relationship between human capital and productivity growth.

Table 3: The contribution of HRST skills to TFP growth equation by sector.

<table>
<thead>
<tr>
<th>Energy</th>
<th>Food</th>
<th>Textile</th>
<th>Chemicals</th>
<th>Machinery</th>
<th>ICT</th>
<th>Automotives</th>
<th>Aerospace</th>
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</thead>
<tbody>
<tr>
<td>Innovation</td>
<td>Occupation</td>
<td>Occupation</td>
<td>Education</td>
<td>Occupation</td>
<td>Education</td>
<td>Occupation</td>
<td>Occupation</td>
</tr>
<tr>
<td>Catching up</td>
<td>Occupation</td>
<td>Occupation</td>
<td>Education</td>
<td>Occupation</td>
<td>Education</td>
<td>Occupation</td>
<td>Occupation</td>
</tr>
</tbody>
</table>

Source: University of Sussex, SPRU, calculations. For details see Crespi and Patel (2008b).

4 HRST stands for Human Resources for Science and Technology. Data on Human Resources for Science and Technology are based on the Community Labor Force Survey available from EUROSTAT. In addition to HRST personnel the annual flow may also have an impact, as well as mobility of researchers. These studies have not focused on this aspect. Future research will shed more light on the importance of personnel flows for productivity growth.
Case Study Evidence 1: Human Resources – BASF / Germany

**SYSTEMATIC sectors:** Chemicals, Eco-innovation

As the world’s largest chemicals company, BASF’s products range from basic chemicals, plastics, performance products and agrochemicals to oil and gas. The company has more than 160 subsidiaries, and employs more than 95,000 people worldwide. It operates over 150 production sites in Europe, Asia, North and South America and Africa and sells its products to more than 200 countries.

- Since the divisions of BASF are highly technical, the firm requires great numbers of highly qualified science and engineering graduates. A viable university system that provides the industry with adequately qualified human capital is therefore vital to the sustainability of innovativeness and competitiveness in the industry. (Friesenbichler, Rammer 2007)

**Sector specific findings on market factors for innovation**

- **Food**

  Firms with better access to public funding and / or access to lending show higher innovative activities. Across countries the sector has a rather unfavourable internal financing situation. The lack of financing hampers innovation in this industry.

  In the Food sector, the occupational skills (HRST personnel) are important; a high level of innovation in the sector is strongly associated with the level of skills. The share of employees with higher education within the sector is far below the manufacturing average, although the share of firms that implement staff training is higher. Moreover, staff training and the percentage of turnover used for staff training (especially concerning work safety, technical issues and computing technologies) correlate significantly with innovation. Despite the low share of employees with higher education, firms consider continuous improvement of the workforce skills important. Human resources are very important to innovation activities in this industry.

- **Energy**

  In the energy sector firms rank costs first among factors hampering innovation. Nevertheless the average annual operating surplus in this sector is about hundred times higher than the average annual innovation expenditure; the energy sector therefore has the most favourable position (due to petroleum processing) in terms of available internal funds. Funds, however, are not equally distributed so that lacking finances is at least of some importance in branches of the energy sector other than the petroleum processing industry.

  Indicators measuring skills (percentage of professionals with high qualifications and the percentage of managers with high qualifications) are positively related to growth of innovative activities in this industry, but results are not significant. Experts furthermore mention that the mobility of researchers is currently less than optimal. However, lacking indicators suggest that human resources are of subordinate importance in the energy sector. Table 2 shows that Energy is the only sector investigated where the effect of human resources for innovation is not significant.

- **Textiles**

  Better access to both external and public funding is positively associated with innovation performance. However, in the case of public funding the relationship is not statistically significant.

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5 The findings reported in this part of the report summarise sector specific findings on specific policy dimensions in the SIW project. A more detailed and comprehensive account of sector specific drivers and challenges for innovation are available in the sector reports produced by the SYSTEMATIC consortium and are available on the Europe Innova website http://www.europe-innova.org/
The level of innovation in the sector is strongly associated with the level of skills. Training is important for innovation. The textile industry however suffers from a labour shortfall as employment in this sector is not appealing. This is not only because of production methods, but the quality of working conditions as well. In part this phenomenon can be attributed to the insecurity of employment reflected in high-rates of part-time employment, notably of women. Overall, human resources in textiles are at least of some importance for innovation.

• **Chemicals**

Chemical firms tend to specialise in relatively high-risk projects with little fixed investment. They rely in particular on internal financing or external equity financing to fund innovation. Econometric analyses show that in the chemical industry the share of firms receiving public funding, higher FDI investments as well as higher foreign R&D-investments per employee correlate positively with innovation performance in the sector. Firms are hampered in financing their innovation plans by difficulties in the area of internal financing, i.e. insufficient cash flow, and above all by a lack of venture capital.

Interestingly, a higher education skill premium is not significantly positively related to TFP-growth in the Chemicals sector, but the impact of occupational skills and also educational skills are important for innovation. Employee training is a relevant innovation activity. Innovation in the sector is strongly and positively associated with the level of skills. Human resources therefore play a highly important role for innovation.

• **Machinery**

As in Chemicals, Machinery firms tend to specialise in relatively high-risk projects with little fixed investment. They rely in particular on internal financing or external equity financing to fund innovation. Especially small companies see the lack of appropriate finance as a sector-specific problem. Finance and access to venture capital are important factors determining innovation in the machinery and equipment industry.

Higher education positively affects TFP growth and the interaction between technology transfer and skills is positive. Furthermore, occupational skills are important for innovation and catching up. Good skills therefore increase both innovation in advanced countries and imitation in less advanced countries. This is underscored by the fact that a high level of skills (for instance high shares of employees with higher education) and high shares of firms using training in a country’s machinery sector correlate with high levels of innovation. Human resources are very important for innovation in the industry.

• **ICT**

ICT is a sector with relatively high-risk research. On the other hand, ICT has a rather low share of enterprises receiving public innovation funding. Although the ICT sector benefits most from European venture capital investments, the level is low compared to the US. Access to finance is therefore viewed as an significant obstacle to European SME’s in the ICT sector. There seem to be country differences, however. In countries with high innovation performance in the ICT sector availability of venture capital and of domestic external finance is better than in countries where the industry is not performing well. Difficulties in financing innovation plays a particularly important role in the ICT sector.

Higher education positively affects TFP growth in ICT and educational skills are furthermore important for innovation. Training as well as a high level of skills are also relevant for innovation. As all these factors appear to be highly significant, the statistical analyses results indicate that human resources are of high importance in ICT.
• Automotives

Projects in the automotive industry have a medium degree of risk and experts of the Europe Innova panel notes that the sector is least affected by financial barriers. Nevertheless, one third of the companies in this sector ranks the lack of an appropriate source of finance within the enterprise or group as factor hampering innovation. On the other hand, a large share of innovative enterprises receives public funding. The evidence suggests that the lack of finance in this industry is due to the selection and allocation function of financial markets and is therefore not related to any general failure in the market.

Higher education positively affects TFP growth in this sector. The interaction between technology transfer (catching up) and skills is positive and occupational as well as educational skills are important for catching up. When measuring the share of employees with higher education and the share of firms using training, these are relevant indicators in comparing the innovation performance of national automotive sectors. Also important is the presence of engineers in the workforce. Thus countries with a high level of innovation performance in the automotive industry have a high share of engineers in that industry. In these countries a higher share of firms also engages in training their own employees. The employment of a highly skilled workforce and the development of skills are important for innovation in the automotive industry.

• Aerospace

Aerospace firms have difficulties financing their innovation expenditure solely out of operating surplus, but firms in the sector generally find suitable sources of funding in public programmes from which a high share of firms benefits. The inter-sectoral comparison of hampering factors shows that the number of companies in the aerospace sector citing innovation costs as being important is one of the highest of all industries indicating that financial constraints are a significant issue for the innovation process in their industry.

The interaction between technology transfer and skills is positive and occupational as well as educational skills (HRST personnel) are important for catching up. Catching up is positively affected by educational skills (HRST personnel). However, due to data constraints the analyses of the impact of skills on innovation in the Aerospace sector are limited, but obviously skills are highly important.

• Eco-Innovation

Almost 30% of firms classified as eco-innovators indicate that innovation costs are too high. Experts indicate that the funding of eco-innovations is a major obstacle to the innovation process. Lack of evidence and data constraints hamper the evaluation of the impact of skills on innovation.

• Gazelles

For fast growing firms (Gazelles) the lack of access to financing is a major obstacle to innovation and further growth. Innovation costs are also often perceived as being too high and only a small share of innovators receives public funding. The evidence is strong that financing is an essential issue for innovation in Gazelles.

Even more important than financial constraints is the lack of a well trained workforce for fast growing firms. This turns out to be the one major obstacle for continued growth in this group of firms.

• Biotechnology

Biotech firms tend to specialise in relatively high-risk projects with little fixed investment. They rely mostly on internal financing or external equity financing to fund innovation. Biotechnology firms have difficulties financing their innovation expenditure solely out of operating surplus but the sector has the highest share of
innovative enterprises that receive public funding. Funding of innovation is not only the most severe innovation problem when compared to other barriers to innovation such as taxation, regulation, demand or human capital, but an inter-sectoral comparison also indicates that Biotech is the sector with the greatest financing difficulties. Furthermore, there is a particular lack of venture capital as a resource to finance innovation projects.

There is not enough evidence on the role human capital plays for the biotech industry. However, due to the high research intensity and the close relation to science of this industry a highly skilled workforce is certainly a major driver of innovation.

### 3.2 Research and technologies

**Knowledge creation and diffusion from a company level perspective**

**The decision to engage in R&D**

One important aspect of the innovation process highlighted in Figure 3 is how firms try to access knowledge needed for their innovation activities. We have called these innovation modes. Firms can either decide to generate knowledge on their own through R&D or to access external knowledge sources. This aspect of the innovation process is important. Even though intramural R&D is the main determinant of innovation on the firm level, more than half of the European firms that declare themselves to be innovators do not conduct intramural or even extramural R&D. These companies use external knowledge to develop new products or processes without bearing the costs — and especially the risk — of conducting research on their own. This is done by acquiring advanced machinery, buying patents or licenses, or carrying out training and marketing activities. Non-R&D-innovation has often been neglected in comparing the innovativeness of firms, regions or countries, but the CIS-3 data show the importance of that kind of innovation for both product development and cost reduction in process innovation (see Figure 9).

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**Figure 9: R&D and Non-R&D Innovators in 2000: breakdown by Country (CIS-3, Micro-aggregated data).**

- **Share of R&D Innovators**
- **Share of non-R&D Innovators**

**Note:**
1. Non-R&D innovators are defined as innovative firms which have product or process innovation, but do not perform intramural and extramural R&D. R&D innovators are defined as innovative firms that perform intramural and extramural R&D.
2. The country code follows the NUTS classification.

**Source:** UNU-Merit calculations. For details see Huang, Arundel, Hollanders (2007).
As has been discussed in Chapter 2 of this report, the mode of innovation a firm chooses is likely to be determined by opportunity conditions, appropriability, the cumulativeness of knowledge and the entrepreneurial strategy a firm pursues. Innovation modes are therefore sector specific. In scale-intensive sectors such as metal manufacturing and vehicles, firms generally tend to develop their own process technology. In textile firms, however, most process innovations come from suppliers. Therefore, R&D intensity does not accurately measure innovation efforts in certain manufacturing sectors, particularly in low-technology sectors.

Whenever a firm has to decide whether to engage in a research project, it will compare the risk of that project (costs, probability of succeeding) with the expected benefits which may be negatively influenced by potential competitors, since profits will be lower the more competitors sell similar products. Hence, the higher the costs of R&D and the lower the probability of success and the more potential competitors exist, the lower is the incentive to invest in R&D. Firms having more financial resources and more experience in R&D will more likely succeed in R&D projects. As a consequence they are more likely to invest in such projects. However, firms can also acquire external knowledge to avoid risky R&D expenditures.

The decisions of firms are also affected by the technological potential of the industry, whereby potential does not only depend on differences in the technological base between industries but also within the same industry if firms are in a phase of technologically catching up. In this case buying existing technology from industry leaders in other regions or countries may be an optimal choice given the lower risk. As these firms build up their technological capability over time and approach the technology frontier, they will be impelled to conduct R&D to move further up the technology ladder, simply because they cannot buy more advanced technology than they already possess. Conversely, for firms in an advanced industry cluster or in a developed region, there is little room to innovate by purchasing existing technology only, simply because they are already at the technology frontier. The question is then how firms allocate the budget to R&D and non-R&D innovation activities.

Huang, Arundel, Hollanders (2007) have studied this problem in a theoretical model and tested its propositions empirically. Their results show that the R&D intensity of a firm decreases if the firm finds purchasing existing technology more effective in terms of cost reduction than conducting it own R&D. Hence, the share of R&D expenditures decreases and the share of non-R&D expenditures increases. Firms that can compete by buying existing technology normally are less advanced technologically. Clearly they are likely to operate in the catching up countries rather than advanced ones. On the other hand, R&D intensities of firms increase with their non-R&D innovation expenditure shares if the firms are at the technological frontier and rely on R&D to innovate. These firms are likely to operate in the advanced countries. The same results are also found to hold if one looks at total innovation expenditure rather than at R&D spending alone.

Table 4 shows that the coefficients for the share of non-R&D innovation expenditures are positive and statistically significant in the regressions for the high-labour-productivity and medium-labour-productivity country groups. The theoretical prediction for the firms in medium-labour-productivity country group is not as precise as for those in the high-labour-productivity and low-labour-productivity groups. The impact is statistically significant and negative in case of the high- and medium-tech firms in the low-labour-productivity country group. However, the respective impact of the low- and medium-tech firms in the low-labour-productivity country group is positive and again statistically significant, which is not consistent with the theoretical prediction. The different signs of the same variable obtained in different regressions on high- and medium-tech and low- and medium-tech firms justify evaluating these firms separately in different sectors. It indicates that the innovation process in the low-productivity country group is driven by very uncharacteristic dynamics.
Each firm’s choice of its innovation budget also depends on the choices of its competitors. Table 4 shows the results for three variables measuring the impact of competitors’ decisions on the innovation choices of firms. They show that in the high-tech segment a firm decreases its innovation budget as its competitor increases its share of innovation investment to purchase existing technology if for such a competitor buying existing technology is more effective in terms of cost reduction than conducting R&D. This means that a firm has an incentive to reduce its R&D efforts if it competes with less advanced firms. On the other hand, if firms have to compete head on with equally advanced firms, then their incentive to distinguish themselves from competitors is high. The result for low- and medium-tech firms in the same country group show a positive impact suggesting that in these segments technology adaptation and technology adoption play a more prominent role in competition.

Table 4: Relationship between Innovation Expenditure Intensity (Dependent Variable) and Non-R&D Innovation Expenditure Share.

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Firms in countries with high labour productivity level</th>
<th>Firms in countries with medium labour productivity level</th>
<th>Firms in countries with low labour productivity level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High- and medium-tech sectors</td>
<td>Low- and medium-tech sectors</td>
<td>High- and medium-tech sectors</td>
</tr>
<tr>
<td>Non-R&amp;D innovation expenditure share of the firm under analysis</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Average non-R&amp;D innovation expenditure share of competing firms in the same country group (dividing 18 countries into three groups)</td>
<td>+</td>
<td>(−)</td>
<td></td>
</tr>
<tr>
<td>Average non-R&amp;D innovation expenditure share of competing firms in a different country group with a higher labour productivity level (dividing 18 countries into three groups)</td>
<td>−</td>
<td>(+)</td>
<td></td>
</tr>
<tr>
<td>Average non-R&amp;D innovation expenditure share of competing firms in a different country group with a lower labour productivity level (dividing 18 countries into three groups)</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Firm size (Logarithm of Employee number)</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Independence of product innovation</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Independence of process innovation</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Continuity of R&amp;D</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Note: Dividing 18 Countries into Three Groups. Countries with high labour productivity level: Italy, Belgium, Finland, Norway, Spain, Germany. Countries with medium labour productivity level: Iceland, Greece, Slovenia, Portugal, Czech Republic, Latvia. Countries with low labour productivity level: Slovakia, Hungary, Estonia, Lithuania, Romania and Bulgaria. +/− in bold denotes a positive / negative effect at the significance level of 1%, +/- at the significance level of 5%, (+)/(-) at the significance level of 10%.

Source: UNU-Merit calculations. For details see Huang, Arundel, Hollanders (2007).
The results consistently show that in high tech industries in countries close to the technological frontier a firm has an incentive to reduce its R&D efforts if it is competing with technologically less advanced competition. In low and medium tech industries instead, the effect is reversed indicating that in these industries technology adoption and adaptation are more important for the competition process.

Case Study Facts 2: Knowledge Creation – Johnson Matthey / UK

**SYSTEMATIC sector:** Chemicals

Main Field of Activity: Johnson Matthey is the leading manufacturer and developer of chemical process catalysts that are used in a range of industrial processes. The company is also a leader in diesel emission control technologies for both heavy and light duty diesel applications. The company engages 7800 employees and has a total turnover of about €6.6 billion.

- Research and development is the lifeblood of Johnson Matthey’s high technology businesses. Johnson Matthey invests significantly in R&D (€84.4 million gross in 2005/06) to develop new products and manufacturing processes. This is part of the group’s strategy to distinguish itself using world-class technology and to ensure the continuous flow of new products and technologies to produce cost effective solutions for legislated and technical requirements. (Rajan 2008)

**Innovation modes and innovation performance at the firm level**

The innovation model in Figure 3 shows that innovation output is determined by a wide range of R&D related activities and non-R&D activities. A firm’s success depends on a number of basic characteristics such as R&D investment, technological opportunities, appropriability conditions, demand conditions, firm characteristics, and market concentration. Firms therefore act differently across sectors, depending on the relationship of these factors. As we have shown in Chapter 2, sectors can be classified by the most common innovation mode. Innovation performance depends essentially on three factors: (i) In-house R&D represents the most important internal factors of a company for innovation. It is also very important for a firm to be able to acquire ideas for new products and technologies from outside and therefore to use (ii), external knowledge. The different ways of accessing external knowledge will be studied in greater detail later in this report. Since innovation is the result of a complex process the environment of a company will influence the degree of innovativeness of a firm. The environment consists of (iii), country and sector effects, since the infrastructure can differ between countries or technological opportunities can depend on the technology itself and therefore on the industry or sector in which the firm is active.

Falk (2007) analyses the impact of innovation intensity, innovation strategy, innovation sources, and firm specific circumstances such as firm size on innovative sales defined as (i) share of turnover of products which are new to the market, and alternatively (ii) share of turnover of products which are new only to the firm. The first indicator could be interpreted as a measure of innovative new market products, whereas the later describes product imitation.

Innovation intensity (expenditures on in-house R&D as percentage of turnover) is the most important innovation input determining innovation success, where the linear model of innovation predicts a simple relationship between R&D and innovation output. R&D leads to inventions that eventually lead to product and
process innovations. Falk (2007) finds the expected positive impact of innovation intensity on both innovation output indicators (sales shares).

However, firms also innovate using other inputs without investing in R&D. For example they can use existing technologies and adapt or modify them. Internal R&D activities, acquisition of other external knowledge, training related innovation expenditures and activities with respect to market introduction of innovation are all crucial factors for the firm’s innovative success. The results show that while total expenditures for innovation are the most important determinant of innovation success across sectors and firms, firms operating in sectors defined as technology users rely more heavily on non-R&D related innovation activities when introducing new products. They rely, for instance on external sources of innovation such as suppliers, customers, fairs or exhibitions. The field of activity of companies is also important, since companies which are successfully established on international markets show higher shares of innovative products. Interestingly, young firms do not only have many more products which are new to the firm, but market novelties are also far more important for their turnover than they are for older firms. Table 5 and Table 6 summarise the results for both innovation performance with product innovation and product imitation.
## Table 5: Impact of innovation inputs on share of turnover of market novelties.

<table>
<thead>
<tr>
<th>Innovation intensity</th>
<th>Technology users</th>
<th>Technology producers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>food</td>
<td>textiles</td>
</tr>
<tr>
<td>Newly founded firm</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Turnover growth due to M &amp; A act</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Turnover reduction due to disclosure</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>National market</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>International market</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Firm size class turnover (25th to 50th)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Firm size class turnover (50th to 75th)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Firm size class turnover (75th to 100th)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Intramural R&amp;D</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Extramural R&amp;D</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Acquisition of machinery and equipment</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Acquisition of other external knowledge</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Training</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Market introduction of innovation</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Government research institutes</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Universities</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Competitors</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Clients</td>
<td>Internal sources</td>
<td>+</td>
</tr>
<tr>
<td>Suppliers</td>
<td>Country effects</td>
<td>yes</td>
</tr>
<tr>
<td># of obs.</td>
<td>748</td>
<td>567</td>
</tr>
<tr>
<td>R²</td>
<td>0.09</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Note: +: significant positive effect; -: significant negative effect. Source: C.D. 3 data. WIFO calculations. For details see Falk (2007).
Table 6: Impact of innovation inputs on share of turnover through products that are new to the firm but not new to the market.

<table>
<thead>
<tr>
<th>Innovation intensity</th>
<th>Technology users</th>
<th>Technology producers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>food</td>
<td>textiles</td>
</tr>
<tr>
<td>Newly founded firm</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Turnover growth due to M &amp; A act</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Turnover reduction due to disclosure</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>National market</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>International market</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Firm size class turnover (25th to 50th)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Firm size class turnover (50th to 75th)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Firm size class turnover (75th to 100th)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Intramural R&amp;D</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Extramural R&amp;D</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Acquisition of machinery and equipment</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Acquisition of other external knowledge</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Training</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Market introduction of innovation</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Design and other preparation</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Fairs, exhibitions</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Conferences, meetings, journals</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Government research institutes</td>
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<td></td>
</tr>
<tr>
<td>Universities</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Competitors</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Clients</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Suppliers</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Internal sources</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Country effects</td>
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<td>yes</td>
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<td># of obs.</td>
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<td>569</td>
</tr>
<tr>
<td>R²</td>
<td>0.15</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Note: +: significant positive effect; -: significant negative effect.
Source: CITE-3 data. WIFO calculations. For details see Falk (2007).
The diffusion of knowledge

Not only do imitation or imitative research projects depend on the firm’s knowledge of global technological developments and trends, but world-first innovation also benefits from external knowledge. Known features can combined in new ways to create market novelties. Obviously, it is essential to know what the competition has invented to be able to imitate or creatively exploit it. There are different ways of acquiring external knowledge:

- Collaboration is a standardised form of (i) jointly working on innovative research and therefore creating knowledge, (ii) sharing knowledge with partners and (iii) – seen from a different perspective – absorbing knowledge.

- Diffusion of informal knowledge is a non-standardised means of knowledge transfer which is also a very important source of innovation for firms. This form of knowledge transfer might happen, for instance, through reading scientific publications, attending fairs or talking to customers and suppliers.

- Embodied technological diffusion describes the process of knowledge transfers through trading of goods or services, which improves knowledge or production process capabilities (e.g. buying new machines) of customers.

In the following sections collaboration and diffusion of informal knowledge will be analysed on the firm level. Embodied technological diffusion is rather difficult to analyse on the firm level as direct and indirect effects play a role, but towards the end of this section it will be discussed on the sector level.

Collaborations

Collaborations are formalized networks which may include agreements within an enterprise group, with up-stream suppliers, downstream customers, competitors, the government and universities and other research institutes. Collaboration is important because it reduces risk and complexity involved in the development of new products and processes by spreading it among several partners with agreed upon complementary aims. It often entails the development and acquisition of new capabilities, as each agreement involves a shared commitment of resources and knowledge, and it is closely related to the idea of ‘learning by interacting’. Often the form of ownership and the location of a partner in the network can have important consequences. If firms are strongly embedded in the local social environment, they tend to cooperate with partners in their local proximity, provided they have the needed complementary resources. If these complementary resources do not exist locally, firms are more likely to collaborate with foreign partners.

The creation, transfer and absorption of new knowledge depend on a wide variety of innovation-related activities, including in-house and acquired R&D, internal and external training, product-embodied knowledge diffusion, and acquisition of external knowledge. Firms build on strategic capabilities containing elements of tacit knowledge, which promotes the need to pool resources with other organisations in order to access knowledge complementary to their own knowledge base. Technological collaboration facilitates the learning process within firms by providing a way for them to observe how other firms perform and better access specific project-based knowledge.

Technological collaboration has been growing in importance because of the increasing complexity of research, intensifying global competition and rapid technological progress. Empirical evidence on strategic alliances broadly confirms the increasing trend of collaboration in technology development in the global economy. Therefore, firms share their knowledge to acquire useful knowledge in return. The partner has to offer knowledge superior to existing capabilities of the cooperating firm, which suggests that technology collaboration between locally and
foreign-owned firms is far less likely in less advanced countries. Cooperation becomes more important in sectors that require more complex sources and forms of knowledge processes.

Organisation proximity through foreign ownership may overcome geographical and cultural distance, which suggests that foreign-owned firms should have easier access to collaboration partners abroad. Foreign-owned firms have an inherent advantage of access to foreign sources of technological knowledge through other firms in the group and parent companies abroad. Large multinational corporations (MNC’s) are often at the centre of a collaborative agreement, but there is little evidence of technology spillovers due to foreign ownership. On the other hand there is strong evidence of technology transfer, which appears consistent with the proposition that MNC’s tend to limit spillovers of their knowledge base to non-affiliated firms to protect their ownership advantages. As they aim to exploit their superior knowledge base through direct investment abroad, they would be expected to channel knowledge from the parent to the local subsidiary, but protect it from spilling over to the host economy.

Case Study Evidence 3: Networks and cooperation – Vaisala / Finland

**SYSTEMATIC sector: ICT**

**Main Field of Activity:** Vaisala’s core business is environmental measurement, especially weather measurement and corresponding industrial measurements. It has been a science-driven company operating in global markets since it was established in 1936 and was considered the flagship of technology industries in Finland for decades before the rise of telecommunications and Nokia. Vaisala has been a pioneer in its sector, basing its competitive advantage on long traditions of developing innovative products that are based on the latest scientific research. The company engages 1069 employees (2006).

- Co-operation with research and technology organisations has been the most important external driver for innovation in Vaisala. In addition to its own internal research activities, Vaisala has participated in several projects together with leading research organisations in the field, such as NOAA (National Oceanic and Atmospheric Administration, USA), NCAR (National Center for Atmospheric Research, USA) and VTT (Technical Research Centre of Finland). (Viljamaa 2008)

Knell and Srholec (2008) have explored these relationships in a study that was part of the SIW project. Empirically, within the European countries the percentage of firms engaged in their own R&D activity is much higher in the industries that are technology producers (chemicals, machinery, electronics and computer and R&D services) than in the industries (food and textiles) that are technology users. International technology collaboration is prevalent in the computer and R&D services. National collaboration tends to be twice as high as international collaboration. Figure 10 summarizes the relationships that determine collaboration. Foreign ownership is the main characteristic. It appears negatively related to individual R&D activity, except in the food, beverages and tobacco industry, and to national collaboration. As expected it is positively related to international collaboration. R&D activity is always positively related to international technological collaboration, which in turn is always positively related to national technological collaboration. External sources of information lead to more international collaboration and intellectual property rights protection lead to more national collaboration.
One striking result is that foreign-owned firms in the European economy as a whole appear to have much less interest in collaborating in the host economy compared to their locally owned counterparts. However, there is no confirmation of this relationship at the industry level except in the food and tobacco industry. In contrast, the evidence shows that firms with international collaborative agreements are much more likely to collaborate nationally. Finally, the appropriability conditions, measured by the patenting track record of a firm, seem to influence collaboration with local partners in the European economy as a whole, and particularly in the industries that are technology producers.

**Case Study Evidence 4: Networks and cooperation – BASF / Germany**

**SYSTEMATIC sectors:** Chemicals, Eco-innovation

*Main Field of Activity:* Being the world’s largest chemicals company, BASF’s products range from basic chemicals, plastics, performance products and agrochemicals to oil and gas. The company comprises more than 160 subsidiaries, and employs more than 95,000 people worldwide. It operates over 150 production sites in Europe, Asia, North and South America and Africa and sells its products to more than 200 countries.

- Large firms are often the driver of technology within sectors. When they operate with an open innovation concept, knowledge spillovers to actors that typically have disadvantages in innovation will be promoted. Many collaborations between BASF and medium sized (and small) companies show that large firms’ knowledge can be transferred to SME’s by mutual R&D. Thus, fostering R&D cooperation in, for instance, collaboration centres (sometimes called competence centres) with smaller firms and also academia can significantly improve the technological competitiveness of a region. (Friesenbichler, Rammer 2007)

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**Figure 10:** Determinants of R&D activities and collaboration within European countries.

Source: NIFU-Step. For details see Knell and Srholec (2008).
A broad range of factors determines collaboration. These factors are different across sectors. However, a general finding is that foreign ownership increases the likelihood of international collaboration but decreases the probability to collaborate at the national level. The results presented here also show that the likelihood of collaborating locally increases when firms carry out their own R&D activities but also collaborate on the international level. On the one hand, this suggests that locally owned firms that collaborate internationally are an important source of technical knowledge from abroad. On the other hand, multinational corporations allow for technology transfers to their subsidiaries, but limit spillovers of their knowledge base to non-affiliated firms. The analysis found less conclusive evidence for specific industries. A possible reason for this may be that in some industries, such as the food industry, many larger multinational firms spread their research portfolio widely, i.e. they carry out a very limited subset of their research activities in just one country, whereas they may co-operate with firms working in different fields in the same country. Hence, no knowledge spillovers are realised. Overall the evidence suggests that the idea of direct foreign investment as an important source for knowledge spillovers and hence for innovation performance should be viewed with some scepticism. The evidence presented here suggests that this might not be the case. However, further research is needed to corroborate this viewpoint.

**Diffusion of knowledge through informal networks**

When choosing to pursue non-R&D strategies firms also rely on publicly accessible knowledge for imitation or as a source for innovation projects. In this way they can combine element of unrelated knowledge to generate innovations. The diffusion of this flow of knowledge therefore has an impact on the overall innovation performance of the sector.

Garcia-Torres and Hollanders (2007) have used CIS-3 micro data, where information about knowledge sources and collaboration is available, to analyse the impact of informal diffusion of knowledge on the innovation behaviour of firms. Based on the assumption that the access to new knowledge can encourage more innovation, Garcia-Torres and Hollanders create a variable indicating whether a company is mainly using informal channels of knowledge transfers. Firms need this stream of knowledge, but they must know what the main determinants of this capability are. When a firm utilizes informal knowledge channels, it is still not clear to what degree diffusion affects innovation performance. In Garcia-Torres and Hollanders (2007), these two aspects are examined by first determining the main firm characteristics enabling the use of informal knowledge transfers, and second estimating how the diffusion affects innovation success. Figure 11 illustrates this approach. Knowledge diffusion has an impact on firms. In the first step, firm characteristics that determine exposure to the diffusion of informal knowledge are examined (Figure 11 left). Depending on these characteristics, firms will be capable of using this stream of knowledge for their own innovation performance. The purpose of this stage is to determine why some firms are able to access this free knowledge to become successful innovators and others are not. This information is used to create a latent variable measuring the access of individual firms to diffusion of knowledge. In the second stage, this latent variable is used to analyse the effects of the underlying diffusion of informal knowledge on the general innovation process (Figure 11 right). The latent variable gives information on the intensity of the flow of informal knowledge.

It is important to understand the effect that R&D expenditures have on diffusion of knowledge. The R&D expenditures might be related only to this diffusion rather than effecting successful innovation. A firm’s R&D expenditures influence two different dimensions: (i) the capacity of a firm to generate innovations, considered the main goal of R&D investment; (ii) It brings the firm closer to the flow of knowledge generated by innovation activity outside the firm. R&D therefore does not affect only the firm’s capacity to generate innovations, but also fosters the access to knowledge flows of the specific sector.
Case Study Evidence 5: Diffusion of informal knowledge – Fernwärme Wien / Austria

**SYSTEMATIC sector: Energy**

Main Field of Activity: Fernwärme Wien is a publicly owned enterprise that mainly provides district heating on the Viennese heating market. The company has started to use overcapacities in its energy production (industrial waste heat) in the summer to operate a district cooling system. The company engages 1168 employees and has total turnover of €352 m.

- Fernwärme Wien strongly depends on technological developments outside the company. It uses new processes and products and applies or combines them when viable. To optimise knowledge inflows, the firm strives to benefit from a climate that fosters scientific cooperation and avoids competitive secrecy. [...] Fernwärme Wien provides an in-house climate of flexibility and supports employees working on ideas and private interests to broaden absorptive capacities for technology trends. (Friesenbichler, Unterlass 2007)

Garcia-Torres and Hollanders (2007) show that the effects of informal knowledge diffusion on innovation performance differ across SYSTEMATIC sectors. In most of the sectors better access to the knowledge base goes hand in hand with the opportunity to be both product or process innovators and to achieve higher innovative turnover shares. In none of the sectors is innovation output significantly negatively influenced by knowledge diffusion, meaning that improving knowledge diffusion conditions always fosters innovation performance. However, when informal diffusion is used to estimate the determinants of innovation success jointly with R&D expenditure and other variables, the significance of the latter falls. For instance, expenditures on extramural R&D are statistically insignificant when the diffusion process is considered, which implies that external R&D may capture important aspects of knowledge diffusion. This would also imply that extramural R&D is not really affecting innovative performance but bringing the firm closer to diffusion channels. Intramural R&D on the other hand typically seems to have a positive impact on process innovation. However, this effect becomes insignificant when considering diffusion. This is an interesting

**Figure 11: The effects of diffusion on firms and the innovation process.**

Source: UNU-Merit. For details see Garcia-Torres and Hollanders (2007).
outcome. It means that a firm’s involvement in intramural R&D does not increase the probability of being a process innovator whenever diffusion is considered. It indicates that knowledge diffusion acts as a (weak) substitute for in-house R&D. The evidence also suggests that innovation policy has to consider the prevailing situation, which determines diffusion channels (e.g. research infrastructure) and expands them to improve innovation performance.

Knowledge creation and diffusion at the sector level

Determinants of sectoral innovation performance across countries

The previous section examined the relationship between innovation inputs and innovation performance at the firm level. In this section we present results on the innovation performance of sectors across countries. Whereas firm level data come with a very high degree of variability, sector data are more homogeneous and therefore allow us to assess factors that have a significant impact on all firms in a sector better, even though some important details might be lost.

The firm level analysis has shown that country effects explain a large part of the variation. The country in which a firm operates is an important factor for innovation. In order to assess innovation performance at the sector level and to understand how national factors affect it, Crespi, Patel and Nesta (2008) have estimated sectoral knowledge production functions. Knowledge production functions capture the effect past accumulated knowledge has on the long-term growth of sectors or entire economies. The concept is related to R&D investment as firms invest in R&D to create new knowledge. However as has been argued at the beginning of this report it is not only the creation of new knowledge that matters for sectoral innovation, but also the stock of past knowledge on which firms draw in order to generate new knowledge. In other words, the cumulativeness of knowledge is an important factor in explaining innovation at the sector level. On the one hand it depends on past R&D-activities and therefore also on the R&D-expenditures, but it also strongly depends on the availability of human resources and accumulated experience.

The analysis presented here analyses the relative importance of the generation of new knowledge through R&D investment and the accumulated stock of knowledge. With this approach it is not only possible to assess the importance of cumulated knowledge in each sector, but it is also possible to find out how the prevailing national situation affects innovation performance, since past changes in any NIS are “embodied” in the stock of knowledge produced in the past.

When assessing the relative importance of direct R&D investment and the stock of knowledge, the latter turns out to outweigh the former significantly. Table 7 shows the short run and the long run elasticities of R&D investment and the knowledge stock with respect to changes in the growth of EPO patent applications in each sector. The short run elasticity for Energy production with respect to the knowledge stock (KS) indicates that a one percentage change in knowledge stock leads immediately to a 0.215 % change in the number of EPO patent applications. The figure for the R&D investment is about ten times smaller. Of course we should not forget that a percentage change of the knowledge capital stock is much larger than a percentage change in the flow variable represented by R&D. Hence, these elasticities need to be interpreted cautiously. In the long run the effect of both factors is higher, but the ratio between the two factors remains approximately the same. By and large across all sectors the impact of the stock of knowledge is four times as great as R&D investments, suggesting that the role of past experience is extremely important for future inventions. This indicates that sector specific policies for innovation may be warranted. However, the high degree of persistence and hence dependence on past knowledge indicates that the level of development of the country in which a sector is located has an impact on the nature of the innovation process there.
A regression analysis was carried out to establish to what extent characteristics of national systems of innovation have an impact on the output of the knowledge production function, i.e. patents. In Figure 3 this was depicted as interaction between the prevailing national situation and industry. The following aspects have been included in the analysis: R&D subsidies (share of BERD financed by public funds), government R&D performance (total GERD by government, IPR protection, monetary stability, freedom to trade, regulations of credit, labour and business, the percentage of domestic credit flowing to the private sector, and foreign direct investment as percentage of GDP in sectoral R&D investment. Table 8 presents a summary of the results.

The main finding is that incentives to invest in R&D are sensitive to characteristics of the NSI and characteristics of the economic environment. However, the magnitudes of the effects are highly sector specific. In fact, most variables can have either a positive or a negative influence depending on the sector. This implies that no clear picture emerges as to which factor most affects R&D investment at the sector level. For Energy, ICT and Aerospace, public R&D subsidies have a positive effect, whereas R&D spending by the government seems to crowd out investment into research and development in Textiles, Chemical and ICT. Of the variables capturing the general economic environment, free market access seems to have a positive effect in Energy and Food, while it has a detrimental effect on ICT and Aerospace. The existence of potentially detrimental effects of free market access agrees with the findings presented in the previous section, where an excess of competition (with respect to R&D investment) was found to be harmful to R&D investment. Nevertheless an increase in both competition and free market access could boost innovation at least in some sectors, whenever the degree of competition or market accessibility lies below the optimal level.

The same set of variables has also been used to explain the efficiency of research. However, it turned out that both the NSI and economic environment variables have a limited ability to explaining research productivity growth. On the other hand the measure for technological backwardness used in this analysis was found

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**Table 7: Short-Run and Long-Run Elasticities in EPO-KPF for SYSTEMATIC Sectors (1987-2000).**

<table>
<thead>
<tr>
<th>Technology users</th>
<th>Short-Run Elasticities</th>
<th>Long-Run Elasticities</th>
<th>Knowledge Capital / R&amp;D Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R&amp;D&lt;sub&gt;t&lt;/sub&gt;</td>
<td>KS&lt;sub&gt;t-2&lt;/sub&gt;</td>
<td>R&amp;D&lt;sub&gt;t&lt;/sub&gt;</td>
</tr>
<tr>
<td>Energy Production</td>
<td>0.022</td>
<td>0.215*</td>
<td>0.080</td>
</tr>
<tr>
<td>Food Production</td>
<td>0.068*</td>
<td>0.309*</td>
<td>0.160*</td>
</tr>
<tr>
<td>Textiles Production</td>
<td>0.019*</td>
<td>0.119*</td>
<td>0.114*</td>
</tr>
<tr>
<td>Chemicals</td>
<td>0.085*</td>
<td>0.311*</td>
<td>0.199*</td>
</tr>
<tr>
<td>Machinery &amp; Equipment</td>
<td>0.069*</td>
<td>0.176*</td>
<td>0.259*</td>
</tr>
<tr>
<td>ICT</td>
<td>0.052*</td>
<td>0.204*</td>
<td>0.185*</td>
</tr>
<tr>
<td>Automotives</td>
<td>0.045*</td>
<td>0.358*</td>
<td>0.100*</td>
</tr>
<tr>
<td>Aerospace</td>
<td>-0.001</td>
<td>0.201*</td>
<td>-0.002</td>
</tr>
</tbody>
</table>

Note: Italics denote non significance at 10% level. R&D<sub>t</sub>: R&D investment in sector i at time t; KS<sub>i,t-2</sub>: Knowledge Stock in sector i at time t-2.

Source: University of Sussex, SPRU, calculations. Detailed information on the data sources is available in Crespi, Patel and Nesta (2008).
to have a strong impact on productivity growth, implying that less advanced countries benefit substantially from advances in research productivity at the frontier. Overall the analysis of research productivity has shown that a convergence in patents per R&D dollar spent exists across all countries in the sample, implying that European industries overall are catching up with technological leaders in some sectors of the US and Japan. However, when looking at the different SYSTEMATIC sectors, this big picture changes. Whereas in Chemicals, Machinery and ICT a fast convergence has taken place no convergence is found in energy production, textiles, and automotives.

**Embodied technology diffusion**

The diffusion of knowledge can take place via trading goods and services. Technology streams embodied in goods and services differ strongly between industries or industry groups. These streams are strongly related to standard business streams and how suppliers and customers are connected. A company's own-R&D activity comprises only a fraction of the knowledge and technology actually appropriated by the firm. Whenever a company buys a product or new machinery, the company will indirectly buy the R&D efforts of the producers. Moreover, since in general there are many inputs necessary to produce goods (and services), the R&D efforts that have been invested in these inputs will also be indirectly bought by the final customer. This is the main reason why it is difficult to quantify the effects of direct and indirect technology diffusion using firm level data. Indirect effects are especially problematic. The report therefore returns its perspective to sector data.

Knell (2008) has used input-output-analysis to investigate the linkages amongst industries as defined in SYSTEMATIC by using a sample of 25 European countries as well as the United States and Japan. Studies of this kind are useful because they capture not only company specific R&D activities, but the role that R&D activities

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**Table 8: The relationship between R&D investment, NSI and the economic environment.**

<table>
<thead>
<tr>
<th>All aggregate sectors</th>
<th>Technology users</th>
<th>Technology producers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value added t-1</td>
<td>+ ***</td>
<td>+ ***</td>
</tr>
<tr>
<td>SUBST-1</td>
<td>- **</td>
<td>- ***</td>
</tr>
<tr>
<td>GOVt-1</td>
<td>-</td>
<td>- **</td>
</tr>
<tr>
<td>(STD) IPRt-1</td>
<td>+</td>
<td>+ + + + + + + + + +</td>
</tr>
<tr>
<td>CREDITt-1</td>
<td>+</td>
<td>+ + + + + + + + + +</td>
</tr>
<tr>
<td>(STD) MARKETt-1</td>
<td>+ + ***</td>
<td>+ + + + + + + + + +</td>
</tr>
<tr>
<td>FDIt-1</td>
<td>-</td>
<td>+ + + + + + + + + +</td>
</tr>
<tr>
<td>(STD) TRADEt-1</td>
<td>- + **</td>
<td>- + + + + + + + + +</td>
</tr>
<tr>
<td>(STD) MSt-1</td>
<td>+ + ***</td>
<td>+ + + + + + + + + +</td>
</tr>
<tr>
<td>Constant</td>
<td>***</td>
<td>- - ***</td>
</tr>
<tr>
<td>Observations</td>
<td>1774</td>
<td>174 261 237 253 254 208 225 162</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.680</td>
<td>0.917 0.929 0.812 0.928 0.951 0.951 0.940 0.897</td>
</tr>
</tbody>
</table>

Note: (**), (*) and (*) significant at 1%, 5% and 10% respectively. Variables marked STD denote standardised transformation of variable. 
(1) Energy Production; (2) Food Production; (3) Textiles Production; (4) Chemicals; (5) Machinery & Equipment; (6) ICT; (7) Automotives; (8) Aerospace. Subs: R&D subsidies (share of BERD financed by public funds); GOV: Government R&D performance (total GERD by government); IPR: Extended Cinante – Park index of IPR protection; MS: Index for monetary stability; TRADE: Freedom to trade index; MARKET: Regulations of credit, labour and business; CREDIT: Percentage domestic credit going to private sector; FDI: Flow of foreign direct investment as percentage of GDP.

Source: University of Sussex, SPRU, calculations. Detailed information on the data sources is available in Crespi, Patel and Nesta (2008)
in other industries might have on the industry under study. These externalities or spillovers as the literature sometimes calls them are important conduits of technology and knowledge transfer across industries. The core indicator of this kind of analysis is therefore the technology multiplier which is simply the ratio of total technology intensity to R&D intensity. It may be thought of as a sector measure of how much R&D in other sectors multiplies technology generation through R&D within the sector. The technology multiplier therefore indicates whether an industry is rather a technology user or a technology producer. Another aspect that is relevant in characterising industrial sectors pertains to the provision of inputs – or their backward linkages – and the utilization of the outputs – or their forward linkages. Backward linkages capture how some sectors depend on others for their input supplies. This implies also that the productive activities in a sector induce attempts to supply necessary inputs. Forward linkages in turn identify those key sectors that distribute their outputs as inputs to other industries further down the value chain. This implies that every productive activity that does not cater exclusively to final demand will induce other industries to use its outputs as inputs in new activities. This idea is not far from what sometimes is called the user-producer linkages of sectors.

From an aggregate cross country perspective Figure 12 shows that the share of company specific R&D is about one-half of the total R&D content in the more advanced European countries and somewhat lower in those countries with relatively lower company specific R&D expenditures as a share of value added. The technology multiplier may be biased upward in these countries if they trade mainly with equally less advanced countries. Nevertheless, the percentage is very similar across the Eurozone, with the United States and Japan averaging almost exactly one-half of total R&D content in each country. The slightly lower percentage found in the Eurozone average may be due to intra-EU trade. Figure 12 shows the countries in descending order expressed in terms of total R&D content. The order should not be surprising as the share of company specific R&D has little variance at the aggregate level, but countries that have a relatively low company specific R&D intensity tend to rely more heavily on embodied domestic technology flows, with some of the smaller countries such as Ireland, Estonia and Slovenia relying relatively more on R&D embodied in imported inputs.

Overall, countries with a higher per capita income tend to have higher R&D intensities in every industry, and the countries that are smaller in size tend to rely

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**Figure 12: Percentage share of total R&D content in the total economy.**

more on acquired technology. For example, Sweden appears to dominate in the R&D expenditures, and it also appears to rely relatively more on international technology in the low technology industries. Despite having one of the highest levels of international technology flows in the pharmaceutical industry, it has the lowest technology multiplier because of the predominance of R&D activities in this industry.

Knell (2008) shows that in general forward linkages are below average in the manufacturing industries and above average in the service industries. It can also be shown that service industries are the main users of products coming from the manufacturing industries, but that some service industries, such as other business services and wholesale and retail trade also showed up prominently as producer linkages in the manufacturing industries. Two conclusions can be drawn from the linkage analysis: (1) services and high-tech industries are closely related, and product-embodied R&D is essential for the relatively low-tech industries; and (2) the sectoral systems of innovation may be more important than national systems of innovation as sectors rely on typical forward and backward relationships that cut across national innovation systems.

This last statement is apparent from Figure 13, which shows the inter-industry linkages for 8 SYSTEMATIC sectors. Backward linkages are relatively more important in the food industry and forward linkages are relatively more important in computer services and software. Overall, the results from non-R&D related knowledge transfer show that technology adoption is an important source of external knowledge for almost all sectors, but especially the food and textile industries and the energy sector rely heavily on external knowledge. For these sectors embodied and disembodied knowledge transfer is more important than intramural R&D activities. This is also reflected by a comparably high share of technology modifying or adopting firms in low-tech industries, as shown in Figure 4 on page 11.

However, Figure 13 disguises considerable differences within a specific sector across countries. The ICT equipment producing industry may serve here as an

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**Figure 13:** Percentage share of total R&D content in various industries, European average.

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example. This industry as a whole tends to rely heavily on company specific R&D activity, but much of its production is being relocated to countries with lower wage rates. This is generally associated with a high amount of intra-industry trade. This may explain why Estonia has such a high share of total R&D content, although it might also be due to accounting anomalies. There is a clear pattern in telecommunications where R&D activity is located in one country, such as Sweden and production takes place in another such as Estonia and Latvia. This supports the stance advanced at the beginning of this chapter that opportunities vary according to the degree of technological advancement.

These results indicate that innovation policy should not focus exclusively on increasing the share of industries that are engaged in R&D; otherwise a broad range of innovation behaviours is neglected. As a large number of firms do not carry out R&D activities technology transfer policies remain an important element in the design of national innovation policies, especially for countries whose industrial structure is dominated by decidedly low-tech sectors.

Summary: knowledge creation as a driver of innovation

The findings presented in the previous sections on knowledge creation and non-R&D related knowledge acquisition show that in many sectors non-R&D related activities are important drivers for innovation. Knowledge acquisition from sources external to the firm is of particular importance in sectors with large shares of technology users, whereas R&D activities are important in sectors where firms dominate that are technology producers. Opportunity conditions differ systematically as a function of the level of economic development of the country in which firms are located. For firms located in countries that are less advanced technologically, frontier technology transfer and non-R&D related innovation activities are extremely important. This is true for technology intensive sectors as well as for sectors with lower technological intensity. On the other hand, for firms located on or close to the technological frontier high innovation intensity is a driver of competitiveness. In order to keep a competitive edge firms need to invest in R&D, acquire and adapt new technologies, and develop other capabilities that support ongoing innovation. Under these circumstances competition becomes a crucial driver for innovation. Indeed, one of the results of the project shows that if advanced technology producers compete with less advanced technology users, they have an incentive to reduce their R&D investment and rely

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Figure 14: Percentage share of total R&D content in the manufacturing of ICT equipment.

more on third party technologies. On the other hand, if these firms engage in competition with firms at a similar stage of technological advancement, their have a higher incentive to increase their own R&D efforts. This is compatible with findings reported later in this report on the relationship between R&D investment and the intensity of competition (see Section 3.3, page 72). Results obtained from sector level data show that on or close to the technological frontier accumulated knowledge and experience are very important for innovation performance. This implies of course that in sectors located in less advanced countries catching up depends on a gradual build up of capabilities. Therefore, convergence in innovation performance across EU member states will be slow and gradual.

The concept of distance to the world technological frontier remains somewhat vague. However, using information provided in Figure 12 where we have presented the percentage share of total R&D content in the economy for most EU member states, it is possible to classify countries as being predominantly technology producers or technology users. This gives some indication as to the level of technological advancement for technology producers.

Figure 15 shows the classification resulting from this R&D accounting exercise. Countries that score high on the “technology user” axis, such as Ireland or Hungary, rely mostly on imported technology. The value for Hungary for instance shows that the share of imported R&D is about four times the value calculated for the Eurozone. On the other hand, countries that score high on the “technology producer” axis such as Sweden, the US or Finland rely mostly on domestic technology. Four country groups can be identified: countries with a low overall technology intensity (IT, ES, PT, GR, PL, BG, LT, LV, TR), countries with a high indirect technology intensity (HU, IE, EE, CZ, SK, SI), countries with an average direct and indirect technology intensity (DE, FR, UK, AT, BE NL, NOR), and countries with a high direct technology intensity (JAP, USA, SE, FI, DK). The country group with a low overall technology intensity has a very low share of domestic technological content in GDP as compared to the Eurozone average, and is either slightly below or slightly above

Figure 15: Technology users and technology producers, based on the direct and indirect domestic and foreign share of R&D in GDP.
the Eurozone regarding technology use. The group of countries with high indirect
technology intensity has a very high share of foreign technological content in GDP,
but is below the Eurozone average concerning company specific R&D. These
countries depend strongly on direct foreign investment in their innovation
activities. The group of countries with an average direct and indirect R&D intensity
comes close to the Eurozone average in both dimensions, and finally, the group of
countries with a high direct technology intensity shows a domestic R&D content in
production that is above the Eurozone average.

Table 9 gives a first view of the relative distance to the technology frontier. The
table combines the classification of countries based on their direct or indirect
technological content presented in Figure 15 on page 49, with the country
classification provided by the European Innovation Scoreboard (EIS). The EIS
classifies EU member states as innovation leaders, innovation followers, moderate
innovators and catching up countries on the basis of a wide range of innovation
input and innovation output indicators as well as measures deriving from the
general set-up of the National Innovation Systems (NIS). It is therefore well suited
to capture core characteristics of NIS’s. The classification based on direct and
indirect technological content of the GDP of a country in turn classifies countries
into groups with a low overall technology intensity, countries with a high indirect
technology intensity, countries with an average direct and indirect technology
intensity, and countries with a high direct technology intensity.

Table 9 shows a clear pattern moving from the lower right corner to the upper left
corner of the table. Countries that have a low overall technological intensity are
either catching up countries or moderate innovators. Their position in the table
indicates that the industrial structure of these countries is biased towards low
tech sectors, but that the national innovation systems do not adequately support
innovation. Countries that have high indirect technology intensity are also mostly
moderate innovators or catching up countries, the only exception being Ireland
which is classified as an innovation follower. The innovation system in these
countries is also not favourable to innovation, but the high indirect technological
content indicates that the industrial structure is biased towards industries with
higher technology intensity. Foreign direct investment and inter-industry trade
are the cause for the high indirect technology intensity. Generally, firms in these
countries are the extended workbench for high-tech firms in economically more
advanced countries. Their industrial specialisation and their (still) favourable cost
structures attract foreign direct investment. While all of this is also true for Ireland,
the country has a more advanced and a better evolved innovation system.
Countries that are close to the Eurozone average are countries that represent the
old European industrial heartland. These are countries that have a well developed
innovation system, but their industrial structure is traditionally still biased towards

<table>
<thead>
<tr>
<th>EIS</th>
<th>High direct technology intensity</th>
<th>Average direct and indirect technology intensity</th>
<th>High indirect technology intensity</th>
<th>Low overall technology intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovation leaders</td>
<td>SE FI DK US JAP</td>
<td>DE UK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Innovation followers</td>
<td>NL FR BE AT</td>
<td></td>
<td>IE</td>
<td></td>
</tr>
<tr>
<td>Moderate innovators</td>
<td>NO</td>
<td>EE CZ SI</td>
<td>IT ES</td>
<td></td>
</tr>
<tr>
<td>Catching up countries</td>
<td>HU SK</td>
<td>GR PT PL BG LV LT</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Clusters were identified using the k-means method with the Euclidian distance measure.
Source: OECD ANBERD, EUROSTAT/OECD Input Output tables. WIFO calculations based on NIFU-STEP calculations.
medium tech sectors. In these sectors, they nevertheless perform very well either as advanced technology modifiers or as technology producers. Finally, the countries with high direct innovation intensity are also classified as innovation leaders in the European Innovation Scoreboard (EIS). They have an industrial structure that is dominated by high tech firms and also have a very favourable institutional set up. While it would be capricious to draw any resolute conclusions from this discussion, it certainly indicates that technological capabilities are very unevenly distributed across EU member states, and that a differential approach is needed to support innovation.

The link between firm types and sectoral patterns of innovation: A new taxonomy of innovation according to sectors

It is possible to develop a sector taxonomy that combines all aspects of technological regimes and entrepreneurship as discussed at the beginning of Chapter 2 and that adequately takes into account the role non-R&D related innovation efforts play in the innovation process and economic performance. CIS-3 micro data Peneder (2007) identify firm types that reflect entrepreneurial behaviour and technological regimes. By means of statistical cluster analysis Peneder constructs a sector classification based on standardised shares in each NACE 2-digit industry. Details on the identification procedure, the resulting sector classifications for each firm type, and the new innovation classification for all sectors are given in Box 1. The new SYSTEMATIC innovation taxonomy classifies sectors as being of high, medium-high, medium-low and low innovation intensity. The resulting industry classification is reported in Table 10.

Figure 16 summarises the distribution of firm types across the five categories in the final SYSTEMATIC classification of innovation. The box itself comprises the middle 50 percent of observations. The line within the box is the median. The lower end of the box signifies the first quartile, while the upper end of the box corresponds to the third quartile. In addition, the lowest and the highest lines outside the box indicate the minimum and maximum values, respectively. Panel A of Figure 16 reveals a distinctive descending order in the standardised value of the share of creative entrepreneurs involved in product innovation, which is highest in the high innovation intensity sector and lowest in the low innovation intensity sector. Similarly, we find an opposite ascending order with respect to the pursuit of opportunities other than the introduction of new products. The industry share of low innovation intensity firms is highest here. Panel B shows that high-R&D performers are very much concentrated in sectors with high innovation intensity. The differences are less obvious when looking at firms pursuing opportunities by means of the external acquisition of new technology. However, medium and medium-low innovation intensity firms have the highest median values. Low innovation intensity sectors also include many firms that pursue the external strategy. Panel C shows that formal patent protection is distinctly more frequent in sectors with high or medium-high innovation intensity. These sectors also rely more on strategic measures of knowledge protection such as secrecy. Overall the share of firms pursuing this option of appropriating knowledge is low in all sector groups. Finally, there is an almost linear positive association of the degree of innovativeness in a sector with the cumulativeness of knowledge. This is shown in Panel D. In low innovation intensity sectors, conversely, cumulativeness appears to be lower. This pattern clearly reflects the distribution of entrepreneurship firm types. However, the variation is much higher for the cumulativeness of knowledge. This indicates that sectors with high innovation intensity introduce more product innovations, but by and large their capability to do so strongly depends on knowledge and accumulated experience. Medium, medium-low and low innovation intensity sectors on the other hand rely more on imitation and the acquisition of external knowledge. This may also be because the cumulativeness of knowledge is low and, as a consequence, competition is more intense.
Box 1: Creating a new innovation taxonomy: The SYSTEMATIC taxonomy

Peneder (2007) constructs the SYSTEMATIC innovation classification on the basis of entrepreneurship types and technological regimes. Here we describe the identification strategy he uses to derive the sector classification from the distribution of firm types in each sector.

Entrepreneurship: The firm classification distinguishes between creative and adaptive entrepreneurship. Creative entrepreneurs are characterised by firm specific innovations and can be further separated into firms performing either (i) their own process innovations (CrPc), (ii) their own product innovations new to the market (CrPd), or (iii) both (CrPP). All other firms are characterised as adaptive entrepreneurs. Among them we further distinguish the group of (iv) technology adopters (AdTA), which either create product innovations that are new to the firm, but not to the market, or process innovations mainly in cooperation with other enterprises or institutions. Finally, there is a residual group of (v) adaptive entrepreneurs that pursue opportunities other than technological innovation (AdOth).

‘Technological regimes’ are characterised in terms of opportunity, appropriability, and cumulativeness conditions, the combination of which defines the particular knowledge and learning environment within which a firm operates.

- **Opportunity conditions**: The classification distinguishes four firm types according to the perceived technological opportunities evidenced by their particular innovation activities as follows: (i) **None**, if the firm undertakes neither intramural R&D nor any purchase of external innovations; (ii) **Aquisitions** (ACQU), if the firm innovates only by means of purchasing external R&D, machinery, or rights (patents, trademarks, etc.); (iii) **Intramural R&D** (IR&D), if the firm undertakes its own R&D, but the ratio of innovation expenditures to total turnover is less than five per cent; and finally (iv) **High R&D**, if the firm records intramural R&D and a share of innovation expenditures in total turnover of more than 5 per cent.

- **Appropriability conditions**: The following identification rules are used to separate firms according to their appropriability regime: (i) **None** for firms applying neither of these tools; (ii) **Strategic** for firms relying exclusively on either secrecy, complexity of design, or lead-time advantage to protect their innovations; (iii) **Formal means other than patents**, for firms which use the registration of design patterns, trademarks, or copyright; (iv) **Patents applied** (with or without strategic or other formal means), and finally (v) **Full arsenal** for firms which make use of all the three methods of protection.

- **The degree of cumulativeness of knowledge**: The CIS does not provide any direct measure of cumulativeness. Therefore an indirect identification is necessary to combine two aspects defined by the CIS. First, we differentiate according to the relative importance of internal vs. external sources of information. Second, we apply contrasting identification rules depending on whether the firm appears to be a technological leader or follower. If a firm was classified as belonging to either of the ‘creative response’ types of entrepreneurship it is now characterised as operating under a highly cumulative regime, when internal sources of knowledge are more or at least as important as external sources. Conversely, cumulativeness is considered to be low if a creative firm draws more from external than from internal knowledge for its innovations. For firms belongs to the ‘adaptive entrepreneurship’ type these rules are reversed.
### Table 10: The new SYSTEMATIC Innovation Classification.

<table>
<thead>
<tr>
<th>NACE</th>
<th>Industry</th>
<th>Entrepreneurship type</th>
<th>Opportunity / Innovation activity</th>
<th>Appropriability type</th>
<th>Cumulativeness</th>
<th>SYSTEMATIC classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>Machinery, nec</td>
<td>HCRE</td>
<td>HR&amp;D</td>
<td>PAT+</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>30</td>
<td>Computers, office machinery</td>
<td>HCRE</td>
<td>HR&amp;D</td>
<td>MED</td>
<td>Med</td>
<td>High</td>
</tr>
<tr>
<td>31</td>
<td>Electrical equipment, nec</td>
<td>HCRE</td>
<td>IR&amp;D</td>
<td>PAT+</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>32</td>
<td>Communication technology</td>
<td>HCRE</td>
<td>HR&amp;D</td>
<td>MED</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>33</td>
<td>Precision instruments</td>
<td>HCRE</td>
<td>HR&amp;D</td>
<td>PAT+</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>72</td>
<td>Computer services</td>
<td>HCRE</td>
<td>HR&amp;D</td>
<td>STRAT</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>73</td>
<td>Research &amp; development</td>
<td>HCRE</td>
<td>HR&amp;D</td>
<td>PAT+</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>17</td>
<td>Textiles</td>
<td>MCRE</td>
<td>IR&amp;D</td>
<td>MED</td>
<td>Med</td>
<td>Med-high</td>
</tr>
<tr>
<td>23</td>
<td>Ref. petro., nucl. fuel</td>
<td>MCRE</td>
<td>IR&amp;D</td>
<td>PAT+</td>
<td>High</td>
<td>Med-high</td>
</tr>
<tr>
<td>24</td>
<td>Chemicals</td>
<td>MCRE</td>
<td>IR&amp;D</td>
<td>PAT+</td>
<td>High</td>
<td>Med-high</td>
</tr>
<tr>
<td>25</td>
<td>Rubber and plastics</td>
<td>MCRE</td>
<td>IR&amp;D</td>
<td>MED</td>
<td>Med</td>
<td>Med-high</td>
</tr>
<tr>
<td>26</td>
<td>Mineral products</td>
<td>MCRE</td>
<td>ACQU</td>
<td>Low</td>
<td>Med</td>
<td>Med-high</td>
</tr>
<tr>
<td>34</td>
<td>Motor vehicles, -parts</td>
<td>MCRE</td>
<td>IR&amp;D</td>
<td>PAT+</td>
<td>High</td>
<td>Med-high</td>
</tr>
<tr>
<td>35</td>
<td>Other transport equip.</td>
<td>MCRE</td>
<td>IR&amp;D</td>
<td>PAT+</td>
<td>Med</td>
<td>Med-high</td>
</tr>
<tr>
<td>64</td>
<td>Post, telecommunications</td>
<td>HCRE</td>
<td>ACQU</td>
<td>LOW</td>
<td>Med</td>
<td>Med-high</td>
</tr>
<tr>
<td>20</td>
<td>Wood, -products, cork</td>
<td>Other</td>
<td>ACQU</td>
<td>None</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>21</td>
<td>Pulp/paper, -products</td>
<td>MCRE</td>
<td>ACQU</td>
<td>LOW</td>
<td>Med</td>
<td>Medium</td>
</tr>
<tr>
<td>28</td>
<td>Fabricated metal products</td>
<td>MCRE</td>
<td>ACQU</td>
<td>None</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>36</td>
<td>Manufacturing nec</td>
<td>MCRE</td>
<td>ACQU</td>
<td>MED</td>
<td>Med</td>
<td>Medium</td>
</tr>
<tr>
<td>62</td>
<td>Air transport</td>
<td>Other</td>
<td>ACQU</td>
<td>None</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>65</td>
<td>Financial intermediation</td>
<td>MCRE</td>
<td>ACQU</td>
<td>STRAT</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>74</td>
<td>Other business services</td>
<td>MCRE</td>
<td>ACQU</td>
<td>STRAT</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>10</td>
<td>Mining: coal, peat</td>
<td>TAD</td>
<td>ACQU</td>
<td>None</td>
<td>Low</td>
<td>Med-low</td>
</tr>
<tr>
<td>11</td>
<td>Mining: petroleum, gas</td>
<td>TAD</td>
<td>ACQU</td>
<td>None</td>
<td>Med</td>
<td>Med-low</td>
</tr>
<tr>
<td>15</td>
<td>Food prod., beverages</td>
<td>TAD</td>
<td>ACQU</td>
<td>LOW</td>
<td>Low</td>
<td>Med-low</td>
</tr>
<tr>
<td>16</td>
<td>Tobacco products</td>
<td>TAD</td>
<td>IR&amp;D</td>
<td>LOW</td>
<td>Low</td>
<td>Med-low</td>
</tr>
<tr>
<td>22</td>
<td>Publishing, reproduction</td>
<td>TAD</td>
<td>ACQU</td>
<td>LOW</td>
<td>Low</td>
<td>Med-low</td>
</tr>
<tr>
<td>40</td>
<td>Electricity and gas</td>
<td>TAD</td>
<td>ACQU</td>
<td>None</td>
<td>Low</td>
<td>Med-low</td>
</tr>
<tr>
<td>41</td>
<td>Water supply</td>
<td>TAD</td>
<td>None</td>
<td>None</td>
<td>Low</td>
<td>Med-low</td>
</tr>
<tr>
<td>66</td>
<td>Insurance, pension funding</td>
<td>TAD</td>
<td>ACQU</td>
<td>STRAT</td>
<td>High</td>
<td>Med-low</td>
</tr>
<tr>
<td>14</td>
<td>Mining: other</td>
<td>Other</td>
<td>None</td>
<td>None</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>18</td>
<td>Wearing apparel, fur</td>
<td>Other</td>
<td>None</td>
<td>LOW</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>19</td>
<td>Leather,products, footwear</td>
<td>Other</td>
<td>None</td>
<td>LOW</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>37</td>
<td>Recycling</td>
<td>Other</td>
<td>None</td>
<td>None</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>51</td>
<td>Wholesale trade</td>
<td>Other</td>
<td>None</td>
<td>None</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>60</td>
<td>Land transport, pipelines</td>
<td>Other</td>
<td>None</td>
<td>None</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>61</td>
<td>Water transport</td>
<td>Other</td>
<td>None</td>
<td>None</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>63</td>
<td>Aux. transport services</td>
<td>Other</td>
<td>None</td>
<td>None</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>67</td>
<td>Aux. financial services</td>
<td>Other</td>
<td>None</td>
<td>None</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

**Note:** 
- **EnType** – HCRE: High creative entrepreneurship with product (and process) innovations; MCRE: Intermediate creative entrepreneurship only with process innovations; TAD: Adaptive entrepreneurship with technology adoption. Other: Adaptive entrepreneurship pursuing opportunities other than from technological innovation. 
- **OpType** – HR&D: High intramural R&D (>5% of firm turnover); IR&D: Intramural R&D; ACQU: Acquisition of new knowledge (R&D, machinery, patents, etc.); None: No innovation activities. 
- **ApType** – PAT+: high use of patents and other measures; MED: Balanced use of various measures; STRAT: Strategic means; Low: Low measures for appropriation; None: no measures for appropriation. 
- **CuType** – High: High cumulativeness; Med: Intermediate cumulativeness; Low: Low cumulativeness of knowledge. For a direct application of the taxonomy on the SYSTEMATIC sectors see Box 2 on page 63. 

Source: CIII-3 data. WIFO calculations. For details see Peneder (2007).
Figure 16: Distribution of selected firm types by the TechType sector classification.

Panel A. Entrepreneurship

Type 1&2: Creative (new products)

Type 5: Others

Panel B. Opportunity condition (innovation activity)

Type 1: High R&D

Type 3: Acquisition

Source: EUROSTAT CIS-3 micro data. WIFO calculations. For details see Peneder (2007).
CHAPTER 3: MAIN DRIVERS OF INNOVATION AT THE SECTOR LEVEL AND ACROSS SECTORS

Panel C. Appropriability

Type 1: Patents+

High Med Med-high Med-low Low

Type 5: Strategic

High Med Med-high Med-low Low

Panel D. Cumulativeness of knowledge

Type 1: High cumulativeness

Type 3: None

High Med Med-high Med-low Low

excludes outside values

Source: EUROSTAT CIS-3 micro data. WIFO calculations. For details see Peneder (2007).
Table 11 compares the SYSTEMATIC classification with the more traditional R&D based classification based exclusively on R&D intensities such as the one used by the OECD. It becomes apparent that the traditional sector classification scheme based on a single innovation indicator neglects important aspects of innovation performance. The most striking difference appears in the textile sector. In the traditional classification it is considered low tech. However in the new SYSTEMATIC innovation taxonomy it is classified as being of medium-high innovation intensity. This reflects the fact that other factors such as the diffusion of knowledge, formal cooperation, design and so forth drive innovation more than R&D. This evidence implies that a classification based exclusively on R&D gives a misleading image of innovation behaviour. This misperception naturally biases innovation policy in the direction of high R&D performers, and may not lead to support of worthy innovations. As has been shown here, innovation depends on a large variety of factors and consequently innovation policy should not be based on evidence provided by one single indicator.

In Figure 3 innovation output and economic performance are shown to be directly determined by the specific ways firms engage in the creation, acquisition and transformation of knowledge to achieve innovation. An appropriate yardstick for the validity of the SYSTEMATIC taxonomy therefore is to assess whether it is able to capture the link between innovation behaviour and indicators for innovation and economic performance. Table 12 is a summary of the results of an econometric exercise carried out to test the association between innovation intensity, economic performance indicators like the growth of value added, employment and labour productivity and total factor productivity as indicators for innovation performance.

The regressions confirm a positive relationship between innovation intensity and the growth of value added and productivity. The positive association applies in particular to sectors with the highest innovation intensity and is most pronounced with respect to the growth of TFP and the level of labour productivity. In contrast, there seems to be no clear correlation between growth of employment and labour productivity. Sectors with high innovation intensity show no significant difference in the growth of employment in comparison to low innovation intensity sectors. Here the most marked difference is between medium innovation intensity sectors and industries with low innovation intensity. In the former, employment growth is significantly higher than in the low innovation intensity comparison group. However, labour productivity and total factor productivity growth are significantly lower for medium and medium low innovation intensity sectors as compared to

<table>
<thead>
<tr>
<th>SYSTEMATIC Sector</th>
<th>NACE-Code</th>
<th>R&amp;D intensity based classification</th>
<th>New SYSTEMATIC taxonomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>15, 16</td>
<td>Low tech</td>
<td>Medium-low tech</td>
</tr>
<tr>
<td>Textiles</td>
<td>17, 18</td>
<td>Low tech</td>
<td>Medium-high tech</td>
</tr>
<tr>
<td>Chemicals</td>
<td>24</td>
<td>Medium-high tech</td>
<td>Medium-high tech</td>
</tr>
<tr>
<td>Machinery</td>
<td>29</td>
<td>Medium-high tech</td>
<td>High tech</td>
</tr>
<tr>
<td>ICT</td>
<td>30-33, 72</td>
<td>High tech</td>
<td>High tech</td>
</tr>
<tr>
<td>Automotive</td>
<td>34</td>
<td>Medium-high tech</td>
<td>Medium-high tech</td>
</tr>
<tr>
<td>Energy*</td>
<td>10-12, 23*</td>
<td>Low tech (Medium-low tech*)</td>
<td>Medium-high tech</td>
</tr>
</tbody>
</table>

Source: OECD classification, CIS-3 data; WIFO-calculations. For details see Peneder (2007)
low intensity sectors, indicating that the two sector groups are losing competitiveness in comparison to the low innovation intensity industries.

Overall, the validation of the SYSTEMATIC sector taxonomy confirms significant differences across the new sector classes in terms of innovation behaviour, sectoral growth and productivity performance. Sectors classified as highly innovative show better economic performance than those sectors that are classified as low innovation intensity indicating that sectors with high innovation intensity are those that boost economic growth. However, as this section has shown, this does not necessarily mean that sectors with high R&D intensity should be the target of innovation policy. Innovation is determined by a multitude of factors. For a direct application of the taxonomy on the SYSTEMATIC sectors see Box 2 on page 63. A sector perspective is useful to understand the differences in innovation behaviour across sectors. An innovation policy that does not take this large variation into account is not likely to succeed.

**Sector specific findings on knowledge creation and acquisition of external knowledge**

- **Food**

Innovation activities in the field of R&D play a significant role for both the proportion of market novelties and new products. However, only a small number of firms invest in R&D; R&D-intensities in the food industry are quite low. New technologies and innovations produced outside the industry are more important than in-house R&D. The food industries are therefore predominantly technology users, with less than half of the total R&D content (2.4 per cent) related to company specific R&D activity. Micro-data show that food firms are also technology modifiers.

Firms in the food and beverages sector therefore regularly seek to obtain ideas for innovation by attending trade fairs and conferences and by reading scientific or business journals. Even though diffusion shows a positive impact on innovation performance, the impact is lower than average across firms and countries. Non-technological innovations related to areas such as communication, training, and distributions are similarly important for the sector in order to cope with prospective innovation challenges. ICT (as a generic technology) is an important part of food distribution, and is increasingly being used to improve efficiency at all levels of the production, processing and distribution of food. The use of ICT and e-business helps to open up new channels for marketing and distribution of

<table>
<thead>
<tr>
<th>Labour productivity 2004 in m€</th>
<th>Average annual growth in % (1995-2004)</th>
<th>Value added</th>
<th>Employment</th>
<th>Labour productivity</th>
<th>Total Factor Productivity</th>
<th>TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>+ **</td>
<td>+ **</td>
<td>-</td>
<td>+</td>
<td>***</td>
<td>+</td>
</tr>
<tr>
<td>Med-high</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Med</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>***</td>
<td>-</td>
<td>***</td>
</tr>
<tr>
<td>Med-low</td>
<td>- **</td>
<td>-</td>
<td>**</td>
<td>+</td>
<td>***</td>
<td>-</td>
</tr>
<tr>
<td>Low</td>
<td>c.g.</td>
<td>c.g.</td>
<td>c.g.</td>
<td>c.g.</td>
<td></td>
<td>c.g.</td>
</tr>
<tr>
<td>Observations</td>
<td>928</td>
<td>639</td>
<td>698</td>
<td>639</td>
<td>272</td>
<td></td>
</tr>
<tr>
<td>Adj. $R^2$</td>
<td>0.30</td>
<td>0.39</td>
<td>0.52</td>
<td>0.38</td>
<td>0.36</td>
<td></td>
</tr>
</tbody>
</table>

Note: "c.g." refers to the "comparison group." *** significant at the 1% level; ** 5%; * 10% level. County and industry fixed effects included.
Source: EUKLEMS data, WIFO calculations. For details see Peneder (2007).
niche products that challenge business operations and contributes to creating competitive advantages.

Furthermore, the share of cooperating SME’s is highly relevant in explaining variation of innovation output across countries. Suppliers and competitors that are used intensively as a source of innovation are associated with an increase in the proportion of market novelties and new products. When considering factors determining cooperation, firm size affects both international and national collaboration positively. On the other hand, foreign-owned firms appear to have much less interest in collaborating in the host economy compared with their locally owned counterparts, but being involved in international cooperation strongly increases the probability of also cooperating nationally.

• Energy

Innovation intensity is significantly and positively related to innovation success but the magnitude of effects is quite small. Firms innovating in-house tend to have higher innovation performance than others, but aggregated R&D-intensity can not explain variation in the innovation performance of countries in the Energy sector. Comparing sectors, the energy sector has the lowest company specific R&D activity making up about 0.7 per cent of value added. It tends to be a technology using sector, relying mostly on domestic inputs. For product innovation and innovative sales, the effect of informal diffusion is by far higher than in any of the other sectors. However it is irrelevant for process innovation, where innovation performance is strongly dependent on the acquisition of machinery and equipment. Most innovators are technology modifiers and adopters indicating that diffusion of knowledge is of central importance for innovation in Energy.

The same holds for cooperation. In Energy, cooperating SME’s have higher probabilities for innovation success than non-cooperating firms. Firms that make use of publicly available technological knowledge are also more likely to engage in cooperative agreements. While there is evidence that knowledge creation is a subordinate issue in the innovation process in Energy, both cooperation and diffusion of informal knowledge are of great importance for innovation success in Energy.

• Textiles

R&D intensity also positively correlates with the share of turnover from new products, but R&D intensities are quite low. This indicates that overall the opportunity conditions for technology creation are unfavourable. Textile firms rely on technologies and practices developed in other sectors. Productivity gains are achieved through innovations in the textile industry, but the clothing industry relies on sewing techniques that have barely changed over the last century. Technological innovations used in this sector are developed in other industries such as the chemical industry (fibres) and the machinery industry (computer-aided design systems). Technology transfer therefore plays a pivotal role in the textiles and clothing industries. The textile industries are therefore predominantly technology users. Less than half of the total R&D content (2.2 per cent) is company specific R&D activity. In all, diffusion of knowledge is of great importance in Textiles, reflected in technology modification and adoption as the most common innovation modes. For textile firms fairs, exhibitions and, to some extent, conferences are an important source for innovation. This factor is significantly and positively related to the share of new products.

Overall, cooperation as well as informal diffusion are important drivers for innovation. On the other hand, there is evidence that knowledge creation is a secondary issue for innovation in Textiles. As in the Food sector, innovation modes focusing on external sources are more relevant for innovation.
Chemicals

R&D expenditures are the best innovation input indicator for this industry. The sector’s R&D-intensity is comparably high. Therefore, the most common innovation modes are strategic and intermittent innovation. The European chemical industry is a technology producer with 13.7 per cent of value added produced by company specific R&D activity. In contrast, product-embodied technology diffusion accounts for only slightly more than 4 per cent of value added. Diffusion of knowledge is positively related to the innovation performance of chemical firms, but there is little evidence that diffusion of knowledge plays a central role for innovation success.

Although collaboration and the formation of strategic alliances have become increasingly important for the chemical sector, there is no evidence that cooperation is a main issue for innovation. Nevertheless, internal R&D is complemented with external links and the absorption of external sources of scientific and technological knowledge. The interaction among agents in the sector has greatly changed over time and so has the organisation of innovation. While universities and small innovative firms are key actors in undertaking basic research and developing product innovations, specialised engineering firms are still a major source of process innovation and diffusion.

When looking at factors determining cooperation agreements, it evolves that being involved in international cooperation strongly increases the probability to cooperate nationally as well. Foreign ownership appears negatively related to company specific R&D activity that would improve absorptive capacity of a firm and the likelihood to engage in innovation collaboration abroad. Furthermore, firms that make use of publicly available technological knowledge are also more likely to engage in cooperative agreements.

Machinery

The European machinery and equipment sector both produces technology and uses it, with somewhat more than 5 per cent of value added from R&D activity and somewhat less than 5 per cent from product-embodied technology diffusion. The effect of diffusion in the machinery sector on the general innovation performance of a firm is below average when product innovation and innovative sales are considered. However, the effect of using diffusion of knowledge in this sector is higher when considering process innovation. Especially general purpose technologies like nanotechnologies or ICT could find numerous applications in the machinery and equipment sector.

However, the evidence suggests that intramural R&D is the most important driver of innovation. R&D intensity strongly and positively correlates with the level of innovative activities. Strategic and intermittent innovators are frequently found among innovating firms. Incremental innovations are more important than radical product innovations, even though this industry scores highly as regards internal innovative capacities.

Users are an important source of innovation, whereas horizontal cooperation agreements for innovation are not very frequent. Nonetheless, cross-sectoral, cross-regional and international partnerships are becoming increasingly important for product and system development, especially with regard to the rise of larger multinational companies. Firm size affects international collaboration positively and being involved in international cooperation strongly increases the probability to cooperate nationally as well.

ICT

Intramural R&D in the ICT sector is positively and significantly related to product innovations. Strategic and intermittent innovators are the most common innovation modes. Furthermore, the ICT equipment sector is the most science
intensive, where company specific R&D expenditures are in the range of 24 per cent of value added, but also product-embodied technology diffusion accounts for slightly more than 24 per cent of value, indicating that Europe is both a producer and user of technology produced in this sector. In general the sector relies strongly on knowledge diffusion that is positively related to product and process innovation, as well as innovative sales. In the ICT sector forward linkages are of central importance. This means that knowledge created in ICT diffuses and creates incentives and spillover effects in the receiving sector.

According to the view of experts of the Europe Innova panel meetings, relationships between research and industry in European ICT is poor, especially for SME’s. Further private–public partnerships are needed to keep Europe at the centre of (global) developments. Firm size affects international cooperation positively and being involved in international cooperation strongly increases the probability to cooperate nationally as well. Company specific R&D activity and willingness to use publicly available technological knowledge improves absorptive capacity of a firm, which in turn increases the likelihood to engage in innovation collaboration abroad. Furthermore, affiliates of foreign companies are more likely to cooperate internationally.

- **Automotives**

Success with the introduction of market novelties is significantly and positively related to R&D expenditures. In the automotive industries, fairs, exhibitions and the use of design as part of a larger innovation strategy play a significant role in determining innovation success. Product-embodied technology diffusion accounts for less than 10 per cent, but the sector shows much stronger response to diffusion of knowledge than any other sector. Intensive co-operation with suppliers is relevant for innovation success. Company specific R&D-activities improve absorptive capacities of a firm and increases the likelihood of engaging in innovation collaboration abroad. However, contrary to most other sectors, firms with international collaborative agreements are not more likely to collaborate nationally. In all, knowledge creation and acquisition of external knowledge are importance, while cooperation with suppliers seems to be essential for innovation success in the automotive industry.

- **Aerospace**

In this sector the most common innovation mode is strategic innovation indicating that R&D based knowledge creation is highly important. However, data constraints hamper detailed evaluation of the relationship between knowledge creation, diffusion, and innovation performance. Further research is needed to clarify this.

According to expert views collaboration between the local aeronautics industry and the research community positively affects innovation in Aerospace. Even if SME’s account for a significant part of the knowledge in the aerospace sector the majority of them are component makers, which limits their abilities to innovate. Creating bridges between SME’s and universities through collaboration is therefore a key issue. Still, data constraints limit the analysis. Some results indicate that cooperation and networks are of some importance for innovation in the aerospace sector. Data constraints also hamper investigation into determinants of cooperation.

- **Eco-Innovation**

R&D expenditures are a relevant indicator explaining variation in innovation performance and the use of internal sources positively affects innovation. The most common mode is intermittent innovation. However, there is not enough evidence to clearly evaluate the importance of the relationship between knowledge creation and innovation by eco-innovators, although it is clear that the effect is in either case positive.
CHAPTER 3: MAIN DRIVERS OF INNOVATION AT THE SECTOR LEVEL AND ACROSS SECTORS

Box 2: SYSTEMATIC sectors according to the SYSTEMATIC innovation classification

**Energy production (NACE 10, 11, 23, 40):** This sector comprises two very distinct groups of industries. On the one hand, the mining industries and the sector of electricity and gas supply are characterised by a large number of technology adopters that pursue opportunities by the acquisition of external innovations and accordingly lack any measures for appropriation. The cumulativeness of knowledge is generally low or intermediate. Overall, the mining sectors are classified as industries with an *intermediate-to-low* innovation intensity. On the other hand, the petroleum industry is characterised by an intermediate share of creative entrepreneurs, substantial (though not high) intramural R&D, and an important role of patents together with other means of appropriation. The cumulativeness of knowledge is of an intermediate degree. Overall, this sector is classified by an *intermediate-to-high* innovation intensity.

**Food, beverages and tobacco (NACE 15, 16):** The main characteristic of this group is the high share of adaptive entrepreneurship, pursuing opportunities through the adoption of new technology. Accordingly, the prevalent mode of innovation activity is the acquisition of new technology with some intramural R&D as well. Appropriability conditions are generally weak and the cumulativeness of knowledge is low. Taken together, this group of industries is characterised by an *intermediate-to-low* innovation intensity.

**Textile and apparel (NACE 17, 18):** This group shows the large heterogeneity found within broad sector classes. The apparel industry exhibits *low innovation intensity* and is accordingly characterised by a predominance of entrepreneurs pursuing opportunities other than from new technology, typically performing no innovation activities nor applying any measures for appropriation. In contrast to public perceptions, the textiles sector is comprised of a substantial share of creative entrepreneurs who employ intramural R&D. However, appropriability conditions are low and the cumulativeness of knowledge appears to be intermediate. Surprisingly, this sector is classified as an industry with *intermediate-to-high* innovation intensity.

**Chemicals (NACE 24):** Operating within a regime of highly cumulative knowledge, this sector exhibits an intermediate share of creative entrepreneurs who protect their returns from intramural R&D by patents and other means for appropriation of intellectual property. The overall sector is classified by an *intermediate-to-high* innovation intensity.

**Machinery and equipment (NACE 29):** Consistent with its high share of creative entrepreneurship, the many firms performing (high) intramural R&D, an appropriability regime based on patenting and other measures, and a knowledge regime that appears to be highly cumulative, this sector is characterised by a *high innovation intensity*.

**Automotive (NACE 34):** This sector exhibits an intermediate share of creative entrepreneurship and firms that perform intramural R&D (albeit below the 5% benchmark). The cumulativeness of knowledge is high and patents are frequently used for appropriation together with other means. The final InnoType classification considers its innovation intensity to be *intermediate-to-high*.

**Electronic equipment and apparatus (NACE 30 to 33, 72):** This group is comprised of ICT-related sectors such as Computers and office machinery, Electrical equipment, Communication technology, and Precision instruments, as well as Computer related services. All these sectors are characterised by a high share of creative entrepreneurship together with many firms performing (intensive) intramural R&D. The appropriability regime depends strongly on the use of patents (frequently applied together with other measures) and knowledge appears to be highly cumulative. This group is uniformly characterised by high *innovation intensity*.

Due to data constraints not all SYSTEMATIC sectors could be classified.
Diffusion of knowledge positively affects the performance of eco innovators. However, data constraints do not allow for a clear evaluation of the degree of these effects. When looking at networks, cooperating SME’s that are eco-innovators show higher innovation success than non-cooperating SME’s. The Europe Innova expert panels support the view that cooperation is at least of some importance for innovation.

- **Gazelles**

R&D expenditures in general positively affect innovation performance of fast growing firms and in-house innovation is a relevant indicator explaining country differences. However, this research has shown that fast growing firms are quite different across countries. It has been established that the relative technological position of a country has substantial influence on the success of innovation-based growth strategies. Firm growth in countries at the technological frontier requires innovation-based strategies. Firms in catching up countries are not required to make substantial investments in knowledge creation but exploit some comparative advantage based mainly on cost differentials. Intermittent innovators and technology modifiers are the most common innovation modes for fast growing firms. In short, the importance of knowledge creation for innovation depends on the stage of development of the country in which the sector is located.

The number of cooperating SME’s is relevant in explaining country differences in innovation. Overall, we find that the collaboration behaviour is different across country groups for gazelles. Collaboration is more important for innovative firms close to the technological frontier. However, it may be that it is more important in advanced countries because firms here need to use new knowledge in innovation projects, while firms in catching up countries can still use old and available knowledge that requires skilled labour but no collaboration activity. In all, cooperation is important for innovation, but data constraints hamper the investigation of determinants of cooperation.

- **Biotechnology**

R&D expenditures and total innovation expenditures are relevant indicators explaining innovation performance in the biotech industry. The driving force of successful innovation in Europe is universities and other R&D institutions with a strong research portfolio, as well as better commercial performance. Overall, knowledge creation through R&D is of high importance for innovation success in Biotechnology.

Once a smaller firm has produced promising research results, collaboration with larger firms becomes vital for growth, since smaller companies do not possess the network and abilities to bring their results to a mass market. Thus, the quality of both incoming knowledge flows and the ability to co-operate with large firms is central to fast growing firms in biotechnology. Therefore, it is clear that cooperating SME’s are more successful in innovation. Furthermore, the increased tacit and abstract nature of the knowledge basis on which innovation draws calls for a high degree of collaboration between the actors in the biotechnology sector. Discoveries in this area are characterised by a high degree of natural excludability. Personal contacts, imitation and frequent interactions will be necessary for knowledge transmission. Confronted with expanding innovative opportunities, it appears difficult for companies, irrespective of their size, to create and control the stock of relevant knowledge on their own. Therefore participation in networks of collaboration is crucial for sustained technological and economic performances. In the case of knowledge diffusion, results are missing due to data constraints.
3.3 Markets and innovation

As argued in Section 1.1 on page v we may distinguish between two types of competition. The first relates to the activity of the “adaptive” entrepreneur, the second is more closely associated with “creative” entrepreneurs. Creative entrepreneurship is related to the exploration of opportunity through the creation of novelty. Creative entrepreneurs try to evade competition by being different from other firms and explore new opportunities that make exceptional profit possible. Adaptive entrepreneurship instead is more closely related to the discovery of opportunities through information revealed by movements in the price system. Firms seek to enhance efficiency through moves towards the current technology frontier. Adaptive entrepreneurs tend to increase competition in a sector due to the predominantly imitative and efficiency improving behaviour of their firms. They try to exploit existing opportunities, thereby gradually erasing exceptional profits of creative entrepreneurs.

Both concepts of entrepreneurship are closely related to the exploration and exploitation of opportunity. The opportunity conditions shown in Figure 3 on page 9 to be an important determinant of innovation behaviour; however, they cannot be explained solely by technology. They relate to profit in general and hence reflect “patterns of technology and tastes and the nature of price competition in the market” (Sutton 1998, p. 70). The behaviour of consumers or of users of a product more generally therefore affects the profitability of products and thereby acts as important source and incentive for innovation. It is therefore important to assess the role the demand factors play for innovation in each sector. Table 2 shows that demand factors are important drivers of innovation in almost all sectors and that unlike with knowledge creation and the acquisition of external knowledge there is no clear pattern across sector classifications.

Case Study Evidence 6: Competition – Johnson Matthey / UK

**SYSTEMATIC sector: Chemicals**

*Main Field of Activity*: Johnson Matthey is the leading manufacturer and developer of chemical process catalysts, which are used in a range of industrial processes. The company is also a leader in diesel emission control technologies for both heavy and light duty diesel applications. The company engages 7800 employees and has a total turnover of about €6.6 billion.

- “Competition is a good thing, it is inspiring, it keeps you on your toes and urges you to perform better.” Martyn Twigg, Chief Scientist – Johnson Matthey (Rajan 2008)

Competition is based on the interplay between the creation of novelty and imitation, between creative entrepreneurs and adaptive ones. The prospect for creative entrepreneurs to gain higher profits acts as an important incentive to invest in R&D and other innovation activities. However, if these profits dissipate too quickly because of imitators incentives to engage in risky research are dampened. This relationship is examined at the end of this section. Table 2 indicates that in some sectors there is an inverted u-shaped relationship whereas in others competition is always positive for innovation.

The role of demand and lead markets

Industrial researchers access external knowledge through many channels. Von Hippel (1988) stresses the importance of customers and end-users as sources of innovation. The author demonstrates that innovation is often driven by customers and end users of products and services. Firms benefit from these customer-driven innovations either through direct observation of the customers’ use of the firm’s
products, or through the customers’ active modification of products (von Hippel, 1988). Innovations developed by end users sometimes become the basis for important new commercial products and services. It has also been argued that such innovations are concentrated in a “lead user” segment of the user community. Morrison, Roberts and von Hippel (2000) show that lead users with sufficient technological expertise often generate product adaptations or solutions with immediate commercial potential for the seller. Therefore it is expected that customer-oriented companies offering increased customer contact are more likely to identify opportunities to develop new products or markets.

Case Study Evidence 7: Demand and user-producer linkages – AVL Group / Austria

**SYSTEMATIC sector:** Automotives

**Main Field of Activity:** AVL is the world’s largest privately owned and independent company for the development of powertrain systems with internal combustion engines as well as instrumentation and test systems. The AVL Group has 3,640 employees (1,550 in Graz and another 2,090 worldwide), and produced €537 million turnover in 2006.

- Car manufacturers are very important clients of AVL when planning research projects. Clients frequently request new solutions for engines, minimising fuel consumption, noise and CO2-emissions. Whenever there is a request for a new product, a department plans the required project. AVL itself also actively seeks clients with problems and interests which can be solved by the company. AVL then makes a proposal to keep the client up to date. This kind of communication strongly depends on the know-how of the client who might ask for products that are impracticable. (Unterlass 2008)

In the SIW project Cleff et al (2008) we have evaluated CIS data in order to assess in which sectors demand is highly important. They show that a total of 26 percent of innovators assess the importance of their customers’ role as high. This is the second most important source of innovations (with enterprise factors being the most important one). Whether or not it is considered necessary to intensively involve customers in the innovation process varies from sector to sector. Compared to other sources users are a very important source of innovation in the automotive industry, the machinery and equipment industry, the ICT sector, the chemical industry, for eco-innovators and for biotechnology firms. While at first it may seem reasonable to assume that sectors in which customers drive innovation should experience fewer problems with customer acceptance of their new products, the data show that this is not the case. As a matter of fact, the results of Cleff et al (2008) show the opposite. As the importance of the customer for the innovation process increases, so does the company’s awareness of the customer as a potential obstacle to innovation. This may be because firms that see demand as an important source for innovation are also more likely to explicitly target customers in their innovation efforts, and as a consequence are also more likely to experience a failure in their innovation efforts.

Besides this pure statistical explanation, it is well known that firms may face an innovators dilemma (see Christensen 1997) if they focus too closely on one specific group of customers. They may loose sight of the developments in potential new markets and as a consequence not be able to enter them because they lack the competence to understand customer needs there. On the other hand, companies that aim to work closely with their customers are often faced with a range of completely different demands, since their clients live in different contexts or, in the case of companies that mainly supply other firms, the various
firms supplied may produce entirely unrelated goods. The customers’ preference structures are therefore not necessarily congruent. On the other hand, in some industries, such as the machinery industry, the customer is also often the sponsor of a product. As a consequence, the customers are also more likely to be satisfied with their purchase. Where the relationship between customer and supplier are more anonymous and demand factors are important, failures are more likely.

These aspects seem to be a problem for many fast growing firms and also for biotech firms. A large number of firms in space and aeronautics as well as in the food and drink industries report the same problem. In these sectors, demand is therefore of above-average importance both as a source of innovation and as a hampering factor. For the machinery and equipment industry and the ICT sector demand is instead an important source for innovation, and customer responsiveness seems not to be perceived as a problem. In markets with a strong international focus, innovations must also aim to meet the needs of foreign customers. It is more difficult to take such international customer needs into account, because customer preferences can vary between different countries or markets. This is the heart of the problem for innovation strategy.

The company’s customers may be in different regional or national contexts and sometimes at different stages of technological development. Nonetheless, they all expect innovations perfectly adapted to their respective technical applications. However, increasing costs for R&D and the increasing need for standardisation and interface compatibility mean that there are economic and practical barriers to national or customer-specific solutions. These barriers compel manufacturers of new products to choose a particular path for their technological development or to opt for a particular design of innovation. Customers will only be prepared to forgo innovations tailored to their needs if the cost savings offered by a new design, which result from standardisation and network effects, are high enough to justify abandoning the current technology. The question remains, however, of where – i.e. in which region and with which customers – the “successful” innovations of the future will be designed. We can consider “successful” designs to be those which first enjoy early national success, then successfully commercialise worldwide and force other innovation designs out of the market in the medium term, to become the world standard. These are the problems entrepreneurs face when they try to introduce novel products in the market.

Case Study Evidence 8: Demand and user-producer linkages – AVL Group / Austria

**SYSTEMATIC sector:** Automotives

**Main Field of Activity:** AVL is the world’s largest privately owned and independent company for the development of powertrain systems with internal combustion engines as well as instrumentation and test systems. The AVL Group has 3,640 employees (1,550 in Graz and another 2,090 worldwide), and produced €537 million turnover in 2006.

- AVL’s greatest risk is to focus on the wrong technology while its competitors research technologies which become accepted. Although the company is active in a high risk research field [...] it is very dangerous to waste time by working too long on the wrong technology. That is why it is very important to correctly predict future developments in technology. AVL’s strength in evaluating risks and potentials and in choosing promising technology trends to follow makes for the company’s success and thus its being an innovation leader. (Unterlass 2008)
How is it possible to recognise from the data whether individual sectors manage to utilise demand as a source of innovation successfully? If innovations bring in high export revenues in a context where customers are important drivers of innovation, this is a sign that the innovation design that meets demand preferences can also dominate abroad. On the other hand, if export shares are low, then firms are likely to be able to meet only very localised preferences and are not able to capture the larger international markets. The CIS data show that this is a problem for pharmaceutical and ICT firms. Fast growing enterprises, the food and drink industry and also the energy production sector face the same problem. The textile industry as well as the space and aeronautics industry are very successful exporters, even though for these industries demand is a subordinate source of innovation.

This reasoning allows us to identify lead markets. If customers are an important source for innovation, but export shares are low, this would indicate consequently that the demand the firms in the sector serve is rather idiosyncratic and does not meet broad tastes. A Lead Market is characterised by the fact that the innovation designs adopted there have an advantage over other country-specific innovation designs competing globally to set an international standard. This advantage leads consumers from other countries to follow the technological standard of the lead market and adopt the design preferred by users there. Lead market characteristics are essentially features of the national innovation system.

There are five factors that determine a Lead Market as illustrated in Figure 17:

1. Markets can gain a price advantage if the relative price of the nationally preferred innovation design decreases. This should compensate for differences between the design and the demand preferences in foreign countries. This is measured by PPP’s.

2. A national demand advantage results from local conditions that facilitate the adoption of nationally preferred innovation designs in foreign markets. This advantage occurs mainly because a country is at the forefront of an international trend. It is based on the calculation of an individual country’s demand specialisation as measured by the share of total demand captured by a sector.

Figure 17: The five Lead Market Factors.
There is an **export advantage** if the domestic demand responds sensitively to global developments. In such cases, domestic users are frequently more aware of global problems and needs than potential adopters in other countries. This is measured by a revealed comparative advantage (RCA) measure.

A country can have a **transfer advantage** if its market has strong communication ties with other countries. The adoption of an innovation design in one country can influence the adoption decisions of users in other countries because the perceived benefit of an adopted design increases for users in other countries. This is proxied by FDI to measure the international diffusion of innovations.

Lead Markets are very competitive markets. First of all, buyers tend to be more demanding when they face competition than when they are tightly regulated or hold a monopoly. More innovation designs are tested in a competitive market than in a monopolised market. A competitive market is subsequently more apt to find a design that is not only the best within the domestic environment but also the best across all national environments. This is defined as the **market structure advantage**. This is measured by differences in the entry rate in the same sectors across the EU member states.

According to these criteria, Cleff et al (2008) singled out countries where each of the SYSTEMATIC sectors has a Lead Market potential. Table 2 shows the numbers of countries of the specific sector which meet the Lead Market criteria in at least three of the five dimensions mentioned above.

### Case Study Evidence 9: Demand and user-producer linkages – Unilever / The Netherlands

**SYSTEMATIC sector:** Food

**Main Field of Activity:** Unilever provides products that fulfil everyday needs for nutrition, hygiene, and personal care. Unilever operates on a global scale. The company develops global brands and has a portfolio of large global brands including 12 with an annual turnover greater than €1 billion.

- The consumer interest in quality and variety is a key driver of the innovation by Unilever. The customer is given an active role in design of future products and the choice amongst a broad range of food products — consumer acceptance is the final criterion for a successful market introduction. Consumers’ points of view are taken into consideration at every stage of food product development, processing and marketing (the ‘fork-to-farm’ perspective). (van Halen 2008)

Table 2 shows that the ICT sector has a Lead Market potential in 6 EU member states, followed by the machinery and equipment industry, the automotive industry, the energy sector, and the food and drink industry, who all have a strong Lead Market potential in at least five EU member states. More details are given in the section on sector specific findings below.
**Case Study Evidence 10: Demand and user-producer linkages – Vaisala / Finland**

**SYSTEMATIC sector: ICT**

**Main Field of Activity:** Vaisala’s core business is environmental measurement, especially weather measurement and corresponding industrial measurements. It has been a science-driven company operating in global markets since it was established in 1936 and was considered the flagship of technology industries in Finland for decades before the rise of telecommunications and Nokia. Vaisala has been a pioneer in its sector, basing its competitive advantage on a long tradition of developing innovative products that are based on the latest scientific research. The company engages 1069 employees (2006).

- The most difficult barrier is small domestic markets and knowledge resources that are too small or limited for companies such as Vaisala working in niche product markets. Even considerable public support cannot drive the domestic markets sufficiently to have an impact on R&D activities. (Viljamaa 2008)

This section has shown that demand is an important source and therefore driver of innovation. Demand factors capture important aspects of the opportunity conditions firms face. The failure to introduce innovations successfully into the market will have repercussions for the willingness of firms to engage into innovation. These kinds of risks can be the result of unknown demand conditions, but demand fluctuations can also cause uncertainty about sales potentials of innovative products. Failures to introduce innovations are often related to difficulties in choosing markets on which to focus and in internal organisation of the innovation process, where the marketing department and the R&D department are often not well coordinated within a firm (see for instance Rosenberg and Kline 1986).

**Competition**

As the discussion at the introduction to this section has argued, a competitive environment of an economy is an important driver of productivity and innovative activities. The main reason competition is positive for productivity is that it fosters the efficient use of resources. However, competition is even more important for innovative activities as it is an incentive for firms to seek setting themselves apart from competitors and thereby establishing their own market niches. This can be done by developing new technologies or exploring new markets. Hence, when considering the prevailing situation that influences innovative behaviour of industries it is important to consider the competitive environment first. Recent advances in economic theory suggest that the relationship between competition and innovation activities follows an inverted U shaped pattern. This means that competition has a positive effect on innovation up to a certain point, after which competition decreases the levels of innovative activity. This relationship is stronger the closer the industries are to their world technological frontier, which implies that the cost of foregone innovation because of too little competition increases for more developed industries close to the technological frontier.

The reason for such a non-linear interdependence is that firms compare profits before and after an innovation. If firms are in a less advanced industry the threat that a technologically more advanced competitor might enter the industry discourages firms to invest in R&D. This is because the likelihood that the investment eventually will not improve their competitiveness vis-a-vis the technologically more advanced competitor is high. However, when the firms are
in an advanced industry, the reverse holds: R&D investment is likely to fend off a technologically advanced competitor. Competition therefore encourages innovation activities. This relationship has been studied by Crespi and Patel (2008a). Using OECD data they studied the relationship between R&D and competition for the pooled sample of industries, but also for eight systematic sectors. As Figure 18 shows, there is indeed an inverted U-shaped relationship between R&D investment and competition as measured by the gross margin in each industry. This result confirms what economic theory suggests and what other studies have found as well: firms have little incentive to invest in R&D if they are not stimulated by competition; conversely too much competition discourages investments in R&D activities because the likelihood that firms will not be able to reap the benefits of their efforts increases.

Crespi and Patel (2008a) also show that the effect of competition on innovation declines when a country lags behind the technological frontier. For many countries and sectors the effect of competition is positive. However, for those cases where sectors are less advanced technologically more competition could actually harm innovation. This implies that more competition initially might not be a good idea for less advanced. However, as they pass productivity thresholds competition would become a valid option for stimulating innovation. This means that in less advanced countries competition policies should not be too strict, and temporarily allow for higher market concentrations.

There is an inverted U shape relationship between competition and R&D across countries and sectors. However results between sectors are quite mixed. Figure 19 and Figure 20 present evidence of an inverted U-pattern in the food, chemical, machinery and equipment and the automotive industries, a concave pattern in the energy sector and for the aerospace industry and an increasingly linear pattern for the ICT sector. Finally, the results for the textile sector are very different, showing a U shaped relationship between innovation and competition.

These findings imply that in general increased competition may be a good thing but that this is different across sectors. Figure 19 and Figure 20 show that more
competition is always good for innovation in ICT, the energy sector and the aerospace industry. In the other sectors, more competition is good up to a given threshold but then has a negative effect on R&D investment. This is the case for the automotive industry, the machinery industry and the food sector. These could form excessive competition in some countries. A peculiar case is that of the textile industry where a U-shaped relationship between competition and R&D investment is found. A possible explanation for this evidence may be that in our research we looked at the textile and the apparel producers as a group. In the apparel industry, more competition may be beneficial and drive firms to develop and introduce new logistic innovations (e.g. H&M), whereas in the textile sector, especially in the field of technical textiles firms may occupy well delimited niches with relatively small market sizes, such that more competition may lower profits and as a consequence R&D efforts. Here further research is needed to confirm this hypothesis.

Further analyses show that in the energy sector and the chemical industry the probability that competition would have a harmful effect on innovation is almost zero. However, for almost 40% of the observations for the food sector the effect of competition on innovation was negative, whereas in the textile sector this goes down to 30% and to somewhat more than 20% for the automotive industry. For all other sectors there is convincing evidence that in general competition is good for innovation. However, the degree of disparity both across and within sectors is very large.

Overall the findings suggest that competition is “on average” a good thing for innovation activities across all the systematic sectors. However, the actual impact in any particular country might also depend on initial competition in that country. Given the inverted U pattern observed in many cases, some sectors in particular countries might suffer from “excess of competition” for R&D investment. In such a situation policy makers have to establish whether the losses from growth due to lower R&D investment outweigh the cost savings to consumers due to lower prices resulting from higher competition.

Figure 19: The simulated relationship between competition and R&D: Energy, Food, Textiles and Chemical.

Source: OECD data, University of Sussex – SPRU calculations. For more details see Crespi and Patel (2008a)
Sector specific findings on markets and innovation

- **Food**

Consumer and market needs are an essential part of the food development process. The vital relationships with the consumer and the credibility of the sector are therefore key issues for innovation. Hence, customers’ preferences are crucial sources of innovation, and a number of factors can play a role in shaping future demand. These include changes in demography and the socio-economic environment, busier lifestyles of many customers, increased awareness about the relation between health and nutrition, environmental and safety concerns, as well as changing demand patterns due to migration and the emergence of ethnic food. The evaluation of CIS 3 data shows that firms in the food sector do not consider customers to be an important source for innovation. There is also no clear evidence determining whether demand factors are a driver or a hampering factor for innovation. Lead Market characteristics are present the food industry in Spain and the Netherlands and to some extent also in Latvia, Lithuania and the United Kingdom.

When looking at competition, there is evidence of an inverted U-pattern between competition and innovation, and free market access also seems to have a positive effect on innovation. Competition amongst established firms is constructive only up to a given threshold.

- **Energy**

Innovation in energy production cannot rely on product differentiation and therefore on market pull forces. Firms in the energy production business compete through efficiency and competitive pricing in delivering the same product. Demand seems not to be relevant for innovation in the energy sector. The demand for environmentally friendly forms of energy production have some influence. Energy suppliers serve well-defined regional markets and therefore export intensity is generally not very high. A strong Lead Market

**Figure 20:** The simulated relationship between competition and R&D: Machinery, ICT, Automotive and Aerospace.
potential has been identified for French energy suppliers. Some lead market potential is also present in the energy producing sector in Cyprus, Italy, Latvia and Lithuania.

The analysis of competition shows that there is evidence of a concave pattern between competition and innovation. Free market access has a positive effect on innovation. More competition is always good for innovation in energy production; the probability that competition could have a harmful effect on innovation is almost zero.

• **Textiles**

Innovation performance in the textile industry correlates positively with the proportion of firms in the industry selling their products in international markets, favourable demand conditions and demand stability. However, the technical textile sector and the clothing industry sector are driven by different factors: the former is characterised by technology-driven innovation whereas innovation in the clothing sector is more market-driven and fashion sensitivity of the market is an important determinant. On the technical textile side, it has also been noted by the Europe Innova Panel of experts that most people have traditional expectations for textiles and this undermines innovation. On the other hand, since industrial textiles are generally not fashion oriented, performance requirements and technical specifications determine the success of a product. Industrial textiles are usually created in close cooperation between the producer and the consumer so as to ensure custom-made solutions for user specific purposes. In all, the evidence clearly shows that demand is an essential determinant for innovation success in this industry. The lack of consumer responsiveness is also not perceived as an important obstacle to innovation. Most firms in the textile industry serve well-defined international markets. However, a very strong Lead Market potential was identified only for the textile industry in the UK. At some distance follow the textile industries of Austria, the Czech Republic, Finland, Germany, Italy, the Netherlands and Spain.

In contrast to all other sectors, there is evidence of a U-shaped relationship between competition and innovation investment, which means that firms with high profit margins potentially engage in more innovative activities. On the other hand, firms with very low profit margins also innovate in order to shield themselves from strong competition in specific market niches. However, more research is needed to explore the relationship between competition and innovation expenditures in this industry.

• **Chemicals**

In the chemical industry innovation performance correlates positively with the proportion of firms that are active internationally. The economically most important innovations in the chemical sector are driven by demand; customers are the dominant source for innovation. Many of the chemical firms that were interviewed mentioned that they implement the lead-user concept in their innovation projects. This is particularly relevant for new markets for environmentally-safe and less polluting products. Despite this first step into the open innovation paradigm, a large share of chemical firms surveyed in the CIS perceives the lack of customer responsiveness to innovations as a significant hampering factor for innovation. There is a clear Lead Market potential for the chemical industry only in the UK and in France.

The relationship between competition and innovation follows an inverted U-pattern. Competition is good up only up to a given threshold. However, the probability that competition has a harmful effect on innovation is almost zero since the threshold is very high.
• **Machinery**

Innovation performance in machinery is correlated with international orientation of firms in the industry and demand stability. Customers buy engineering equipment for reasons of quality and reliability. Stable reliability of supply builds up commercial good-will over time, and this is an important aspect of the market success of firms. Demand and stable customer relationships therefore influence innovation. Most likely due to the close relationship firms in the machinery sector maintain with their customers the lack of customer responsiveness to innovations is not perceived as a major obstacle to innovation. Lead Market potential has been identified for the Czech, the French, the German, the Dutch and the British industries.

As an inverted U-pattern between competition and R&D investment is determined in this sector it can be concluded that competition is good only up to a given threshold after which there are diminishing returns.

• **ICT**

For the ICT industry the size of the market and the number of firms active internationally are very important factors for innovation performance. The Europe Innova Panel experts agree that public procurement is also an important driver of innovation in the sector. Demand conditions therefore seem to be very important for the innovation process in the ICT sector. Unlike other industries, firms in the ICT sector do not find the lack of customer responsiveness a significant hampering factor for innovation. Lead Market characteristics were identified for the ICT industry in France, followed by the UK and Finland. The ICT industry in Belgium, the Netherlands, and Sweden still shows lead market characteristics in three of the five dimensions mentioned above.

The relationship between competition and R&D investment is characterised by an increasingly linear pattern indicating that increased competition is good for innovation.

• **Automotives**

Customer willingness to pay for innovative products is a decisive factor for automotive innovation. The success of companies depends heavily on supplying the market with vehicles that closely meet customer tastes and needs. In this highly competitive sector, innovation plays an important role in attracting new customers. Motorcar companies can focus on product innovation by designing attractive car models that sell in large quantities or on process innovations that tap all available sources to achieve higher cost efficiency and productivity. Furthermore, worldwide demand for safer and more environment friendly vehicles drives research and innovation in power trains, fuels, electric vehicles and lightweight materials. In short, demand is a crucial factor for innovation success in the automotive industry. Despite this many firms indicate the lack of customer responsiveness to be a major hampering factor to innovation. The industry has a lead market profile in France and Germany, and to a lesser extent in Belgium, Spain and the UK.

The relationship between competition and innovation follows an inverted U-pattern; more competition is good only up to a given threshold followed by diminishing returns. On the other hand, entering a new market seems to have a detrimental effect on the innovation performance of the sector. This may reflect the effect of accumulated knowledge on the industry.

• **Aerospace**

Public procurement is a major driver of innovation in the aerospace sector. This puts European firms at a disadvantage, as their home market is smaller than for instance that of US companies. Public demand for aerospace products in the US is
almost four times as large as in the EU. Despite the importance of the demand side and public procurement for this industry a large share of firms perceive the lack of customer responsiveness as a hampering factor for innovation.

The results for the relationship between competition and R&D investment are comparable to those in the ICT sector. There is evidence of a concave pattern such that more competition always has a positive impact on innovation. On the other hand, entering a new market seems to have a detrimental effect on the innovation performance of the sector. This may reflect the effect that accumulated knowledge has for innovation in this industry.

- **Eco-Innovation**

The evidence for eco-innovators suggests that customers are a relevant source for innovation but resistance to innovations is also perceived to be a major hampering factor. Demand factors are somewhat important for innovation by eco-innovators. The role of lead markets and the relationship between competition and R&D investment could not be analysed due to data constraints.

- **Gazelles**

There is no evidence that demand plays a role for innovation by fast growing firms. Neither do firms indicate that they perceive customers as an important source for innovation nor do they indicate that the lack of customer responsiveness is a hampering factor for innovation.

The relationship between competition and R&D investment could not be analysed in this sector due to data constraints.

- **Biotechnology**

The healthcare sector is the largest market for biotechnology products at the moment. Other domains of biotechnological applications play a relatively marginal role. As a consequence public procurement is very relevant for firms producing biotech products. Even though the consumer market potential is very large, in the past problems of acceptance by the civil society of biotechnological products (esp. GMO’s in agrofood) has had a relevant impact on innovation activities by biotech firms. Whenever the public does not accept new products, firms will not invest in their development. The demand side is therefore highly important for innovation in biotech firms. The impact of competition on R&D efforts in the sector was not analysed due to data constraints.

### 3.4 Innovation environment

The sectoral innovation model presented in Figure 3 on page 26 assumes that innovation behaviour at the sector level is influenced by a number of country specific factors. In previous chapters of this report it has also been argued that a considerable part of the variation in several innovation indicators, such as sectoral R&D intensity, is explained by the interaction effect of sector and country characteristics. In the SIW project three aspects of national innovation environments that may have a significant impact on innovation behaviour were examined. Two of these reflect the activity of national governments and regulators — regulation and the incentive friendliness of the tax system — and one looks at soft factors called “innovation culture”.

#### Regulation

Regulatory activities include laws that influence the decision-making behaviour of firms. In the context of innovation, they may provide incentives to encourage or deter firms from conducting particular innovation activities. Regulatory activities might also hamper innovation by critically limiting innovation processes for
ethical, environmental or other reasons. It is important to differentiate between various types of regulation: The SIW project has analysed:

- Regulatory activities that establish particular technical standards that must be fulfilled by a firm that wishes to engage in innovation or production activities.
- Enforcement of regulations by the price mechanism that directly influences a company’s decisions.
- Regulation of the quality of a product.
- Changes in the rules for the protection of intellectual property, i.e. patents, that grant a temporary monopoly to the patent holder. These can substantially alter incentives to innovate.

Technical norms are most frequently used in the member states followed by regulation of quality, IPR regulation and price regulation. Sectors with the highest instance of regulations are the biotechnology, food and drink, chemicals, energy and eco-innovation industries. In contrast to regulation via technical norms, quality and the IPR system, it is price that proves to be rather uncommon in the various countries. In short, the overall evaluation of regulation with regard to its impact on innovation activities of companies in the member states tends to be positive.

When looking at regulation as a driver for innovation among the observed industries, chemical firms account for the highest share of firms that report fulfilling regulations through their innovation activities. This sector is followed by the food, energy and automotive sectors. As previously reported, these results can be explained by the exposure of these industries to regulations which are more pronounced in environmental and consumer sensitive sectors. Compared with other effects on innovation activities, however, the importance of complying with regulations is rather low.

On the other hand, regulation is also perceived as a barrier to innovation. The results by Cleff et al (2008) presented in Table 13 below show that the observed companies rank the insufficient flexibility of regulations and standards 6th out of 9 innovation barriers. The number companies that rated regulation as a highly important innovation barrier equals almost 8 percent. Given the rank of this particular hampering factor for innovation amongst the other hampering factors, regulation does not seem to be significant amongst influential innovation activities.

Table 13: Barriers to innovation perceived as high by all companies.

<table>
<thead>
<tr>
<th>Innovation barrier (high)</th>
<th>All companies (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovation costs too high</td>
<td>23.9</td>
</tr>
<tr>
<td>Lack of appropriate sources of finance</td>
<td>18.8</td>
</tr>
<tr>
<td>Excessive perceived economic risks</td>
<td>16.4</td>
</tr>
<tr>
<td>Lack of qualified personnel</td>
<td>11.1</td>
</tr>
<tr>
<td>Lack of customer responsiveness to new goods or services</td>
<td>8.2</td>
</tr>
<tr>
<td>Insufficient flexibility of regulations or standards</td>
<td>7.9</td>
</tr>
<tr>
<td>Organisational inertia within the enterprise</td>
<td>6.0</td>
</tr>
<tr>
<td>Lack of market information</td>
<td>5.4</td>
</tr>
<tr>
<td>Lack of technology information</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Case Study Evidence 11: Regulation – Johnson Matthey / UK

SYSTEMATIC sector: Chemicals

Main Field of Activity: Johnson Matthey is the leading manufacturer and developer of chemical process catalysts, which are used in a range of industrial processes. The company is also a leader in diesel emission control technologies for both heavy and light duty diesel applications. The company engages 7800 employees and has total turnover of about €6.6 billion.

- Much of the stimulus for the development and growth of Johnson Matthey’s products arises from new legislation governing the environmental or health impact of its customers’ products in different jurisdictions worldwide. This is most significant for Environmental Catalysts and Technologies where historic and future growth depend on global tightening of emissions limits for on-road and off-road vehicles. (Rajan 2008)

An assessment by sector experts showed that in most sectors the effects of regulation acts as an incentive for innovation. Table 14 below gives some evidence for this. It presents the frequency with which firms have cited regulation as the outcome of their innovation efforts. “Meeting regulations” figures rather prominently. The case studies reported in this section also testify to the importance of regulations as a driver for innovation. Only in the automotives and aerospace industries do experts indicate that the effect of regulations is not always positive and that their role as driving factor or obstacle depends on how well the technological and market aspects in a specific sector are taken into account. The effect of regulation is also ambivalent. On the one hand, lack of regulatory convergence within Europe hampers trade and therefore reduces innovation incentives because potential benefits of innovation are reduced due to small markets. On the other hand, regulation as a driving force for environmental and technical standards encourages innovation, especially, for instance, for automotives. However, there are large differences across sectors, regarding which areas of regulation are important for innovation. The degree of the impact of regulation on innovation differs across sectors according to sector experts.

Table 14: Effects of innovation activities.

<table>
<thead>
<tr>
<th></th>
<th>Food</th>
<th>Textiles</th>
<th>Chemicals</th>
<th>Machinery</th>
<th>ICT</th>
<th>Automotive</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased range of goods</td>
<td>36.8</td>
<td>32.9</td>
<td>42.6</td>
<td>37.8</td>
<td>48.8</td>
<td>40.8</td>
<td>15.0</td>
</tr>
<tr>
<td>Increased market share</td>
<td>32.2</td>
<td>23.1</td>
<td>36.2</td>
<td>32.4</td>
<td>40.7</td>
<td>35.3</td>
<td>17.2</td>
</tr>
<tr>
<td>Improved quality</td>
<td>40.9</td>
<td>33.4</td>
<td>39.3</td>
<td>36.4</td>
<td>45.4</td>
<td>42.6</td>
<td>30.2</td>
</tr>
<tr>
<td>Improved production flexibility</td>
<td>22.9</td>
<td>24.1</td>
<td>20.3</td>
<td>22.0</td>
<td>26.6</td>
<td>24.3</td>
<td>18.4</td>
</tr>
<tr>
<td>Increased production capacity</td>
<td>29.5</td>
<td>20.5</td>
<td>23.7</td>
<td>17.8</td>
<td>21.1</td>
<td>28.1</td>
<td>14.0</td>
</tr>
<tr>
<td>Reduced labour costs</td>
<td>21.9</td>
<td>16.2</td>
<td>18.2</td>
<td>13.1</td>
<td>15.1</td>
<td>23.3</td>
<td>10.4</td>
</tr>
<tr>
<td>Reduced materials</td>
<td>13.3</td>
<td>9.9</td>
<td>13.1</td>
<td>8.2</td>
<td>4.8</td>
<td>14.6</td>
<td>13.7</td>
</tr>
<tr>
<td>Improved environmental impact</td>
<td>20.0</td>
<td>12.0</td>
<td>25.8</td>
<td>14.0</td>
<td>4.9</td>
<td>20.4</td>
<td>31.3</td>
</tr>
<tr>
<td>Met regulations</td>
<td>26.9</td>
<td>14.1</td>
<td>28.2</td>
<td>14.9</td>
<td>14.2</td>
<td>20.4</td>
<td>26.0</td>
</tr>
</tbody>
</table>

Case Study Evidence 12: Regulation – Unilever / The Netherlands

**SYSTEMATIC sector:** Food

**Main Field of Activity:** Unilever provides products that fulfil everyday needs for nutrition, hygiene, and personal care. Unilever operates on a global scale. The company develops global brands and has a portfolio of large global brands, including 12 with an annual turnover greater than €1 billion.

- Changes in food regulation can have an extreme impact on business models and value chains. Increasing regulation of products can have both a positive and a restrictive impact on innovation. (van Halen 2008)

Case Study Evidence 13: Regulation – SIOEN / Belgium

**SYSTEMATIC sector:** Textiles

**Main Field of Activity:** SIOEN Industries N.V. (SIOEN) is a Belgian-based company active in the textile sector which is innovative in terms of both production techniques and applications and its markets. As of 2007, SIOEN is the world market leader in coated technical textiles, the European market leader in industrial protective clothing, a niche specialist in fine chemicals and one of the biggest global players in the processing of technical textiles into semi-manufactured goods and technical endproducts. SIOEN engages 4645 employees (2006).

- Legislation (e.g. standards, counterfeiting issues) is an important driver of innovation and is an important challenge for the European textile sector. Drivers of innovation can often come from regulation. For instance, after the Mont Blanc tunnel accident in 1999, the need for even more flame retardant truck sidings was imposed by French and Italian authorities. Higher safety standards are a driving force for the company’s products and innovations in the technical textile field. (Reid, Bruno 2008)

Case Study Evidence 14: Regulation – AVL Group / Austria

**SYSTEMATIC sector:** Automotives

**Main Field of Activity:** AVL is the world’s largest privately owned and independent company for the development of powertrain systems with internal combustion engines as well as instrumentation and test systems. The AVL Group has 3,640 employees (1,550 in Graz and another 2,090 worldwide), and produced €537 million turnover in 2006.

- Regulation as a driver for innovation: Another important point concerning public issues affecting the success of AVL is emission regulation. The EU’s commitment to reduce CO2 emissions forces automotive companies to use engines with lower emission rates. Since these engines have yet to be invented AVL can benefit directly from additional requirements in emission regulation. This is a good example of regulations boosting the innovation activities of companies. (Unterlass 2008)
Taxation

Taxation may affect innovation through various channels. On the one hand, a high tax burden may decrease the propensity to invest in general. On the other hand, specific tax incentives for R&D and innovation will presumably support decisions to carry out innovation activities. There are two main ways in which the national taxation system may influence innovation activity of firms: (i) R&D allowances: Firms may fully claim current R&D expenses in the year of their expenditure; (ii) Tax credits allow firms to deduct a certain percentage of their R&D expenses directly from their tax burden. Apart from these indirect means of promoting R&D there may also be direct means of R&D promotion in the form of specific grants or subsidies.

The advantages of indirect R&D promotion are that fiscal R&D incentives are characterised by a high degree of neutrality towards firms' decisions to allocate. Furthermore, fiscal R&D incentives should have relatively low entry barriers for firms. This should be of particular relevance for small and medium sized enterprises. Last, from the policymaker's point of view, fiscal incentives particularly stand out because of their comparatively low administrative costs as well as “compliance” costs on the side of the companies.

An analysis of R&D incentives across member states and sectors carried out by Cleff et al (2008) shows that direct R&D promotion seems to be more popular in the member states than indirect instruments such as R&D allowances or tax credits. Of the indirect instruments, tax credits prove to be more frequently used than R&D allowances. Cleff et al (2008) have carried out simulation studies where for each sector a representative firm was constructed. The authors have tried to establish through a simulation model whether a tax system of a specific country supports or hinders innovation. The simulations were run under alternative sets of assumptions on key variables such as pre-tax receipts and expenses, types and age of assets, sources of finance, R&D expenditure. The results for all sectors and for each country are shown in Figure 21. In nine of the 25 EU countries the combined effect of different instruments of the fiscal system is neutral insofar as it does not provide any incentive for R&D at all. These countries are Cyprus, Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Luxembourg, Slovakia, and Sweden. It is interesting to note that some of the countries like Finland, Sweden, Denmark or Germany that have the highest aggregate R&D expenditures figure among these countries. This suggests that opportunity conditions and other aspects are probably more significant for innovation than pure fiscal incentives. In contrast, in three countries – Portugal, the Czech Republic and Spain – the combined effect of fiscal instruments reduced the cost of R&D expenditure by about 20 percent. For Slovenia, the Netherlands, Malta, France, Great Britain, Hungary and Greece this figure is at 10 percent. More moderate tax refunds for R&D spending were observed for Italy, Austria, Belgium and Ireland. The analysis also shows that the tax-based incentives to perform R&D are therefore not substantially different across sectors and are largely determined by horizontal national tax schemes.

When looking at implicit innovation preference of the tax system in terms of how excise taxes introduce or eliminate price distortions and thereby guide the behaviour of customers, it turns out that most excise taxes exist in the markets in which eco-innovators are active, followed by energy production, the automotive, chemical, food and drink industries as well as machinery and equipment sector. In these sectors the existence of excise taxes is thought to have an impact on the innovation performance of firms. In the remaining sectors, excise taxes seem to be of less importance. Table 15 below shows the results of an enquiry among national industry experts concerning the impact of excise taxes on their industry. The table shows that excise taxes seem to play only a secondary role with regard to their impact on innovativeness.
Figure 21: Average tax saving through R&D (all sectors).

Table 15: Evaluation of the impact of excise taxes on innovativeness.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Positive</th>
<th>Negative</th>
<th>No impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biotechnology</td>
<td>2</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Food/Drink</td>
<td>4</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Machinery/Equipment</td>
<td>4</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Textiles</td>
<td>2</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Chemicals</td>
<td>7</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Energy</td>
<td>8</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>ICT</td>
<td>2</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Space &amp; Aeronautics</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Automotive</td>
<td>5</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Eco-innovation</td>
<td>10</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Gazelles</td>
<td>4</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>

Innovation culture

In Figure 3 the innovation culture of a country is shown as a factor affecting the innovation performance of firms. Socio-cultural factors can act as barriers but also as driving forces for innovation. They affect the risk perception and risk propensity of entrepreneurs, but also the novelty interest of consumers. Reinstaller and Sanditov (2005) for instance show in a theoretical model that the adoption and diffusion of consumer good innovation is critically affected by the social embeddedness of individuals and an either more conformist or more individualistic mindset of people. Similarly Reinstaller (2005) shows that the diffusion of environmentally friendly technologies in the pulp and paper industry was determined by different social learning processes across countries, such that the diffusion patterns eventually differed substantially across countries. Viewed more broadly, socio-cultural factors include consumer habits, tradition and culture and mobility of the workforce, which are most often used to characterise a geographically defined community (e.g. a nation, a region, etc.) rather than a sector of economic activity.

The various dimensions of a socio-economic environment can be used to describe the socio-cultural characteristics of a community (whether it be geographically or professionally defined). In the SIW project four dimensions are used to identify the socio-cultural characteristics of communities relevant to innovation: (i) cultural capital & consumer behaviour, (ii) human capital, (iii) social capital, and (iv) organisational capital & entrepreneurship. 6

- Cultural capital was defined by Pierre Bourdieu (1981) as “the inherited and acquired properties of one’s self. Inherited not in the genetic sense, but more in the sense of time, cultural, and traditions bestowed elements of the embodied state to another usually by the family through socialisation. It is not transmittable instantaneously like a gift. It is strongly linked to one’s habitus - a person’s character and way of thinking”. The definition refers to the cultural background and basic value system that is shared by individuals in a community and manifests itself in their attitudes and habits, including consumption. In this context, demand is composed of individual consumers and firms characterised by different attributes, knowledge and competencies, and is affected by social factors and institutions. As has been emphasised the evolution of demand specific to sectoral communities is likely to sharply influence the dynamics of sectoral systems (Malerba 2005).

- Human capital, a more familiar concept, is defined by the OECD (2005) as the knowledge, skills and attributes derived from education, training and work experience. Knowledge plays a central role in innovation and production.

- The concept of social capital has many different definitions. In “The Forms of Capital” (1986) Pierre Bourdieu defines social capital as “the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance and recognition.” The OECD (2001) defines social capital as “networks together with shared norms, values and understanding that facilitate cooperation within or among groups.” Social capital is therefore about the nature and intensity of relationships. The essential assumption is that social networks have value, which means that social contacts affect the productivity of individuals and groups.

- Organisational capital may have an important impact on the innovation capacity of a company. An organisation’s resources are not just the obvious ones like cash flow or R&D personnel, but also the company’s culture.

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6 Three of these dimensions have been used previously at the European level (Ricardis project, 2006) but in a different context to define the intellectual capital of a company. To emphasize the importance of individual habits and attitudes, cultural capital and consumer behaviour have been added to the analysis.
routines, structure, morality and management styles. Organisational learning “amplifies the knowledge created by individuals and crystallises it as part of the knowledge network of the organisation” (Nonaka and Takeuchi 1995). Several aspects may reflect the organisational capital as well as the entrepreneurship dimensions: the attitude towards work of individuals; the relation between employers and employees; the attitude towards risk; the extent to which companies implement organisational innovations, and the level of organisational inflexibility.

In order to be able to draw comparisons on cross country differences of national socio-cultural framework conditions, Bruno et al (2008) have constructed a composite index based on these four assets. The data were drawn mostly from Eurobarometer indicators and from the CIS4 database. More details are in the cited report. Higher levels of each of the four assets in a country are considered to indicate a more open and liberal social climate that is more conducive to innovation activities. A high level of cultural capital indicates that citizens in a country have on average a more genuine interest in science and technology, or are more aware of environmental or social problems than in countries where the level of the indicator is low. High levels of human capital suggest that a country has a qualified workforce that is better equipped to engage in innovation activities than if human capital levels were lower. A high level of social capital is thought to capture the willingness to cooperate, the level of trust people generally grant to others or the level of corruption. Organisational capital captures aspects such as the empowerment of employees or the relation between employers and employees.

Figure 22 shows a comparison of the values the summary indicator for the socio-economic environment assumes in each member state. Finland, Denmark, Luxemburg, Sweden and the Netherlands have the most favourable socio-cultural environments for innovative activities when compared to all EU25 member states. At the other extreme, Italy, Portugal, Poland, Malta and Greece have the least favourable socio-cultural environments for innovation.

Figure 22: Indexes of socio-cultural environment across EU25 countries (basis 100: European mean).

A cluster analysis allows us to group countries in terms of their socio-economic environment. Three groups emerge from this exercise:

- **Rigid socio-cultural environment**: these countries do not attain high performance for either cultural, human nor organisational capital.
- **Closed socio-cultural environments**: this group of countries has low performance in terms of social capital.
- **Strong socio-cultural environment**: these countries perform well on average for all four socio-cultural assets considered by this study.

Table 16 shows which EU member states fall into which of the three groups. It is striking that the best innovation performers as they result from the analysis reported in Section 2.2 of this report, are also in the group with a strong socio-cultural environment. Linking the index for the socio-cultural environment to economic and innovation performance indicators uncovers this relationship.

Figure 23 shows that the share of business expenditure for research and development in the GDP (BERD) positively correlates with the index. Other results indicate that a sub-indicator for organisational capital strongly correlates with labour productivity. However, the relationship is only very weak between labour productivity and the summary index. The relationship to another innovation output indicator (patents) is even more apparent for the overall socio-cultural environment. The weaker the socio-cultural environment, the lower the number of EPO patents per million population. Breaking down the analysis at the sector level shows that the results are rather homogeneous across sectors, indicating that the aggregate picture presented here captures the most relevant aspects of the relationship.

This evidence supports the hypothesis of the innovation model presented in Figure 3 that innovation is a socially embedded phenomenon, and that innovation policy transcends boundaries typically set by policy. However, the results presented here are preliminary explorations into the complex relationship between the characteristics of the socio-economic environment and innovation performance and need to be confirmed by more extensive research.

<table>
<thead>
<tr>
<th>Rigid socio-cultural environment</th>
<th>Closed socio-cultural environment</th>
<th>Strong socio-cultural environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Czech Republic</td>
<td>Austria</td>
<td>Belgium</td>
</tr>
<tr>
<td>France</td>
<td>Cyprus</td>
<td>Denmark</td>
</tr>
<tr>
<td>Hungary</td>
<td>Germany</td>
<td>Estonia</td>
</tr>
<tr>
<td>Lithuania</td>
<td>Greece</td>
<td>Finland</td>
</tr>
<tr>
<td>Latvia</td>
<td>Spain</td>
<td>Ireland</td>
</tr>
<tr>
<td>Portugal</td>
<td>Italy</td>
<td>Luxembourg</td>
</tr>
<tr>
<td>Slovakia</td>
<td>Malta</td>
<td>The Netherlands</td>
</tr>
<tr>
<td>Poland</td>
<td></td>
<td>Sweden</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slovenia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>United Kingdom</td>
</tr>
</tbody>
</table>

Case Study Evidence 15: Innovation culture – Unilever / The Netherlands

**SYSTEMATIC sector:** Food

**Main Field of Activity:** Unilever provides products that fulfil everyday needs for nutrition, hygiene, and personal care. Unilever operates on a global scale. The company develops global brands and has a portfolio of large global brands including 12 with an annual turnover greater than €1 billion.

- An open and innovative culture is needed to understand the consumer perception and (lack of) confidence and the following consumer choices. The researcher should be cognizant of trends in society to understand the process of behavioural change and characteristics of segmented consumer groups. This knowledge is also essential to understanding the diversity and dynamics of fundamental values, cultures and habits across the world. (van Halen 2008)

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**Sector specific findings on the role of the innovation environment for innovation**

- **Food**

The food and drink industry faces a high number of regulatory constraints regarding its processing activities and the resulting processed food. Regulatory structures and legislation can have lasting consequences for industry’s activities and perspectives, and it may be difficult to flexibly adapt them rapid technological change. Biotechnology is one of the most promising drivers of innovation and growth in the food and drink sector. In Europe, however, uncertainty over regulations and insufficient public acceptance has driven many R&D investors away from biotech projects for agricultural applications. EU food legislation has developed considerably to respond to growing concerns regarding food safety, information and fair market conditions, resulting in increased administrative burdens and compliance costs for firms, seen as a factor that hampers innovation.

---

**Figure 23: Business expenditures in R&D and socio-cultural environment.**

![Graph showing socio-cultural environment and business expenditures in R&D](image)

Source: EUROSTAT, Technopolis Group calculations. For more details see Bruno et al. (2008).
for the food and drink industry. Due to the creative destruction type of competition, regulations relevant to the introduction of new products have a cataclysmic impact on industrial structures.

_Innovation culture:_ Conservatism of food consumers is seen as a hampering factor for innovation in this sector. However, if radical innovations are followed by proper conditions relating to price, labelling, information and health benefits and sensory qualities of foodstuffs, consumers are less critical. This suggests that innovation in this sector must be followed by non-technological innovation in order to reach its market goals.

- **Energy**

  Sorting companies into those that are innovative, those that perform R&D continuously and those that have introduced market novelties, about 1/5 of all firms declared that innovation activities were carried out to comply with formalities. Therefore regulation is an important impulse to develop and introduce new technologies. Tax incentives for R&D are not significantly associated with innovative performance, whereas R&D subsidies are a relevant indicator for explaining innovation success and have a positive impact on R&D spending. There is contradictory evidence on the effect of excise taxes on innovation in the energy sector.

- **Textiles**

  Regulation is not considered to be relevant for innovation in the textile industry. When we sorted companies into those that are innovative, those that perform R&D continuously and those that have introduced market novelties, about 1/5 of all firms declared that innovation activities were carried out to comply with regulations. Excise taxes play only a secondary role for this industry.

  _Innovation culture:_ Social capital is considered extremely important in this sector on the demand side. Social networks and social cascades are important for the diffusion of fashion products.

- **Chemicals**

  Regulation is highly important for innovation in the chemical industry. Experts assess the effect of regulation to have a positive effect on innovation. About 1/4 of innovators in this sector have declared in the CIS that they have introduced market novelties in order to comply with regulations. Following the assessment of industry experts excise taxes seem to have a positive impact on the innovation activities of firms. Subsidies also positively affect the innovation output of chemical firms.

  _Innovation culture:_ no sector specific deviation from the overall results found.

- **Machinery**

  Regulation is of secondary importance for the machinery and equipment industry, even though experts consider the impact of regulation to be positive for innovation. About 1/5 of innovative firms in this sector declared in the CIS that innovation activities were carried out to comply with regulations. Excise taxes have very little impact on innovation. However, subsidies for R&D are positively associated with innovation performance of firms in this sector.

  _Innovation culture:_ no sector specific deviation from the overall results found.

- **ICT**

  Regulation is of limited relevance for innovation in the ICT sector. The share of firms that have indicated in the CIS that they innovate in order to comply with regulations is very small. Similarly, excise taxes are of little importance to ICT firms. However, innovation subsidies have a very significant impact in innovation activities in this sector.
Innovation culture: Security issues, and notably privacy concerns, are key determinants of innovation in the sector. As ICT technology becomes ever more closely entwined in society, so it becomes indeed more closely related with people’s political and ethical values. Open source which is strongly user- and brand-oriented will be the main business in ten years’ time. Brand image should there help in generating trust. Concluding, innovation culture and especially attitudes towards novelties are highly important for innovation success in ICT.

• Automotives

Regulation in the automotive industry is highly important. The EU has the capacity to succeed in environmentally friendly technologies. Regulatory policy is considered to be crucial in this regard especially for the automotive industry. In particular the introduction of control maintenance systems is at stake. Redefinition of standards is of fundamental importance, from average car fleet exhaust gas emission to class-dependent car fleet exhaust gas emission. A strong IPR regime is needed, as is the role of public procurement. The latter may be crucial in convincing the populace of successful innovations and influencing mental shifts. There is no evidence that excise taxes and tax incentives for R&D have an impact on innovation.

Innovation culture: no sector specific deviation from the overall results found.

• Aerospace

The evaluation of CIS data as well as expert interviews suggest that regulation is of limited importance for the aerospace sector. Similarly, excise taxes do not have any significant impact on innovation performance. R&D tax subsidies instead are important but the sector is already well supported by many specific programmes across EU countries.

Innovation culture: no sector specific deviation from the overall results found.

• Eco-Innovation

For eco-innovators regulation is highly important. Its impact on innovation activities is widely considered to be significant. Eco-innovators indicate that regulations are the single most important driver of innovation. Eco-industries mainly began with traditional, now mature, markets driven by the demand for essential commodities such as water supply and services such as waste collection. The growth of the water supply sector is largely dependent on population growth. However, developments in the sector are related to environmental policies. “Legislation-driven” markets are recent markets based on investment needs generated by new environmental policy and legislation. Some of these markets such as renewable energy and eco-construction show high growth potential. Environmental regulations and improvement of a firm’s image are seen as the main determinants for eco-innovation here. Excise taxes exert a very important effect on the innovation success of eco-innovators. They affect demand in that they may change relative prices in favour of environmentally friendly products. For most eco-innovators subsidies and tax credits for R&D are an important means to finance their innovation efforts.

Innovation culture: High income, high education level, liberal political orientation and, perceived consumer effectiveness are positive determinants of environmental attitudes and behaviour. Consumers’ attitudes and responses to environmental issues are therefore a function of their belief that they can positively influence the outcome of environmental issues. Cultural factors relate to historically forged traditions and beliefs. These include the level of trust in institutions involved in Eco-innovation projects. Local traditions influence the ability of projects to mobilize bottom-up initiatives or to introduce top-down plans without resistance. Levels of environmental awareness influence the relevance of environmental arguments (such as combating climate change) in justifying the projects. Innovation culture is therefore of high importance for innovation (marked green).
Evaluation of CIS data and expert interviews shows that regulation is not very important for innovation activities of fast growing SME’s. About one quarter of fast growing SME’s that are also innovators indicate that they also innovate to comply with regulations. Excise taxes and R&D subsidies seem not to be relevant for gazelles.

Innovation culture: no sector specific deviation from the overall results found.

- Biotechnology

Regulation influences innovation behaviour in the biotech sector significantly. Excise taxes and R&D tax incentives play a subordinate role in the innovation behaviour and innovation performance of biotech firms. Regulation acts as a constraint but it opens up many new avenues as well, not only in medical applications, but also in agricultural and environmental biotechnologies. The call for regulation will depend on the knowledge about the effect of modified products on the environment on the one hand, and on ethical issues and customer acceptance on the other. This is closely related to the aspect of innovation culture in the member states.

Innovation culture: Europeans are indifferent regarding agricultural biotechnology and opposed to both genetically modified (GM) food and the cloning of animals. By contrast, perceptions of medical and environmental biotechnology are very positive. The nature of demand and the market vary therefore very strongly according to the main sub-sectors of applications for biotechnology products and processes. With the exception of Austria (only 43%), a majority of European citizens is of the opinion that new technologies in biotechnology and genetic engineering will have a positive effect on society, but overall, Europeans think GM food should not be encouraged. There are mixed opinions on the acceptability of buying GM food. The most pressing biotechnological issues relate to health, the reduction of pesticide residues and environmental impacts.

The significance of public acceptance and demand in shaping innovation in biotechnology, the difference of these characteristics between sectors, and the differential effect on innovation of sectors with domestic and global markets suggests that the development of biotechnology in Europe takes place mainly at the sectoral level. The institutional features of national systems of innovation would affect biotechnology innovation to the extent that sectoral innovation occurs in specific national venues and is dependent on history and the trajectory of innovation. Overall, the acceptance of biotechnologies (esp. genetically modified organisms in agrofood) by the civil society is a key issue for innovation success in Biotechnology.

3.5 Drivers of fast growing firms (gazelles)

Fast growing SME’s – often called “gazelles” — are recognised as a central source of dynamism in developed and developing economies. The special role of fast growing SME’s is also increasingly recognised by policy makers. Yet, despite the importance observers attribute to gazelles, knowledge about these companies is surprisingly limited. The research on gazelles in the SIW project of DG Enterprise summarised in the sector report from Hölzl and Friesenbichler (2008) attempts to provide evidence on the innovation behaviour of gazelles. The aim was to provide representative evidence based on the third CIS micro dataset which is accessible in the SAFE centre of Eurostat in Luxembourg. Unfortunately, a longitudinal dataset covering innovation variables was not available. The key research questions: are gazelles are more innovative than other firms; secondly, do gazelles differ in their cooperation behaviour in comparison to other firms? Moreover, do
gazelles perceive innovation obstacles differently than average firms and do they use different strategies to protect their innovations.

Distribution of growth rates forms a tent shape (Box 3). Its mean lies around nil and its tails are rather fat, i.e. while most firms do not grow there are a number of outliers to the right and left. The former are fast growing firms – gazelles – and the latter are firms which decline in size very fast. These results can be reproduced for both high and low tech industries, for the old and new member states, for the entire sample and for single industries. The evidence that growth rate distributions are tent-shaped is quite robust. It does not matter whether growth rates are based on turnover, employment or value added. These findings are also robust across manufacturing industries at the aggregate and at a more disaggregated level (provided that the number of firms is sufficiently large). Moreover, Fagiolo et al (2006) show that the tent-shaped pattern is also characteristic for time series of country growth rates. Thus, the finding seems to be a stylised fact, which also implies that the phenomenon of gazelles is primarily an economic one, and not a technological one.

From an economic point of view, the evidence suggests that corporate growth (and decline) is driven by relatively frequent and relatively “big” events that cannot be accounted for with normally distributed shocks. Thus, being a gazelle seems to be a temporary phenomenon in a firm’s life cycle, and indeed, firm growth is “lumpy” over time due to adjustment costs and uncertainty. There are many factors which can trigger the growth process, such as new technologies, new organisational structures, internal capabilities that allow for cost reduction or allow the firm to react quicker to market trends, the social capital of the entrepreneur, or the exploitation of unique opportunities. Furthermore, it is also possible that gazelles use incremental innovation rather than radical innovation, since radical innovation is linked to high R&D expenditures, which require resources smaller firms do not have.

Therefore, firm growth is affected by a large number of factors, such as technology, the micro- and macroeconomic environment including regulation, institutional factors at the regional or sectoral level, and – most prominently – firm-specific determinants. Indeed, systematic differences across sectors and regions were found, since a gazelle count reveals a significantly higher number of them in the new member states.
Thus, the 17 country dataset was split up into four regions in order to allow for the respective stage of technological development. First, continental Europe includes Austria, Germany, Luxembourg, Belgium, Sweden, Finland; Southern Europe was defined as Italy, Portugal, Greece and Spain; the new member states consist of Slovenia, Slovakia, Estonia, Hungary, Czech Republic, Lithuania and Latvia; Romania and Bulgaria were later treated separately. The EU15 and the new member states (excluding Romania and Bulgaria) were looked at as aggregates.
In this country clustering the study generally followed the European Innovation Scoreboard indicator, the map of the structural funds of the EU, or Verspagen (2007) who provides a spatial hierarchy of technological change for the EU-27. Following this “distance to the technological frontier” approach, differences between gazelles in the regions defined by means of t-tests were explored testing the following hypothesis:

**Hypothesis**

<table>
<thead>
<tr>
<th>Given that there is a substantial technological distance between the old member states and the new member states in the European Union we can conclude:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Both innovation input (R&amp;D), innovation success (number of products new to the market), innovative entrepreneurship and innovative output play a substantially more important role in countries close to the technological frontier than in countries further away from the technological frontier.</td>
</tr>
<tr>
<td>• The differences between gazelles in the old member states and the new member states are more substantial than the differences between gazelle firms and non-gazelle firms.</td>
</tr>
<tr>
<td>• In particular, Gazelles differ from other firms especially in country groups close to the technological frontier but not in other country groups.</td>
</tr>
</tbody>
</table>

---

**Table 17: Innovation indicators used to test the hypothesis.**

**Innovation Input**

A very important input into the innovation process are R&D expenditures. R&D expenditures are measured by R&D intensity (R&D expenditures over turnover) and the R&D expenditures by employee. A third indicator used is not only an input to innovation itself, but an “in house” indicator of the formal capabilities of a firm: the share of employees with tertiary education, which we call “skill intensity” (skillint). R&D expenditures and skilled personnel are not only relevant for the generation of novel know-how, products and processes but also central in understanding new knowledge. These indicators are also important for firms to strengthen their absorptive capacities (Cohen and Levinthal, 1989).

**Innovation Output**

Hölzl and Friesenbichler (2008) use a very simple and straightforward innovation indicator (inno), which is defined as a mere dummy variable whether the respective firm launched a new or significantly improved product or process.

**Innovative Entrepreneurship**

Output indicators allow us to identify innovative entrepreneurship. As in Section 0 entrepreneurship types were defined: the first is creative entrepreneurship (entype_cr). Creative entrepreneurs develop processes themselves, launch products which are new to the market, or engage in both. Creative entrepreneurs are innovation leaders. To have a contrast to creative entrepreneurs there is a second entrepreneurship type that uses an adaptive strategy (entype_ad). Adaptive entrepreneurs pursue innovations by purchasing products or processes already available on the market.

**Innovation success**

Hölzl and Friesenbichler (2008) measure innovation success by the percentage of sales achieved with products that are new to the firm (turnin) and – more important - new to the market (turnmar).

Source: WIFO. For details see Hölzl and Friesenbichler (2008)
The analysis follows Arvantitis et al. (2004) by dividing innovation indicators into innovation input, innovation output and innovation success indicators. In addition, indicators on innovative entrepreneurship derived from Peneder (2008) (see Section 0) were used. The CIS III questionnaire allows selecting indicators for each of these four groups.

A first method used to test the hypothesis was to compare the populations of gazelles between country-groups using the method described in Box 5. The test statistics report means of the gazelle population in the respective country groups, t-values and p-values. Table 18 reports the results for the t-tests across country groups using the 10% gazelle definition (i.e. the top decile of firms if they are ranked according to their turnover growth rate) and using the whole sample (innovative and non-innovative firms). The columns with the country group means give the mean value of the indicator for the manufacturing sectors. For example the share of innovating firms is 60.7% in the northern and continental country group, it is 59.7% in the southern country group, 34.6% in the new member states group and 16.0% in the group Romania and Bulgaria.

The results provide a clear indication that there is a statistically significant difference between the country groups with regard to innovation. With the exception of the indicator “inno” capturing innovation output there is a clear ranking of country groups with regard to the innovativeness indicators. Gazelle

**Box 4: Matching estimator and selection criteria**

The selection of firms is based on exact matches on 2-digit NACE classifications and a country dummy. This avoids the problem of comparing firms that act in different sectoral or national environments. The control group is further selected on the basis of firm size in 1998, whether they are part of an enterprise group, the export intensity (exports over turnover in 1998) as a proxy for the firms’ internationalisation, and where the most significant market is (i.e. regionally, nationally). Furthermore, only firms growing organically were used, i.e. firms growing through mergers and acquisitions were excluded. For each gazelle two firms in the control group (non-gazelles) were selected and then tested to determine whether the two sets of firms are different over a number of innovation variables by means of a t-test. Figure 25 illustrates how statistically similar firms denoted by an ‘x’ are matched, i.e. how gazelles are assigned to firms as similar as possible. Other companies, designated by a ‘y’, are not considered in the comparison. Moreover, the approach from above was applied that splits up the data into these geographical areas chosen according to the countries’ overall productivity: entire EU, Continental Europe, Southern Europe, New Member States and Romania and Bulgaria.

**Figure 25: The basic idea of matching**
firms in the northern/continental group have the highest level of skilled workers; they are more likely to be creative entrepreneurs or adaptive entrepreneurs than gazelles in the southern European countries, the new member states and Romania or Bulgaria. The opposite is true for non-innovative gazelles. This result clearly confirms that gazelles are different across country groups. Innovation is more important for countries close to the technological frontier.

The research also tried to identify the defining characteristics of a gazelle by analysing whether gazelles differ from similar firms by comparing them with a matching estimator (see Box 5). This method allows comparing gazelles to similar companies across several dimensions such as country, industry, size in the base year, or the location of the most significant market. Interestingly, differences are much more pronounced between gazelles of different country groups rather than within country groups. This suggests that gazelles derive much of their motivation from the exploitation of comparative advantages.

Table 19 provides an overview of the results obtained from the matching estimations of the group using all firms. Hölzl and Friesenbichler (2008) find that gazelles are more innovative especially in the EU 15 country group (EU Cont und EU South). Gazelles mainly belong to the creative entrepreneurship type in statistically significant terms in the EU 15 countries and to a significantly lesser extent in the new member states and Romania or Bulgaria.

Table 18: Gazelles and innovation: Evidence from t-tests across country groups (all firms).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean EU Cont</th>
<th>Mean EU South</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>inno</td>
<td>0.670</td>
<td>0.595</td>
<td>0.309</td>
<td>0.757</td>
</tr>
<tr>
<td>skillint</td>
<td>0.200</td>
<td>0.112</td>
<td>5.460</td>
<td>0.000</td>
</tr>
<tr>
<td>entype_cr</td>
<td>0.540</td>
<td>0.431</td>
<td>3.083</td>
<td>0.002</td>
</tr>
<tr>
<td>entype_ad</td>
<td>0.130</td>
<td>0.163</td>
<td>-1.337</td>
<td>0.181</td>
</tr>
<tr>
<td>entype_noinno</td>
<td>0.329</td>
<td>0.405</td>
<td>-2.528</td>
<td>0.024</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean EU Cont</th>
<th>Mean EU South</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>inno</td>
<td>0.670</td>
<td>0.162</td>
<td>13.574</td>
<td>0.000</td>
</tr>
<tr>
<td>skillint</td>
<td>0.200</td>
<td>0.096</td>
<td>6.590</td>
<td>0.000</td>
</tr>
<tr>
<td>entype_cr</td>
<td>0.540</td>
<td>0.116</td>
<td>12.606</td>
<td>0.000</td>
</tr>
<tr>
<td>entype_ad</td>
<td>0.130</td>
<td>0.045</td>
<td>3.789</td>
<td>0.000</td>
</tr>
<tr>
<td>entype_noinno</td>
<td>0.329</td>
<td>0.837</td>
<td>-15.478</td>
<td>0.000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean EU Cont</th>
<th>Mean EU South</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>inno</td>
<td>0.595</td>
<td>0.162</td>
<td>19.738</td>
<td>0.000</td>
</tr>
<tr>
<td>skillint</td>
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<td>0.096</td>
<td>2.013</td>
<td>0.044</td>
</tr>
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<td>0.431</td>
<td>0.116</td>
<td>10.4499</td>
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</tr>
<tr>
<td>entype_ad</td>
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<td>0.05</td>
<td>7.601</td>
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</tr>
<tr>
<td>entype_noinno</td>
<td>0.405</td>
<td>0.837</td>
<td>-18.919</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Note: The “10% definition of gazelles” is the top decile of firms if they are ranked according to their turnover growth rate. Definitions of variables: inno: innovation output variable indicating whether the firm has adopted a product or a process innovation; skillint: number of employees with higher education; entype_cr: creative entrepreneur according to definition in Section 0; entype_ad: adaptive entrepreneur according to definition in Section 0; entype_noinno: non-innovative firms. Country groups: EU Cont (Continental): Austria, Germany, Luxembourg, Belgium, Sweden, Finland; EU South (Southern Europe): Italy, Portugal, Greece, Spain; EU NMS (New member states): Slovenia, Slovakia, Estonia, Hungary, the Czech Republic, Lithuania, Latvia, Ro & Bg (most recently joined): Romania, Bulgaria.

Source: WIFO calculations, CIS III micro data (Eurostat). For more details see Hölzl and Friesenbichler (2008).
3.6 Developing adequate indicators of innovation at the sector level

As this report has shown, there are huge differences across sectors and countries amongst the drivers of innovation. These differences are often not considered when comparing national or sectoral innovation performance using standard indicators.

The European Innovation Scoreboard (EIS) has been developed as a consequence of the Lisbon European Council in 2000 to benchmark and compare the innovation performance of EU member states. It has become an important part of the Open Method of Coordination (OMC) that is based on the dissemination of information and the development of benchmarks with the aim to support member states in their efforts to reach specific goals. As the aim of the Lisbon Council was to foster structural change in Europe towards technology intensive industries, the EIS focuses on high-tech and provides indicators for tracking the progress of member states towards the Lisbon goal. To develop a more differentiated view, in 2005 for the first time a Sectoral Innovation Scoreboard was developed, that provided composite indicators on innovation performance at the sector level similar to those provided by the EIS.

In general such indicators are useful in their ability to integrate large amounts of information; results strongly depend on the choice of indicators and weighting schemes and can lead to misleading information. This is important, as the factors determining innovation success vary significantly by sectors as has been shown in the previous sections of this chapter. There are sometimes large differences in areas such as innovation behaviour / innovation modes, strategies, sources, and IPR protection measures between sectors. These aspects could be summarized in

### Table 19: Matching results for all firms - Gazelle definition 10% across country groups: innovation and innovation success.

<table>
<thead>
<tr>
<th></th>
<th>Inno</th>
<th>entype_cr</th>
<th>entype_ad</th>
<th>turnmar</th>
<th>skillint</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Diff.</td>
<td>p-value</td>
<td>Diff.</td>
<td>p-value</td>
<td>Diff.</td>
</tr>
<tr>
<td>EU All</td>
<td>0.049</td>
<td>0.000</td>
<td>0.043</td>
<td>0.000</td>
<td>0.004</td>
</tr>
<tr>
<td>EU Cont</td>
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<td>0.061</td>
<td>0.094</td>
<td>0.040</td>
<td>0.034</td>
</tr>
<tr>
<td>EU South</td>
<td>0.101</td>
<td>0.000</td>
<td>0.084</td>
<td>0.006</td>
<td>0.012</td>
</tr>
<tr>
<td>NMS</td>
<td>-0.022</td>
<td>0.505</td>
<td>0.019</td>
<td>0.443</td>
<td>-0.000</td>
</tr>
</tbody>
</table>

Source: WIFO calculations, CIS III micro data (Eurostat); statistically significant differences are in italic. For the definition of variable names and country groups see Table 18. For more details see Hölzl and Friesenbichler (2008).
differences (i) between the impact of different innovation output indicators on a specific performance measure (such as productivity), and (ii) the impact of one specific innovation output indicator on alternative performance measures.

The European Sector Innovation Scoreboards (ESIS) basically apply the methodology developed for the European Innovation Scoreboard (Commission 2008) to each sector in the same way, i.e. assuming that the same set of indicators is relevant in the same way for each sector, and each indicator used has the same weight in each sector with respect to representing strengths and weaknesses in innovation performance. The aim here is to test this assumption and to potentially derive a sector specific list of relevant innovation indicators, including some indication on the relative importance of relevant indicators. Starting point is the list of twelve indicators used in the ESIS:

1. Share of employees with higher education
2. Share of firms that use training
3. R&D expenditures (% of value-added)
4. Share of firms that receive public subsidies to innovate
5. Share of firms innovating in-house
6. Share of SME’s co-operating with others
7. Innovation expenditures as a percentage of total turnover
8. Share of total sector sales from new-to-market products
9. Share of total sector sales from new-to-firm but not new-to-market products
10. Share of firms that patent
11. Share of firms that use trademarks
12. Share of enterprises that use design registrations

The basic idea of Peters, Gottschalk and Rammer (2007) is to use micro information (anonymised CIS-3 micro data of 15 European countries, German CIS firm panel data, 1993-2005) to test the relevance of these indicators for a specific sector. For this purpose, a two-step model is applied (see Crepon, Deguet Mairesse 1997) as illustrated in Figure 26:

- In a first step, an innovation output model is developed that attempts to identify the factors influencing the firms’ success in innovation activities. This model links innovation input to innovation output, adding other explanatory variables such as size, competition and other product market characteristics. Innovation input indicators are indicators (1) to (7). Innovation output is measured through indicators (8) to (12).

Figure 26: Innovation input, Innovation output and economic performance.

Source: ZEW calculations. For details see Peters, Gottschalk and Rammer (2007)
In a second step, an economic performance model is developed that uses innovation output indicators to explain economic performance of firms, again considering other explanatory variables as well, such as capital and material intensity, size, product market characteristics. Performance measures may be productivity, sales growth, growth in employment or profitability.

Empirically it can be shown that only a restricted set of innovation input variables is relevant to explain innovation output, and only some innovation output indicators are relevant to explain economic performance. In general, there is a closer link between input and output indicators of innovation activities, while the link between innovation output and economic performance is rather weak. This is especially true for analyses based on CIS-3 data. These suffer from missing time lag measurements and a poor measure of economic performance, i.e. sales growth within a three year period.

Table 20 summarises the main findings. The various regression results have been condensed into a table with ordinal information: Highly relevant effects (++), relevant effects (+). If significant effects were found only for German CIS panel data but not in the full sample of countries in the CIS 3 micro-aggregated database, the result is set in parenthesis. The results show that no uniform set of indicators should be applied to compare sector innovation performance among countries, but that all input indicators used are relevant for the one or the other sector. There is only one ESIS input indicator that turns out to be relevant in almost all sectors considered here and this is R&D intensity (with the Energy sector being the only outlier in this respect). Receiving public subsidies and innovating in-house are further input indicators for knowledge creation that exert positive, though typically less wide-spread or strong effects in most sectors considered here. For the textile industry no effect from in-house innovation expenditures could be identified. Given our results from the SYSTEMATIC innovation classification, this comes not as a surprise. For the food and automotive industries public funding has no significant effect.

Regarding the relevance of ESIS output indicators, the situation is less clear since for most output indicators no strong effects on economic performance could be identified. This is at least partially because of insufficient data availability with respect to CIS-3 anonymised data. When turning to German CIS panel data, which are much more suitable for analysing performance effects of innovation, we find positive effects for most indicators, even though not for all that are used in the ESIS.

When looking at output indicators measuring the outcome of knowledge creation, the share of sales from market novelties is with no doubt the most relevant innovation output indicator with respect to its influence on economic performance. Rather strong effects were found for ICT, Automotive, Biotechnology and Eco-Innovation, and some positive effects for most other sectors except Food and Gazelles. German CIS panel data moreover reveal important effects for the use of patents, while performance effects stemming from sales shares with product imitations, the use of trademarks and the use of design registrations are very limited and seem to be irrelevant for most sectors. There is (at least) one important variable missing in the ESIS (and the EIS), and that is cost savings due to process innovations, which is also one of the potential results of knowledge creation. This variable has a positive impact on firm growth in the Biotechnology sector, and we also found relevant impacts in Chemicals and Eco-Innovation based on German CIS panel data. For all other sectors, we were able to identify a positive impact of rationalisation success of innovation on one performance indicator, except Textiles.

Considering factors that could be summarised under innovation modes or entrepreneurship, co-operation in innovation is found to be relevant in most sectors (except ICT), as are non-R&D innovation expenditure (except Chemicals). Strategic and organisational changes, a variable that comes rather close to the newly introduced concept of organisational and marketing innovation which will
be applied to CIS in future, show highly relevant effects on innovation output in the automotive sector, as well as for ICT and Gazelles. This variable is also relevant for the food and chemicals industries, and we found some effects in the textiles sector and among eco-innovators.

In the case of human resources, training activities are important in all sectors except the energy sector and in biotechnology firms, though the effect of this indicator is rather limited and relevant only for a few output indicators in most sectors. The weakest impact on innovation output is found for the skill level of employees, which is a relevant indicator in the automotive sector only, and shows some impact in the machinery industry, ICT, for eco-innovators and Gazelles. For food, textiles, chemicals, energy and biotechnology, no significant impact of the skill level on innovation output could be identified.

Regarding measures for IPR-protection as innovation output factors influencing economic performance, results are quite different between sectors. Trademarks are only relevant in ICT, while design registrations are influential in the energy sector and to some extent for fast growing SME’s. Patents as the most popular indicator for IPR’s are not relevant for the food, textiles, ICT and biotech industries. In the other investigated sectors, patents are only a weak measure explaining economic performance.

Concluding, in order to accurately monitor innovation activities on a sector level across countries — as a base for deriving sector specific policy conclusions — a sector specific system of innovation indicators should be applied. Such a system — like the European Sectoral Innovation Scoreboard (ESIS) — should consist of a few key indicators that are applied to all sectors, and of additional indicators which vary across sectors:

• With regards to key indicators, R&D expenditure, non-R&D innovation expenditure and innovation co-operation are indicators that give relevant information about the efforts a sector is undertaking in order to generate innovation.

• Measuring innovation output accurately at a sector level is extremely difficult, and no single measure is available than can be applied across sectors. Output indicators should thus be treated with caution in the ESIS, and their weight could be reduced.

• For a number of indicators, only restricted evidence could be found for their relevance at all, such as design and trade mark registrations, and the share of sales from new products not new to the market. These indicators could be dropped from the ESIS completely.

In the current ESIS, some important innovation indicators are missing. Attempts should be made to close this gap. This refers, first, to effects of process innovation, in particular cost savings, which may be an important output of many innovative efforts of firms in many sectors, and which tends to be a particularly important innovation output in some sectors. Secondly, marketing and organisational innovations tend to be relevant in a number of sectors as well.
Table 20: Summary of the relevance of ESIS indicators to capture innovation performance in each of the SYSTEMATIC sectors.

<table>
<thead>
<tr>
<th>ESIS Indicator</th>
<th>Food</th>
<th>Textiles</th>
<th>Chemicals</th>
<th>Machinery</th>
<th>Automotive</th>
<th>ICT</th>
<th>Energy</th>
<th>Biotechnology</th>
<th>Eco Innovation</th>
<th>Gazelles</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input Indicators</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share of employees with higher education</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>(+)</td>
<td>0</td>
<td>0</td>
<td>(+)</td>
<td>(+)</td>
<td>(+)</td>
</tr>
<tr>
<td>Share of firms that use training</td>
<td>(+)</td>
<td>++</td>
<td>(+)</td>
<td>(+)</td>
<td>++</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>R&amp;D expenditures (% of value-added)</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>0</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>(+)</td>
</tr>
<tr>
<td>Share of firms receiving public subsidies</td>
<td>0</td>
<td>(+)</td>
<td>++</td>
<td>(+)</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>(+)</td>
</tr>
<tr>
<td>Share of firms innovating in-house</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>(+)</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>(+)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Share of SMEs co-operating with other</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>(+)</td>
<td>(+)</td>
<td>+</td>
<td>(+)</td>
<td>++</td>
<td>(+)</td>
<td>(+)</td>
</tr>
<tr>
<td>Innovation expenditures (% total turnover)</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>(+)</td>
<td>(+)</td>
<td>+</td>
<td>(+)</td>
<td>++</td>
<td>(+)</td>
<td>(+)</td>
</tr>
<tr>
<td><strong>Further Indicator used</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strategic / organisational changes*</td>
<td>+</td>
<td>(+)</td>
<td>+</td>
<td>0</td>
<td>++</td>
<td>++</td>
<td>0</td>
<td>0</td>
<td>(+)</td>
<td>++</td>
</tr>
<tr>
<td><strong>Output Indicators</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales share from market novelties</td>
<td>0</td>
<td>(+)</td>
<td>(+)</td>
<td>0</td>
<td>+</td>
<td>++</td>
<td>(+)</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Sales share from product imitations</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>(+)</td>
<td>0</td>
<td>(+)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Share of firms that use trademarks</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Share of firms that use design registrations</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>(+)</td>
</tr>
<tr>
<td><strong>Other Indicators</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost reduction through process innovation**</td>
<td>0</td>
<td>0</td>
<td>(+)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>(+)</td>
<td>0</td>
</tr>
</tbody>
</table>

**Note:** *This indicator is not part of the ESIS 2005, but is used in the EIS. **This indicator is neither part of the ESIS nor of the EIS, but turned out to be a relevant innovation output indicator in many sectors based on German CIS data. ++: highly relevant; +: relevant; (+): relevant only in very few situations; 0: not relevant.

**Source:** CIS 3 microaggregated data and Mannheim Innovation Panel. ZEW calculations. For more details see Peters, Gottschalk and Rammer (2007).
Chapter 4
Challenges and policy priorities at the sector level and across sectors

4.1 Innovation challenges and policy priorities

In the previous chapter we focused on the factors driving innovation. In this chapter we will discuss the three most important challenges which have been identified to affect all sectors, and present the top challenges for each of the sectors examined in this project. The main challenges are summarised in Table 21. It is based on the innovation drivers matrix presented at the beginning of Chapter 3. This matrix of innovation challenges and priorities identifies policy areas based on statistical evidence, opinions of the Europe Innova expert panels and evidence gathered from case studies on innovation leaders in each sector. In Table 21 a challenge has only been identified as such if the policy area was identified as a main driver of innovation in the analysis presented in Chapter 3. As with the innovation drivers matrix on page 17, cells coloured in green represent very important challenges, cells in yellow important challenges, whereas white or grey cells indicate either that a specific policy area is not an important challenge or that the different sources report inconclusive evidence.

A first glance at Table 21 indicates that the three top challenges all industries studied in the SIW project face are related to human capital, the support of knowledge creation, diffusion and technology transfer, and to financial constraints. Other aspects like regulation, innovation culture, competition or demand factors play a significant role in some sectors. However, the analysis also reveals that these issues are very sector specific and hence not of equal importance to all industries. The challenge represented by the lack of well-qualified human capital is probably the most significant. It affects almost all sectors and is likely to become a major constraint for innovation capabilities and, as a result, the competitiveness as well as the long run growth potential of the EU member states. Fostering R&D spending but also supporting knowledge and technology transfer remains a top priority. However, the results from Chapter 3 of this report reveal that a differentiated strategy is needed across EU member states. For some less advanced countries or those on a catching up path, technology transfer remains an extremely important means of innovation and technological development. R&D activities in these countries also fulfil the aim to increase absorptive capacities needed to adopt and adapt new technologies more effectively. For countries that are close to or on the technological frontier R&D is the main investment to foster growth and competitiveness. However, as this report has shown there are considerable differences across sectors that have to be taken into account when developing innovation policies. An example mentioned in the previous chapter was the textile industry. Finally, the third major challenge is to overcome financial constraints that for some sectors, especially for small innovative firms, represent major obstacles for innovation activities and growth. We will discuss these three main challenges in more detail in the next section.

4.2 The three top challenges across sectors

Human resources

Improving the educational skill base on a broad level and in tertiary education remains a major challenge of European innovation performance. The
Competitiveness Report for 2007, for instance, states that the transition from resource-based to knowledge-based manufacturing will also make knowledge and skills crucial to future growth and competitiveness. Among these, the report cites, particularly soft skills become more important as organisations are progressively globally networked while non-technological innovation, predominantly organisational innovation, bears added significance in maintaining and improving competitiveness (Commission 2007e, p. 12). Case study evidence produced in the SIW project confirms this view. It suggests that across sectors firms foresee technological capacities, strategic planning, specialist knowledge and skills, management capabilities/leadership, customer involvement in R&D and innovation activities, as well as different types of partnerships as key drivers of innovation success in the future. These drivers require highly skilled technical and non-technical personnel. However, the educational systems of the EU member states do not provide an adequate supply of human resources. Evidence collected in the SIW project suggests that there is a real, but also a projected undersupply of a well-trained workforce. This mismatch between the demand and the supply of highly skilled labour amounts to a market failure which needs to be addressed with great urgency.

There are clear differences in the problems different sectors face. For technology intensive sectors the issue is that they are not able to hire enough qualified science and engineering graduates. European universities do not seem to be able to supply enough graduates to the business sector in a number of disciplines. Some non-European countries, especially the United States, provide a better knowledge

Table 21: Innovation challenges and policy priorities.

<table>
<thead>
<tr>
<th>Policy dimensions</th>
<th>Sector classification</th>
<th>Markets factors for innovation</th>
<th>Research and technologies</th>
<th>Markets and innovation</th>
<th>innovation environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sectors</td>
<td>Innovation intensity</td>
<td>Technology source</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICT</td>
<td>High</td>
<td>Tech. producers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machinery</td>
<td>Med-High</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerospace</td>
<td>Med-High</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical</td>
<td>Med-High</td>
<td>Tech. users</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automotive</td>
<td>Med-High</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td>Med-High</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Textiles</td>
<td>Med-Low</td>
<td>Tech. producers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food/drink</td>
<td>Med-Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eco-Innovators</td>
<td>Tech. producers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gazelles</td>
<td>Tech. producers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biotech</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend: very important, important, no significant evidence.

Source: Analysis by WIFO.
infrastructure and better career opportunities for the best educated and qualified scientists and engineers. For the very same reason it is also difficult to attract the best-qualified engineers, scientists and specialists from abroad to Europe. This imbalance between brain drain and brain gain reduces the pool of high-level human resources. Sectors with low technology intensity instead have to cope with different, but two closely related problems: even though the overall demand for highly skilled employees is comparatively low in these industries, they still lose highly skilled employees to technology intensive industries, and are a-priori not so attractive for employees anyway. Firms in the food or textile industry, for instance, find it at times very difficult to attract and hire qualified personnel and fill vacancies in R&D departments. Finally, there is clear evidence that the undersupply of highly skilled people is the main obstacle to further expansion in fast growing SME’s. Some larger, renowned firms are able to compensate for these problems due to a reputation that makes them attractive as employer. It is more difficult for new and fast growing firms. The case study boxes in this section give a plastic view of the human resource problem from the perspective of innovation leaders in different industries. The human resource problem is significant as a barrier for growth, but also as a factor to attract and keep knowledge intensive businesses in Europe, because if companies cannot find enough people with the right skills in Europe, they will look elsewhere to invest.

The problem has even wider implications. The advent of strong competition from emerging economies, and the quickly growing competencies of firms in these countries require achieving greater competitiveness through product innovation and increased productivity. This goal can only be met through more research and a well-qualified workforce. If this is not possible firms will face the alternative to either relocate, or to engage in less expensive process innovation. Such a development in the labour market would either drive down wages for the unskilled or lead to higher unemployment rates in this group. Another consequence would be a sharp increase in income disparities between the low and the high skilled (see Aiginger et al 2005, Montalvo et al. 2007). To avoid such dilemma and its consequences more investment in innovation and effective education and training policies will be crucial.

The European Commission has recognised these problems and is promoting mobility, cooperation and excellence in research. Initiatives such as the Education and Training 2010 work programme that includes also the European Qualification Framework (adopted in April 2008) or the conception of the European Institute of Technology, aim at overcoming mobility barriers and educating top researchers in the EU. However, our results indicate that both quality and quantity of highly skilled people in many domains are deficient. These two dimensions cannot be overcome by increased mobility or the support of excellence and research networks alone. As education policies remain mainly a national competence, the member states should be encouraged to take action to increase the number but also the quality of the education of graduates in science and technology as well as in disciplines that provide important managerial, entrepreneurial and soft skills. It is also important that more efforts are made to increase the willingness of young people to choose disciplines where a lack of young recruits exists.

A potential barrier to achieving these goals is the public good nature of education and training, especially for higher education. As long as higher education is provided by the state as a public good an incentive problem arises when European Single Market regulations are stretched in a way to prohibit discriminatory actions against students from other countries. The incentive to invest in higher education may thus be weakened both in the target country when a large fraction of the students are foreigners and in the originating country because students can study abroad. In order to re-establish incentives some form of cross-country redistribution of costs is required (see e.g. Falk et al 2008). Further in-depth research on this issue is needed because solutions to address the challenge represented by the lack of well-qualified human capital is critical.
Case Study Evidence 16: Human Resources – BASF / Germany

SYSTEMATIC sector: Chemicals, Eco-innovation

Main Field of Activity: Being the world’s largest chemicals company, BASF’s products range from basic chemicals, plastics, performance products and agrochemicals as well as oil and gas. The company has more than 160 subsidiaries, and employs more than 95,000 people worldwide. It operates in over 150 production sites in Europe, Asia, North and South America and Africa and sells its products to more than 200 countries.

- Since the businesses of BASF are highly technical, the firm requires great numbers of highly qualified science and engineering graduates. A university system that provides the industry with adequately qualified human capital is therefore vital for the sustainability of innovativeness and competitiveness in the industry. (Friesenbichler, Rammer 2007)

Case Study Evidence 17: Human Resources – SIOEN / Belgium

SYSTEMATIC sector: Textiles

Main Field of Activity: SIOEN Industries N.V. (SIOEN) is a Belgian-based company active in the textile sector which is innovative in terms of both production techniques and applications and its markets. As of 2007, SIOEN is the world market leader in coated technical textiles, the European market leader in industrial protective clothing, a niche specialist in fine chemicals and one of the biggest global players in the processing of technical textiles into semi-manufactured goods and technical end products. SIOEN engages 4645 employees (2006).

- Despite the success of SIOEN (in financial and employment terms, including maintaining employment in textiles in Belgium, France and other EU Member States), the company continues to face a challenge to attract employees, particularly skilled engineers. (Reid, Bruno 2008)

Case Study Evidence 18: Human Resources – Avanti Telecommunications Group / UK

SYSTEMATIC sector: Aerospace

Main Field of Activity: Avanti Communications operates satellites and sells bandwidth wholesale to telecoms and media companies. Avanti plans to launch its own satellite (HYLAS – Highly Adaptable Satellite) in 2009. The company engages 60 employees and has a total turnover of about €13 million (2006).

- The company believes that the most important internal innovation barrier is the shortage of available skills. The market for key personnel tends to be centralised within the group of global operators that dominate the industry. This makes it difficult for an SME to recruit and retain high quality staff. (Clark 2007)
Case Study Evidence 19: Human Resources – BMW / Germany

**SYSTEMATIC sector:** Automotives

**Main Field of Activity:** The company is a leader in the market for premium automobiles, selling 1.4 million cars worldwide in 2006. The firm operates production facilities throughout the world. Manufacturing sites are located in Germany, Austria, the UK, the United States, South Africa and — in the form of a joint venture — in China.

- A lack of engineers in the fields of electrics/electronics, hybrid technology and materials technology is foreseeable. Even if this shortage of engineers does not affect BMW directly, due to its attractiveness as an employer, the company might be hit indirectly: its in-house production depth is 35-40 per cent, i.e. about 60 per cent of its products are provided by suppliers. Therefore, BMW is strongly involved in political activities and on-the-spot activities interest young people in technical professions and presenting BMW as an attractive employer. (Schwarz 2008)

Case Study Evidence 20: Human Resources – ThyssenKrupp / Germany

**SYSTEMATIC sector:** Machinery

**Main Field of Activity:** ThyssenKrupp is one of the world’s largest technology groups. At its plants and branches in over 70 countries, more than 191,000 employees work in the areas of steel, capital goods and services. The five segments of ThyssenKrupp – Steel, Stainless, Technologies, Elevator and Services – are among the world’s leading suppliers of products and services in their markets.

- Access to top level human resources was identified as the most important external driver of innovation. ThyssenKrupp has not yet faced major problems in attracting skilled people, owing to its image, its international presence, its size and the success of the company. (Vari 2008)

Case Study Evidence 21: Human Resources – Skysails / Germany

**SYSTEMATIC sector:** Eco-innovation

**Main Field of Activity:** SkySails is a fast growing technology start-up that has developed a wind-powered ship propulsion system. The system is ready for market and the firm is about to enter a huge market. The company expects to rapidly increase the number of employees from 47 in 2007 to 800-900 by 2015.

- As the company is predicting substantial growth in the next few years, the availability of qualified staff, such as technicians and engineers, is crucial for SkySails’ success. However, the company faces problems in finding suitably trained employees. This is the consequence of a well known lack of engineers and technicians in Germany. Unfortunately, employing foreigners does not seem to be an answer. SkySails’ experiences with engineers from abroad have been disappointing so far, as the workflow has been severely disrupted because of language barriers. (Schwarz 2007)
Knowledge creation, diffusion and technology transfer

There are several aspects that make the creation and acquisition of knowledge a key-challenge for the next five to ten years. Previous studies and results from the SIW project offer the following evidence:

- The US and Japan are attracting more international R&D expenditure than the EU, whilst there is emerging evidence that countries such as China and India are becoming important locations for new R&D investments. (Commission 2005, p. 5; Thursby and Thursby 2006).

- EU manufacturing overall remains specialized in medium-tech sectors and has not taken advantage of the fast growth of certain high tech sectors. A much smaller share of corporate R&D investment in the EU is carried out by firms in high-tech sectors than in the US (see also Commission 2007d, Commission 2007b).

- The R&D productivity is lower in Europe than in the US or Japan. This may lead to the relocation of research activities where the situation concerning human resources and scientific infrastructure is better (Harrison, Griffith and Van Reenen 2004). Even though our results show that a convergence in R&D productivity is taking place and technology gaps are decreasing (Crespi and Patel 2007), the lack of human capital may negatively affect this process.

- Results from case study research among innovation leaders in the EU show that firms themselves perceive the development of in-house capabilities through R&D and specialist knowledge as the most important firm-internal challenge (Männik 2008, see also Table 22).

Over the past eight years in the EU market mechanisms have not been able to encourage enough R&D activities to reach the higher levels of R&D-expenditures across the EU as envisaged by the Lisbon agenda. This would suggest that existing policy measures have not been able to overcome the market failure associated with the production of knowledge. But the problem is more complex.

Firstly, the findings presented in this report provide clear evidence that European economies differ considerably in their industrial structure and in their state of economic development. Whereas convergence and cohesion is a central goal of EU policies, this is a slow process and innovation policies therefore must take into account that industrial structures and the state of economic development in EU member states differ and as a consequence innovation policies also must be adapted to these realities. In countries far from the technological frontier technology transfer and the development of absorptive capacities through R&D and training must be the first priority. In countries close to the technological frontier technology production and R&D aiming at product innovations must be the focus of innovation policy. Policies are likely to fail if the targets it sets do not take into account the industry structure and state of economic development. In countries with an industrial structure where sectors with low R&D intensity predominate targets should not be set too high, even below the 3% Barcelona target. On the other hand, in countries with an industrial structure dominated by high tech sectors, that target may be too low.

Secondly, our analyses have shown that the knowledge stock (such as experience and past investments in R&D) is a very important determinant for innovation, and the effect on innovation is much higher than actual investments in R&D. The role the stock of knowledge plays in innovation performance of sectors has direct implications not only for the success of the Lisbon agenda but for innovation policies generally. If the importance of the knowledge stock outweighs actual R&D investment as a determinant for innovation and total factor productivity (TFP) then this finding implies for the Lisbon agenda that policy measures to increase the R&D-intensity in all European countries may take effect only over a longer time period. On the other hand, there are also large differences across
sectors regarding factors such as cumulativeness, and appropriability conditions affecting the main innovation modes (R&D versus non-R&D innovation). This again calls for sector specific measures supporting knowledge creation of firms and underscores the necessity to consider the industrial structure and the state of development in each European economy.

Thirdly, the efforts to classify industries according to their innovation intensity and innovation modes undertaken in this project suggest that innovation and the role of R&D strongly differs across industries and countries. In some sectors innovation is mostly effected by non-R&D activities. In a broader context some industries, such as the textile industry, are of relatively high innovation intensity even though they may be of low R&D intensity. Furthermore, technology intensive industries also rely on and benefit from a host of non-R&D related methods of knowledge acquisition, be it through technology acquisition, formal cooperation or diffusion of knowledge. The policy priorities matrix in Table 21 shows that in some industries these non-R&D related forms of knowledge acquisition represent an even higher challenge than R&D related knowledge creation. Firms increasingly realise that specific types of interaction in networks lead to very complete diffusion of knowledge and source knowledge (see e.g. Cowan and Jonard 2003, 2004). High innovation performance therefore requires an optimal mix between formal R&D based knowledge creation and formal as well as informal methods of knowledge acquisition which are different from sector to sector. Policies that focus on fostering innovation exclusively through R&D are likely to neglect innovation intense industries that rely little on R&D even if they are being innovative or have a high innovation potential.

Our results suggest that knowledge acquisition is more important for innovation in industries with low innovation intensity. If at present the industrial structure of many EU economies is such that high tech industries have a low weight, it is not surprising that aggregate R&D is not on the rise, even though innovation activities may have been scaled up in the EU. In these industries models of innovation other than the R&D based approach may be needed. In industries that rely heavily on external knowledge, but are also actively creating new knowledge the open innovation paradigm may be an alternative. However, for this to work the technology markets must be well developed. Currently, as has been shown by van Pottelsberghhe and François (2008), this is not the case in Europe. It is too costly to patent and therefore to engage into processes of selling one’s own knowledge and acquiring knowledge of others more intensely, as the open innovation model suggests. To foster the diffusion of knowledge and thereby support industries that rely more heavily on external knowledge, the European IPR system must be improved considerably.

Fourthly, European firms may be facing a system failure. There are inherent complementarities between the lack of highly qualified human capital and under-investment in R&D if we consider that the largest part of R&D investment is spent on researcher salaries. If firms are willing to increase their R&D investment, but cannot find enough researchers for their research projects, they have either to stop the investment, relocate to a country where the human resources are available, or use labour of lower quality, hence lower research productivity. None of these options is desirable and amounts to a system failure, as potential innovators are not able to act in their own best interest. This problem also extends to activities related to technology transfer, knowledge absorption and efforts to modify existing technologies. As we have argued in previous sections of this report the access to external informal knowledge is important for both product and process innovation. One of the main determinants influencing a firm’s capability to apply this knowledge is the level of the firm’s human capital. The quality of human capital is a very significant variable reflecting the benefit from the flow of knowledge with a higher number of educated workers translating into
a higher capacity of the firm to adopt and modify new technologies. With inadequate human resources the success rate to adopt and modify technologies is likely to decline.

The problem affects countries on and off the technological frontier equally, although the policy implications are different. Whereas in countries off the technological frontier educational and training efforts should focus on disciplines fostering catching up to the frontier, such as engineering and vocational training in technical fields, countries close to the frontier need not only to maintain a high level of engineering and technical capabilities but they also must strive to achieve excellence in academic research, as this becomes the most important and effective

Table 22: Most important innovation barriers.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Type of factor</th>
<th>Barriers to innovation in the next 5-10 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biotechnology</td>
<td>Internal</td>
<td>No common patterns</td>
</tr>
<tr>
<td></td>
<td>External</td>
<td>No common patterns</td>
</tr>
<tr>
<td>Food &amp; Drink</td>
<td>Internal</td>
<td>Forecasting technology and markets</td>
</tr>
<tr>
<td></td>
<td>External</td>
<td>No common patterns</td>
</tr>
<tr>
<td>Machinery &amp; Equipment</td>
<td>Internal</td>
<td>* specialist knowledge and skills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* human resource development and motivation policies / practices</td>
</tr>
<tr>
<td></td>
<td>External</td>
<td>access to top-level human resources</td>
</tr>
<tr>
<td>Textiles</td>
<td>Internal</td>
<td>* specialist knowledge and skills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* forecasting technology and markets</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* resources available for evaluating / testing new ideas</td>
</tr>
<tr>
<td></td>
<td>External</td>
<td>access to top-level human resources</td>
</tr>
<tr>
<td>Chemicals</td>
<td>Internal</td>
<td>Organisational structures</td>
</tr>
<tr>
<td></td>
<td>External</td>
<td>access to top-level human resources</td>
</tr>
<tr>
<td>Energy</td>
<td>Internal</td>
<td>* specialist knowledge and skills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* empowerment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* human resource development and motivation policies / practices</td>
</tr>
<tr>
<td></td>
<td>External</td>
<td>access to top-level human resources</td>
</tr>
<tr>
<td>ICT</td>
<td>Internal</td>
<td>* resources available for evaluating / testing new ideas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* specialist knowledge and skills</td>
</tr>
<tr>
<td></td>
<td>External</td>
<td>* access to top-level human resources</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* favourable policies and programmes supporting innovation</td>
</tr>
<tr>
<td>Space &amp; Aeronautics</td>
<td>Internal</td>
<td>* specialist knowledge and skills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* IP management</td>
</tr>
<tr>
<td>Automotive</td>
<td>Internal</td>
<td>* in-house R&amp;D and technological capacities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* human resource development and motivation policies / practices</td>
</tr>
<tr>
<td></td>
<td>External</td>
<td>* access to appropriate financing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* access to top-level human resources</td>
</tr>
<tr>
<td>Eco-innovation</td>
<td>Internal</td>
<td>* organisational structures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* forecasting technology and markets</td>
</tr>
<tr>
<td></td>
<td>External</td>
<td>* access to top-level human resources</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* access to appropriate financing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* clear and appropriate laws, regulations and standards at European level</td>
</tr>
</tbody>
</table>

source of new ideas able to trigger further research in the business sector. To this end the interaction between universities and the business sector should be fostered and further developed. The recent communication on “Promoting Improving knowledge transfer between research institutions and industry across Europe: embracing open innovation – implementing the Lisbon agenda,” puts forward a number of policy propositions which should be applied in all member states. They are considered a starting point for discussions on a common European framework for knowledge transfer (SEC(2007), 892). However, little attention is paid to the problem that across countries and sectors needs differ. According to the experts from the Europe Innova panel, the gap between universities and companies in some countries is currently so wide that cooperation between the two would not lead to more innovation.

Financial constraints

The decision to invest in innovation depends on the initial incentive to allocate resources for innovation, the capacity to dispose of all non-financial resources needed to carry out the innovation activity (such as human resources) and the capacity to raise the necessary financial means to realise the project. As is well known from the literature, the limited appropriability of knowledge may distort incentives to invest should private returns to innovation fall short of social returns. Capital market imperfections in turn may lead to under-investment even if incentives are not distorted. In this case capital markets do not provide enough financial means to carry out innovation projects because of incomplete information about their possible future outcomes. Financial constraints therefore act on the incentives to innovate as well as on the effective realisation of innovation projects. Consequently, it does not come as a surprise that firms in all systematic sectors declare the lack of financing to be a hampering factor for innovation. However, there are considerable differences across sectors and firm types for the causes of this problem.

As we have argued in Chapter 3.1, there are major differences across sectors concerning financial constraints for innovation depending on R&D-intensities and economic risk. Especially for firms carrying out high-risk research, for young and small start-up firms and for firms facing extraordinary growth opportunities the lack of financial resources constitutes a serious problem due to the murkiness of the associated market potentials or the lack of tangible assets that may be used as collateral for loans. Results from the SIW project show that the lack of venture capital, especially for the seed financing stage is therefore a major problem for many small ICT and biotech firms as well as for fast growing SME’s. These firms in most cases have to rely on the personal funds of the founders in the seed-financing stage.

Public efforts should therefore focus on improving the financial environment and stimulating risk capital markets. In this respect the European financial system is not well developed and a system failure is the likely consequence; due to a lack of proper of institutions coordination between different agents in the system does not take place at all or are rather inefficient such that an under-investment in innovation projects is the consequence. Private equity investment for early stage activities, as well as high-yield bond financing is low in most European member states except for the Nordic countries and the UK (Philippon und Véron 2008). The development of venture capital markets is also important because based on long-standing experience venture capital firms are able to select and monitor high risk projects better. Venture capitalists help overcome information asymmetries that are an important cause for the undersupply of financial resources. However, in order not to crowd out private financial intermediaries public activities should focus on matching nascent entrepreneurs with financial
Access to alternative funds increases as firms accumulate tangible assets and strengthen their reputation with financial intermediaries. This also depends on the nature of their activities. For instance, capital intensive firms find it easier to offer collateral due to their higher stock of tangible assets. However, there is broad evidence that firms prefer to rely on their own cash flows and retained earnings in favour of external finance, or if this is not possible on debt financing. Therefore, for older firms and in more mature industries, the finance-related under-investment is more closely related to the incentive problem to allocate resources for innovation activities. Innovation is no longer hampered by the lack of financial resources but by the limited expected profitability of innovation projects as opposed to the costs of R&D and other innovation expenditures. By pure economic reasoning, firms try to keep R&D costs at reasonable levels and as a consequence for some innovation projects resources are scarce.

Instruments other than risk capital are therefore necessary to stimulate more innovation. The rationale for policy intervention is here to compensate for social returns being higher than private returns, or in other words, for appropriability problems and positive spillovers that come with them. Here, the EU member states have already developed a wide range of instruments, such as tax credits or allowances, and direct funding. However, a policy mapping exercise carried out within the SIW project shows that resources here remain very fragmented and are very likely to operate at sub-critical levels as well as lacking transparency and coordination (see Reid and Peter 2008). For some industries, it would be desirable to include informal sources and non-technological innovations into financial support schemes. This would be warranted as long as there is a clear case of non-appropriability of spillovers (see Peneder 2008).

**Case Study Evidence 22: Financial constraints and knowledge creation – AVL Group / Austria**

**SYSTEMATIC sector:** Automotives

**Main Field of Activity:** AVL is the world’s largest privately owned and independent company for the development of powertrain systems with internal combustion engines as well as instrumentation and test systems. The AVL Group has 3,640 employees (1,550 in Graz and another 2,090 worldwide), and produced €537 million turnover in 2006.

- Reduce the administrative burden of public support programmes for innovation: While AVL is large enough to afford a division working solely on support schemes and filing applications, this task is too expensive and time-consuming for small companies. Small companies have to cooperate with larger partners to be able to obtain public financial support because otherwise it would not be possible for them to be sufficiently schooled in the support schemes. Much potential sponsorship is unused because of its complexity and the large amount of administrative effort required. Therefore, it is recommended to reduce or at least avoid an increase in the administrative burden of applying for the financial support of research projects to allow smaller companies to participate. (Unterlass 2008)
4.3 Top challenges by sector

In this section we discuss the top challenges for each sector as presented in Table 21. Sectors with a larger set of challenges are presented first. 7

ICT

ICT firms tend to specialise in relatively high-risk projects with little fixed investment. They are faced with higher technological and economic risks in innovation while innovation expenditures consist mainly of intangible investment (including a large proportion of current expenditure for salaries, external services and material). ICT firms therefore have to rely predominantly on internal financing or external equity financing to fund innovation. The problem of financing innovation plays a particularly important role in the ICT sector. According to the national experts’ opinion, the venture capital market should be further expanded for these high-tech sectors.

The growing shortage of absolute numbers of ICT workers, a mismatch between supply and demand for specific skills, and a decline in the number of students studying IT and computer science, is an innovation challenge in that it can lessen the speed of adoption of new technologies reduce the “go-to-market skills” needed to drive business growth. An increase in quantity and quality of both engineers and blue-collar workers in the ICT sector is important. The lack of mobility of people, both between departments and sectors and between the business and public sector, are presently also a challenge in the ICT industry.

Entrepreneurship is a skill that needs to be added to the curricula of technical disciplines at institutes of higher education. ICT sector experts view this as a challenge that needs to be addressed in order to encourage and promote an “entrepreneurial mindset” in Europe. Another set of skills needed in the sectors is project, technology and business management. A interdisciplinary approach should be incorporated into the education system. This concerns not only technology fields but also the combination of technology and entirely different domains (e.g. Master in bioscience and entrepreneurship). The appointment of people with entrepreneurship experience as heads of departments is an example for making socio-cultural changes happen in the university in order to make it more receptive to innovation. Since innovation is not only linked to new technology, and innovative design, the introduction of new business models can be just as important in the development of leading industry sectors.

The ICT sector’s position is under threat of fierce competition from the emerging economies. It is therefore essential that the sector maintain its competitive advantage by investing in top quality research and education. The challenge for Europe’s ICT sector will be to build continuously upon its ability to develop frontier technologies and further, to facilitate the demand for them in potential leading markets within the context of the European social model. It is important to increase the quantity and quality of research in future emerging information and communication technologies such as photonics. However, Europe is investing less than other major countries in innovation and R&D, and if the current trend continues China will have caught up with the EU by 2010 in terms of GDP allocated to R&D. Europe is vulnerable to increased competition, and current research leadership in some areas is endangered. Europe Innova Panellists have argued that the main task is to build up critical mass in research so as to attract research to Europe. However, in the eyes of experts initiated research programmes are often too bureaucratic and they do not properly address the market side of the value chain (from research to market).

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7 The results presented here draw on sector specific reports on innovation challenges produced in Workpackage 7 of the SIW project, and on the Sector Reports of the project. In the Appendix we list all reports.
In order to strengthen the ICT industry and increase its competitiveness, the adoption of ICT’s in all segments of the economy is important. To raise the demand for the technologies it will be important to focus on the skill to use ICT effectively. This will drive investment and growth in the ICT sector. The large share of SME’s (less than 250 employees) in the EU hinders the adoption of ICT in the economy. In many SME’s there is a lack of awareness of the potentials of ICT’s, and these businesses also find it difficult to implement the necessary organisational changes in order to benefit from them. Furthermore there are not enough suitable applications of relevance to SME’s. These are important barriers to ICT adoption in the economy and result in lack of efficiency and productivity. ICT adoption in the public sector and public procurement are important drivers of innovation in the ICT sector. The main innovation challenge lies in how to change the culture of public procurement to favour innovative solutions and at the same time focus on support for R&D and innovation. Next is harmonisation of regulation in these sectors.

As mentioned above in the Chapter 3.4 on innovation drivers, security issues and privacy concerns are important socio-cultural aspects which have a significant effect on innovation in the sector. As ICT technology becomes ever more embedded in society, it becomes more closely related with people’s political and ethical values. Generating trust is one of the main challenges in ICT to successfully exploit potential applications. In short, innovation culture and especially attitudes and belief in novelties are highly important for innovation success in ICT and should therefore be focused on by policy makers. The Europe Innova Panellists furthermore recommend the European Commission to try to learn from different European models as regards the socio-cultural factors and their relevance for innovative behaviour. The diversity in Europe on the four socio-cultural properties identified in this study could be turned into a strong asset.

The European ICT market is still a fragmented market where national interests dominate. There is a need for one single internal market, both in production and in research. The reach, scale and complexity of what can and should be made interoperable in order for the benefits of convergence to be obtained have grown even further. Interoperability is an important aspect of ICT uptake, and the legal, semantic and organisational interoperability issues that exist in Europe have a more direct impact on the differing levels of ICT uptake in the EU than in the rest of the world. It is recommended to enable and empower local businesses to gain access to the larger global market by participating in the eBusiness community.

The European ICT industry faces increasing competition from emerging economies. The ICT industries of Korea, China and India have made tremendous progress. In order for the EU to cope with its relative decrease in world ICT production, a prospective innovation challenge lies in how to raise the awareness of its ICT products and services.

### Biotechnology

One of the main issues for innovation in biotech firms is the creation of a risk capital market for biotech projects. The focus should lie on improving financing possibilities (venture capital, funds for the promotion of biotechnology research). Therefore, the framework for investment has to be enhanced through boosting investments in the biotech and life sciences sectors and facilitating start-up of biotech companies.

The supply of skilled labour is an important determinant of innovation in the biotechnology sector. The Europe Innova Panel experts underscored the great importance of developing innovative thinking already at the university. Policy should encourage universities to develop innovation-oriented courses where for instance a biotech curriculum is combined with an entrepreneurship curriculum.
From the perspective of the industry, the issue of skills and human capital is complex. Jobs in biotechnology are diverse, creating excellent employment opportunities in many different areas. It is crucial for firms to employ people with strong scientific skills, but there is need for more generic skills such as communication, problem-solving skills and the ability to work in teams. As Europe has high levels of immigration, it appears also important that immigrants, who are potential innovators of the future, participate in the education system from primary school to university level. Providing better access for women to research carriers is also important to increase Europe’s competitiveness in the biotechnology industry; their exclusion represents a loss of potential knowledge.

Biotechnology innovation is most often described as departing from biotechnology research in academic laboratories. This is probably the only sector where the linear model of innovation fits. Improvement of conditions for life science research is very important to be internationally competitive. The preparation and implementation of a public support programme for biotechnology is therefore needed. A top level in research cannot be maintained without intense collaboration with laboratories abroad and strong links to the local research community. The commercial exploitation of biotechnology has to be increased through intensification of modes of technology transfer between academia and industry enabling sustainable translation of academic research to industrial potential and market value. Investment for the establishment of national centres of excellence and core facilities of applied industrial focus are needed. However, Europe Innova Panel experts did not think that cluster policies were either relevant or useful except in the case of supporting “organically” developed clusters. Clusters as a policy concept, and particularly in relation to funding, have not proven to be adequate. In the past policy initiatives have led to the creation of artificial clusters with little effective interaction between participants. A further development of clusters would not be beneficial to an industry already overly fragmented in Europe unless the purpose was to concentrate the activity around a very small number of the most successful existing clusters.

Acceptance of biotechnologies (esp. GMO’s in agrofood) by society is the most important challenge in biotech innovation on the demand side. Consumer behaviour has been deeply affected by public opposition to GMO’s, although its force varies from country to country. This public attitude, combined in turn with delays in setting up a coherent regulatory framework, has reduced the possibilities to import or grow GMO’s in the EU. In this sense the biotechnology industry is still a rather immature industrial branch. It still needs to break into a “new paradigm” where laws, regulations, consumer wishes and the supply of biotech products are mutually consistent. This lack of coherence increases the risk of biotechnology products and therefore exacerbates financial constraints the sector faces. Developing and implementing a European commercialisation strategy of the biotech sector should aim to homogenise the fundamental assumptions of the sector across countries. The goal is to create a critical mass required for success. This requires the enhancement of communication between institutions and people in the area. The sector needs a real internal market in Europe. The experts of the Europe Innova Panel argued that public policy should focus on a more objective public perception of biotechnology products. This would support the demand for innovative products.

Food

In the food industry human resources are essential for innovation. A prospective innovation challenge for the sector is therefore to attract and hire qualified employees which is becoming increasingly difficult.

The greatest challenge for the industry is to engage more firms in innovative efforts by increasing research activity, and how to arrange for knowledge diffusion and technology transfer between firms and related sectors. Integration along the supply chain, upstream and downstream, is a trend in the industry. In order to improve internal processes and in order to interact with partners along the value chain, intensive use of ICT is needed. In the sector, ICT use needs to be further improved in order to raise efficiency at all stages in the production, processing and distribution of food.
A high number of new or modified products are often combined with process innovations. Three especially innovative fields in the food industry are in the area of genetically modified organisms, functional food, and organic food, representing market opportunities which, however, also have different obstacles and drivers. A future innovation challenge to the agro-food industry will be to tackle the new multiple scientific approaches and technical opportunities that have an interdisciplinary character. The creation and strengthening of interfacing competencies as well as the establishment of new external knowledge and competence networks seems to be of strategic relevance. The target for policy should be to support the advances of the knowledge base of the food industry companies themselves and the diffusion of new scientific approaches and technology, not sole concentration on stimulating knowledge generation with relevance for the food industry.

Europe Innova Panel experts view conservatism of food consumers as an innovation challenge for the sector. Non-technological innovation is crucial here. If radical innovations are priced and branded adequately and if the sensory qualities of foodstuff are good this problem will not be critical. More difficult are the regulatory and legislative constraints. Political and regulatory framework conditions in the EU often fail to keep pace with the scientific and technical discoveries or developments on the demand side. Legal uncertainty and non-harmonised regulatory conditions impede innovation activity and may result in a loss of market opportunities. Regulatory convergence with trade partners and the promotion of international harmonization efforts (e.g. Codex Alimentarius Standards, HACCP principles) will help reduce the cost of complying with third country regulations.

**Aerospace**

The Aerospace industry is a high-tech industry and is a powerful driver of innovation in the economy as a whole. Aircraft development and production is by far the largest component of the industry. Space activities account for less than 10% of the activities in the Aerospace industry. The European Aerospace industry is world leader in large civil aircraft, business jets and helicopters, aero-engines and defence electronics. The industry is going through an ongoing consolidation process and the number of major players has decreased from 30 to 11 in 2003.

The Aerospace industry is one of the few sectors where it may be claimed that military purposes are still a driver for technological development. The European problem is that on the defence side of the sector, Europe is spending only one-eighth of the US R&D budget and, even worse, these funds are not centralized but national. The US is thus capable of financing and executing larger and more focused programs. The failure to invest in potentially disruptive technologies such as nanotechnology or generic technologies such as unmanned aerial vehicles (UAV) as well as to efficiently comply with emerging environmental pressure to develop more fuel-efficient and less polluting aircraft will put European Aerospace companies at a disadvantage. Therefore, Europe Innova Panel experts argue to create a “one stop centre for aerospace excellence” for aerospace companies. This objective is achievable if policy concentrates on developing infrastructure, investment in research, product development and innovation. Since public procurement is a central source of demand, this generates a natural disadvantage for European firms that do not possess a similarly sized home market. Furthermore, developing one single European internal market, in particular for the defence sector, is a main issue in Aerospace innovation policy.

Besides military procurement the main challenges of innovation for the sector are globalization, environmental and security issues. Aerospace firms need to meet the increased need for safety and security in civilian aviation by developing new technologies. The failure to efficiently comply with emerging environmental
pressure to develop more fuel-efficient and less polluting aircraft is crucial for international competitiveness of the industry. European aerospace must also adapt to the new requirements from airlines that demand support and maintenance services.

Public support for innovation is still fragmented with individual EU-Member States funding their own national programmes. More coordination among the various national programmes would be required to establish a single European research market. The Aerospace industry faces a major skills shortage due to the cyclical nature of the industry, the off-shoring of low-cost manufacturing work and Aerospace engineering education is insufficient in quality and content. Aerospace companies consider forecasting technology and markets and in-house R&D capacities as the most important innovation drivers of the sector.

Chemicals

The chemical sector is facing radical structural change over the next 20 years. The most important driving forces are increasing competition from the continuing trend towards globalization of the industry, a regulatory regime that is increasingly sensitive to environmental issues and sustainable development, and an increasing need to improve new technologies for new product and process development.

A major challenge for the European chemical industry in terms of globalization of the industry is the fast growth of installed capacity and production in Asia and the Middle East. Already many chemical plants in these regions are bigger than their European counterparts, resulting in an important competitive advantage in an industry with substantial economies of scale. Different branches of the industry are likely to be affected in different ways, with immediate pressures being felt in basic chemicals (especially petrochemicals).

The growth in the price of oil and other raw materials has important implications for the industry. Crude oil is a key input in the basic chemical industry and a dramatic rise in its price will negatively affect the mark up in the industry unless some of the higher costs can be passed on in terms of higher prices. To some extent this will depend on the strength of demand, where two issues are important. First is EU regulations and potential changes in the Community Agriculture Policy, which may lower the demand for fertilizers from the agriculture sector. Additionally as textile producers continue moving their production base to South-East Asia, the man-made fibres industry may follow, negatively affecting the demand for basic chemicals in Europe.

Firms perceive a lack of skills at world-class levels in the workforce, which is directly influencing the industry’s ability to remain close to the technological frontier of this sector. Demographic data indicate a potentially serious shortfall of skilled new recruits for the future, particularly at technician and operator level. This is serious as the industry’s age profile is already skewed towards an older workforce. Fewer students are opting to study science and technology at both graduate and vocational levels. The industry is less attractive to new entrants, and vocational routes are seen as less attractive than more academic ones. Chemistry currently scores last among the most preferred subjects studied at secondary school. This result may be due in part to the poor quality of teaching, and the limited availability of chemistry laboratory facilities. Therefore, the workforce is ageing because of too few young recruits.

From the regulation point of view, a major challenge for the sector is the successful implementation of the Registration, Evaluation and Authorization of Chemical substances (REACH) system, which entered into force on 1 June 2007. This will ensure a homogeneous regulatory regime in the internal market, improving competitiveness while achieving a marked improvement in relation to
environment, health and safety standards. Another challenge faced by the chemical industry is in relation to environmental regulations. The problems faced by the industry with regard to the environment include the pollution caused during the production process and the downstream pollution that occurs during consumption and disposal of the industry’s final products. These will require substantial investment in R&D and innovation.

A large part of the solution to the above challenges will be based on successful enhancement of new technologies arising from advances in nanotechnology and biotechnology. Mastering nanotechnology will yield both a new generation of materials with enhanced properties and lead to improvements in materials efficiency resulting in further new applications. Industrial biotechnology, which uses enzymes and micro-organisms to make products, can make a significant contribution by minimising hazardous materials and waste. This broadening of the technology base may contribute and improve its overall competitiveness. This might break up the “monocultures” of some regions and allow customer tailored solutions, which also might attract international venture capital. This is why especially for new fast growing firms in the chemical sector risk capital is needed. Overall, intensifying R&D activity in the chemical sector (with the exception of the pharmaceutical industry, there is too little R&D and no substantial R&D projects) and promoting SME’s’ R&D activities and commercialization capabilities are key policy priorities in this industry.

Automotives

The European car markets are large and established. However, major growth opportunities are arising in emerging countries such as Brazil, China, India and Russia. Hence, innovation strategies need to be adjusted to reflect not only the market needs in these countries but also production opportunities.

Innovativeness of Europe’s automotive sector depends now heavily on high quality education of engineers and managers. In particular, the innovation performance of the sector can be enhanced by providing engineers with entrepreneurial skills, which is an additional skill to ensuring a sufficient supply of highly-qualified labour (engineers). The current trend in the automotive sector requires innovation at a continuously higher pace which is generally increasing the demand for a highly educated labour force of engineers and scientists. Increasing the share of women in the automotive workforce (especially female engineers) is important since there is a clear need for more expertise in the development and designing of cars for special groups of customers. There should also be no restrictions in terms of international employees. Even if European universities educate many foreign engineering students the integration into company human resources planning is insufficient. Special attention should be paid to the nurturing of talent in order to establish skills that help to bridge traditional company and industry borders and to foster international cooperation. Furthermore, the demand for personal and business mobility will rise. At the entry level the attractiveness of careers in the automotive industry should be promoted by changing stereotypes of unattractive, loud and noisy work environments. Besides, priority should be given to the development of competences that combine traditional expertise in the Automotive Sector (e.g. mechanics) with new opportunities, for example, in the fields of chemicals or electronics. Finally, competences for converting technological inventions into market ready innovations should be strengthened.

Technological opportunities in the Automotive industry emerge increasingly outside the traditional fields of expertise, most notably for alternative engines/fuels (e.g. batteries, ethanol) as well as from electronics. The Europe Innova Panel experts recommend to set up Joint Technology Initiatives in the two priority areas of clean fuels and vehicles (e.g. hydrogen and fuel cells) and intelligent vehicles and
roads should also continue. Boundary-spanning competences are required to identify, assimilate and exploit these new opportunities. In this sense, it becomes important to strengthen knowledge flows between firms and with universities. Regional proximity in clusters as well as capability mapping (to find and exploit opportunities) are important elements of facilitating these exchanges. Universities play an important role in this system, too, as they provide not only research outputs but are also responsible for educating engineers and managers with the necessary technological acumen to identify opportunities across firm and industry boundaries and also to have the soft skills to initiate and manage the knowledge flows.

The collaborative nature of innovation in the Automotive Sector requires organisational processes and institutional rules that facilitate and propel innovation. This calls for extending and reinforcing collaboration along the supply chain and with research centres or regional universities. Most importantly, this includes the management of complexity as well as effective systems for rewarding investments in R&D (e.g. intellectual property rights).

In terms of intelligent transport systems the experience in Europe is rather fragmented. Nevertheless many automotive manufacturers are interested in and motivated to developing this kind of technology. Also within this domain success depends on an effective intellectual property rights (IPR) regime. Fast adoption of a regulatory framework is also one of the factors that would shorten the time to market and help create new markets. The public sector should be the pilot customer. While there is sufficient risk capital in this market, investment in infrastructure is needed in order to boost the potential of these kinds of technology.

The EU has the capacity to become successful in sustainable climate technologies. Regulatory policy is considered crucial in this regard. It is in particular the introduction of control maintenance systems that is at stake. Redefinition of standards is of fundamental importance, from average car fleet exhaust gas emission to class-dependent car fleet exhaust gas emission. Public procurement should play a more preeminent role, as it may be crucial in demonstrating innovations and influencing mental shifts. Examples of where public procurement may have a role include: environmentally-friendly cars and trucks for public transport, waste management, fire services, police services, search and rescue, and defence as well as in demonstrating the reliability and benefit of the given innovation. Regarding the need for financing projects of development and application, there is no immediate need as the automotive suppliers are expected to take on that responsibility in the short and medium term.

**Eco-Innovation**

Eco-innovations are hampered by a lack of finance during the development phase (especially for SME’s), as well as by risk aversion and uncertainty among potential adopters. Environmental technologies are perceived as risky investments due to the costs they involve and uncertain returns due to difficulties in anticipating consumer responsiveness. It would be useful to establish policy targets for the medium/long term in order to make investment in eco-innovation more attractive and less risky for potential investors. The establishment of harmonized standards for environmental products (e.g. construction standards) could contribute to promote the quality of outputs delivered by eco-industry and develop awareness of the consumers.

A proper awareness initiative should be combined with a proper leadership at EU level. The evermore convincing evidence for global warming and climate change provide political windows of opportunity for more radical policies; and influencing eco-innovation potential through regulatory or legislative change is effective, but again further study is needed. Europe Innova Panellists maintain that there is a need to establish the “extended producer responsibility.” In
particular, firms and households will not voluntarily adopt environmental technologies that are relatively expensive. Market prices often do not reflect the full value of environmental resources, which means that markets do not provide the right signals to investors and consumers. Markets often simply reflect the direct economic costs and no indirect costs of environmental pollution (such as health care costs from urban air pollution). This leads to systematic under-investment in innovative technologies by both firms and households. Cost effective solutions for environmental problems are not taken up, and there is less incentive to research and develop such technologies. The internalization of environmental externalities through excise taxes would considerably improve the competitiveness of renewable energy.

Given the importance companies assign to their public identity and self-promotion today, to rank companies on eco-innovation or to provide their products with eco-labels could indeed be an effective and simple mechanism to drive the market. This ranking or labelling could be either positive or negative, but it would foster competition on eco-innovation.

Energy

The prospective innovation challenges in the energy sector are linked to the broader challenges related to global climatic change and the EU’s energy policy targets. The energy sector faces three basic challenges: sustainability, security of supply, and competitiveness. It has been argued that these challenges or policy objectives are partly contradictory. In particular there is concern about meeting targets of security of supply and sustainability, given the dominant role of fossil fuels in Europe. Clean fossil fuels are cost intensive and have yet to benefit from technological innovation. It is difficult to see how policy targets of sustainability are to be reached without fundamental changes in energy consumption patterns in European countries in the foreseeable future. This depends largely on development and innovation in the energy sector, and represents a prospective innovation challenge with relevance to the demand side and the markets of the energy sector.

The supply side of the energy system, energy production, is struggling to increase production efficiency and stability in energy supply. Increased production and problem-free market access for renewable energy is difficult to implement as long as it has to compete with energy from fossil fuels and nuclear energy which is cheaper compared to renewable energy sources. This form of market failure (lack of charging for the negative environmental impact) and system failure (fossil fuel as dominant technology) is the main argument for a policy intervention in this market, both on the supply and demand side. Regulatory mechanisms to facilitate emission trading, investment in energy efficiency as well as regulatory and market mechanisms that allow renewable energy entry into energy markets are therefore key challenges for innovation in the energy sector. Coordination of national legislation with EU Law is also recommended.

Our findings show that competition is a main driver of innovation and a prerequisite for sustainable technological change in the energy sector. The lack of competition on the energy market has negative effects on innovation. A precondition for increasing the use of competition as a tool to foster innovation in the energy sector is to develop a European energy market with a pricing system ensuring that the beneficiaries pay all costs, including cost to the environment.

Textiles

The competitive advantage of the textile industry in Europe lies in producing knowledge-intensive products (“intelligent” textiles), or by strengthening links to the fashion and design industry (moving down the value chain). This poses
challenges to the textile and clothing industry in many ways. An important challenge is related to the industry's capability to maintain the lead in high value-added products such as technical (or intelligent) textiles and non-woven materials such as industrial filters, geo-textiles, hygiene products and products for the automotive industry and the medical sector. Market areas considered to have the highest potential (lead markets) are in the field of technical textiles and include the next generation of intelligent personal protective equipment that include future medical and health-care textiles and new light-weight, high-strength construction and transport related materials. Engineering and design will be important in this respect.

The textile sector’s potential strength is also closely related to non-technological innovation. There is a need to better define and identify non-technological innovation which will also enable appropriate recognition by the EU’s state aid regime. As the industry faces growing difficulties to obtain financing for innovation projects, it seems necessary to tailor relevant support programmes that cover important innovation input in the sector, such as programmes directed towards the textile industry's ability to absorb advanced technological knowledge from other sectors (technology transfer between sectors), non-technological input of importance to innovation, and different fields of R&D activities. There is no strong tradition of joint research and product development between companies and research institutes in the textile sector, suggesting an important area of public policy intervention.

Prospective innovation challenges with regard to process innovation lie in new process (production) technologies, automation and flexible high-tech processes that, for example, can offer tailor-made clothing in a mass production system. Challenges are related to new textiles and composite materials and their need for process and production innovation. With regard to new machinery, processing methods and processing activities, challenges will lie in breakthroughs in technology areas such as biochemistry, biotechnology, plasma, laser and nanotechnology. Many new technological processes are still not economically viable.

A challenge for manufacturers in the textile and clothing industry is how gain access to market information available mostly in the downstream retail business that will allow quick adjustments and reactions to market needs. The potential lies in the “creativity lead” and to make mass customised goods available for consumer (B2C) trade on the Internet. In order to reach this goal market research and competitive watch should be promoted.

A challenge with regard to new prospective possibilities is how the industry will attract the relevant skills to this low tech and declining industry. New skills and human capital able to interact with and absorb knowledge from a high-tech knowledge-intensive environment are needed. This also requires an educational system providing these skills. A huge challenge, therefore, for the textile and clothing industry is resolving the conflict of how to create interest in higher education institutions and training possibilities for an industry whose downsizing would seem to reduce such demand.

**Gazelles**

The challenges for innovation for fast growing enterprises vary over the different stages of firm development:

At the pre-start phase a key policy challenge is to address and motivate the right people. This part of gazelle policy is essentially entrepreneurship policy. Policy should influence individuals’ career choices by ensuring that they are aware of the entrepreneurial options such as entrepreneurship promotion and entrepreneurship education. In short, policy should motivate the skilled and competent individuals to make the entrepreneurial choice.
At the start up stage, a key policy challenge is the availability of seed capital and the process of incubation. Emphasis should be placed on increasing the specialisation of incubation services across Europe. A focus on particular sectors and technologies enables incubators to employ staff with sectoral expertise and encourages a critical mass of innovative activity, facilitating links with universities and R&D centres, attracting investors and stimulating a cross fertilisation of knowledge skills. Due to the lack of profits and in many cases tangible assets, risk capital is essential in this phase. As we have discussed at the beginning of this chapter, during this phase of the development process financial support is most crucial.

At the growth stage a major policy challenge relates to labour market failures that impede continuous growth, whereby continuous growth requires adequate skills and senior management. The key here is fostering the mobility of talented managers (and researchers) toward high-growth firms. Policy should ensure that a well functioning market for skilled labour is in place and fosters managerial mobility. Making such markets work probably requires careful consideration of incentives, as talented managers are attracted by good salaries but it also requires raising the awareness that working in highly promising SMEs can be a rewarding experience. The availability of qualified personnel as hampering factor to innovative activity is much more important in countries close to the technological frontier than for countries that are catching up. The findings do not suggest that gazelles are different in the perception of hampering factors within country groups.

The two main challenges for innovation for fast growing SMEs are therefore the lack of financial resources in the seed phase and the lack of human capital in the expansion phase.

**Machinery**

The machinery and equipment sector faces the challenge of bringing different areas of sciences together to enable a full range of possibilities and applications. For instance, nanotechnology is involved in electronic and non-electronic elements and functions on the nano-scale for sensing, actuation, signal processing, display, control and/or interface functions. To be able to absorb and use these scientific results skilled labour is indispensable. However, there is a shortage of skilled labour, especially in the engineering industry in most EU countries. The future technological challenges of the sector show that technological change in the machinery and equipment industry is skill-based, shifting labour demand toward employees with high levels of education, i.e. engineers. Consequently, there is need for continuous improvement of skills and competencies both in form of on-the-job learning and vocational training. Increased efforts regarding vocational education and the promotion of lifelong learning schemes are therefore key priorities in this industry. Education of engineers should combine a solid basic education in mathematics and physics with the development of skills needed to meet changing management needs. Direct participation of managers in relevant educational programmes must be encouraged and, in return, teachers must be offered the opportunity of interaction with industry.

### 4.4 The innovation policy landscape

The results presented in the previous chapter and in this one have shown that drivers and barriers to innovation differ from sector to sector. We have also shown with sectoral innovation taxonomies that enterprises in different sectors innovate differently. However, there are some drivers, obstacles and challenges that are also similar across sectors. These reflect commonalities in the innovation process and structural weaknesses of the European economies that affect all sectors in a similar way. Given the observed disparity of sectoral modes of innovation it could
be argued that sectoral innovation policies may contribute to tackling market and system failures leading to more efficient investment in innovation activities. In this project sector both specific challenges and challenges cutting across all sectors have been identified. The question therefore is not whether sectoral innovation policies should be carried out in place of horizontal policy ones, but rather what mix of horizontal and sector specific policy measures may improve innovation performance at the sector level and support the development of competitive industrial structures in each EU member state.

Reid and Peter (2008) have carried out a policy mapping exercise with the aim to provide a first empirical analysis of existing sectoral innovation policies in Europe. They have identified close to 1200 policy measures of relevance to the eleven SYSTEMATIC sectors studied in the SIW project. Their results show that the majority of policy measures do not target individual sectors explicitly. Most measures are relevant for two or more sectors, or by their implementation target specific modes of innovation that favour some sectors more than others. The authors also observe that differences in types and targets of policy measures are observable across sectors. For instance, cluster policies are less frequently observed in the chemical industry or the energy sector, whereas regulatory actions are more important for the food sector or eco-innovators. To what extent these frequencies effectively relate to existing challenges in each sector needs to be clarified in further research. The results are summarised in Table 23 for the SYSTEMATIC sectors.

While this evidence is not sufficient to draw conclusions on the right policy mix to support innovation performance at the sector level it shows that the sector perspective in the design of innovation policies is rather the exception than the rule. Moreover, the sheer number of measures indicates that resources are very fragmented across member states and industries. This makes it very likely that many measures operate at sub-critical levels and lack transparency for their users. As progress continues innovation policy in itself will become a challenge for sectoral innovation performance.
<table>
<thead>
<tr>
<th>Sector</th>
<th>Observed characteristics of sectoral innovation policy measures</th>
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<tbody>
<tr>
<td>ICT</td>
<td>• 128 measures from 20 countries were identified; however a much lower number of measures (31) were ‘sector specific’;</td>
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<td></td>
<td>• Relatively strong focus on ‘technology diffusion’ initiatives (e.g. broadband access) in line with pervasive importance of ICT as a technology.</td>
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<td>• Clusters, technology platforms and innovation programmes are preferred compared to measures aimed at regulations, etc.</td>
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<td>• Sector with 74 identified measures concentrated in a limited number of member states (14), in line with concentration of sectoral activities in this high-tech sector;</td>
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<td>• Relatively high share of sector specific measures (50) suggesting that policy-makers view this sector as requiring particular forms of support;</td>
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<td>• Austria, Belgium, Greece and the Netherlands are particularly active in supporting this sector;</td>
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<td></td>
<td>• Above average presence of measures for space sector linking national organisations into international agencies or programmes (e.g. European Space Agency)</td>
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<tr>
<td>Automotive</td>
<td>• For the automotive sector 106 measures were identified, or 5 on average, in 21 countries.</td>
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<td></td>
<td>• Lithuania, the Czech Republic, Austria, Sweden, Estonia and France had the largest number (between 8 and 10). However, only the Swedish measures are predominantly addressed at a ‘particular industry’.</td>
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<td></td>
<td>• Good examples of sector specific measures come from Austria (a number of automotive clusters); Sweden Automotive Research Programme; Green car 2; Intelligent Vehicle Safety System Programme and the UK (e.g. Automotive Materials Technology Knowledge Transfer Network; the Automotive Academy).</td>
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<tr>
<td></td>
<td>• Innovation programmes are the dominant type of measure in the automotive sector. All types of regulation based measures scored low; while fiscal initiatives are relatively important.</td>
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<tr>
<td>Biotechnology</td>
<td>• With a total of 114 measures identified, the sector is slightly above average for all sectors; 5.7 measures were identified per country on average.</td>
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<td>• Only 49 (43%) were labelled as aimed at a ‘particular industry’ and the re-coding of all measures further reduced this number to 32 (28%)</td>
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<td>• The measures in the chemical sector tend to overlap with those in favour of biotechnology and textiles, underlining the link between the production and innovation activities in these fields.</td>
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<td></td>
<td>• Innovation programmes are most prevalent while, surprisingly, regulation despite REACH is not a focus of policy measures and fiscal initiatives are cited to a lesser degree than in other sectors.</td>
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<td></td>
<td>• 13 measures concern training as a ‘target’, which is high compared to other sectors. Only the food sector has a similar number.</td>
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<tr>
<td>Chemicals</td>
<td>• A total of 121 measures were identified for eco-innovation, which is above the average for all sectors; an average of 6.4 measures were identified per country;</td>
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<tr>
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<td>• Only a relatively small number were ‘sector-specific’ (37) measures, suggesting that as for ICT, biotechnology and gazelles, eco-innovation is very much a horizontal issue;</td>
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<tr>
<td></td>
<td>• a number of measures refer to environmental technologies (waste and water treatment), discernable as a sub-sector or industry group; because a number of these concern renewable energy, there is a significant overlap with the energy sector measures;</td>
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<td>• Almost 50% of measures were classified as innovation programmes, however, the overlap with cluster initiatives (19) and technology platforms (23) was frequent.</td>
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<td>• The share of regulatory measures and fiscal initiatives is well above the all-sectors average; 22 of the 59 innovation programmes were equally fiscal initiatives. The number for quality regulation is low, given that an improvement in product or process quality relating to the environment might be expected.</td>
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</table>
Energy

- A total of 117 measures were identified for the energy sector, above the all-sector average. On average there were 5.3 measures per country.
- There is a significant overlap with the eco-innovation sector (in particular on renewable energy), and, moreover, several measures address regulatory issues which impact not only the core energy sector, but are relevant across industry sectors.
- Targets of measures are evenly spread between larger firms, SME’s, research organisations and individuals (as consumers). This reflects both the industry structure and the importance of managing energy demand and use.
- Compared to the other sectors analysed, cluster initiatives are given low prominence in the energy sector, and even technology platforms or innovation programmes are relatively less important. In contrast, measures most often focussing on regulatory and fiscal measures are relatively more used, with the sector in third place behind gazelles and eco-innovation for this type of measure.

Food

- 102 measures were identified as being relevant for the food sector, slightly below the average of 109 for all sectors. For the 22 countries reporting measures, the average number per country was 4.6. However, the number fell to 45 when only taking into account measures addressing a ‘particular sector’.
- The food sector has a large number of innovation programmes (44) and a smaller number of cluster initiatives (23) and technology platforms (14). In terms of regulation, the sector is more distinct: it has the highest shares among all sector of measures addressing competition and quality regulation (26.1% and 20.6% respectively).
- Typical measures include the French PNDIAA national partnership for food industry development or the Irish Food Institutional Research Measure (FIRM), and Graduate Development Programme.

Gazelles

- For the gazelles 117 measures were identified. For the countries reporting, this means an average of 5.3 measures per country. The vast majority of measures were open to all manufacturing, and indeed, service sectors; only three measures were targeted at specific high-tech sub-sectors;
- For 69 measures out of the 117 (59%), it was possible to examine the targets more precisely: 33 measures address spin-offs, while another 34 addressed SME’s more generally. Only three measures mention explicitly high-tech firms as a target (e.g the German ‘BioChance’ and ‘NanoChance’ programmes).
- In terms of types of measures, there are clearly two main types: innovation programmes and fiscal initiatives (the strongest focus of all ‘sectors’). An additional group of measures are also finance related underscoring the importance of access to finance for small fast-growing firms (e.g. Austrian ‘Start up’ initiative);

Machinery

- The national experts identified 94 measures in the machinery sector; an average number per country of 5.2.
- A large number of measures are not sector specific and rather than the machinery sector it is the ‘manufacturing sector’ in general that they address.
- Concerning the type of measures, innovation programmes are the most often mentioned type. Cluster initiatives and technology platforms are rarer.
- The Austrian Mechatronics Cluster or the Finnish programme MASINA - Technology Programme for Mechanical Engineering 2002-2007 are examples of measures.

Textile

- The textile sector has a below average number of measures (96); in 21 Member States which returns an average of 4.6 measures per country. After further appraisal 27 sector specific measures were retained.
- In line with the structure and technological specialisation of the sector, SME’s are the main target of measures with a lower than average focus on research organisations.
- Innovation programmes are the most prevalent form of measure although regulatory measures are above the all-sector average. Clusters and technology platforms are also relatively present (13 and 15 measures each).
- Examples of measures include the Czech CLUTEX - Technical Textiles Cluster, the CETELOR (Textile Technology platform) in Lorraine, France or the Spanish ‘made in Green’ eco-textile label.
Chapter 5
Conclusions

The aim of the Sectoral Innovation Watch project was to provide policy-makers and stakeholders with background knowledge on the factors driving innovation at the sector level. The project analysed firm and sector specific parameters, as well as institutions and prevailing conditions influencing innovation performance and innovation potential in eight sectors and three overarching areas. The aim of this report was to identify similarities and differences across sectors and countries. This should not only help to establish the importance of the sector perspective for the analysis of innovation and innovation policy design, but also to provide answers to two essential questions.

1. “What is the right strategy for more innovation in Europe from a sector perspective?” or “Is a high-tech strategy the right formula for European competitiveness?”

2. “Is there a need to promote innovation at the sector level through sector specific policy measures?”

Our findings on the main drivers of innovation in Chapter 3 as well as the identification of the principal challenges between and within industry discussed in Chapter 4, allow us to draw a number of well-informed conclusions in answer to the first question. It is, however, more difficult to find straightforward and satisfactory answers to the second question. Here more research is needed.

As we have argued in the introduction of this report, there is a common awareness, reflected in many policy documents, that the European Union is not as commercially competitive as the United States or Japan. There is also a general agreement amongst policy makers and economists alike that the European economy needs to be more innovative in order to overcome this structural weakness. As a consequence a number of policy initiatives have been implemented to stimulate innovation performance in Europe. The Lisbon agenda with its commitment to increase the EU’s R&D-to-GDP ratio to three percent by 2010 is the linchpin of all these efforts. So far, however, the EU member states have failed to deliver on this goal. This has (partly) been blamed on the fact that “EU manufacturing remains specialised in medium-tech sectors and has not taken advantage of the fast growth of certain high-tech sectors [...]”, Commission (2007b). The implication is that the European economy should become more high-tech, i.e. policy should support the development and growth of sectors with high technological intensity. Given that the specialisation of most European economies is in sectors with lower technology intensity, and given the differences in economic development across the EU member states, the question becomes whether the high-tech strategy is the right formula for Europe to become more competitive.

Our findings indicate that there are two aspects that need to be considered. First, we have shown that innovation is driven by factors that are different in each industry. Knowledge creation through R&D is not in all cases the most important driver of innovation. As a matter of fact, the SIW project has produced evidence that sectors may be highly innovative in spite of relatively low R&D intensity. Typically firms in these industries rely on technologies developed in other sectors, and concentrate their innovation efforts on innovation activities that are not R&D based such as design, marketing or learning about upstream technological innovations and absorbing them. Knowledge is acquired either through capital investment in equipment, through cooperation with universities, by acquiring patents and licenses or through absorbing knowledge spillovers originating in
other firms. Traditional technology transfer and knowledge transfer through formal and informal networks are therefore important drivers of innovation. The textile industry is an example. In the SYSTEMATIC innovation taxonomy (see page 52) it rates as an industry with medium to high innovation intensity because of its high levels of non-R&D related innovation activities. This suggests that classifying sectors as not being innovative solely on the basis of their R&D activity is misleading. Innovation policies based on this erroneous belief are not only likely to miss a large number of innovators, but are also likely to fail to encourage companies to become innovators in sectors where R&D plays a subordinate role. The findings of Chapter 4 clearly suggest that steps likely to support and stimulate new innovation through R&D or technology transfer are alleviating the shortages of human capital and ensuring that capital markets provide the needed financial resources throughout the innovation cycle.

Our results also show that most sectors with high innovation intensity are also predominantly sectors with a large number of firms actively engaging in knowledge creation through R&D. These sectors — with a few exceptions — are generally more productive, show higher employment growth and also show better innovation performance in terms of output than sectors with fewer R&D performers. This success is mainly because these industries have more technological opportunities. This evidence speaks in favour of a strategy fostering the development and growth of high-tech, i.e. high innovation intensity sectors. Nevertheless, policy makers should know that in some sectors innovation is not driven by R&D and that an approach is needed that takes this into consideration.

The second aspect that needs to be considered when assessing whether a high-innovation intensity strategy is the right formula for fostering competitiveness in the European Union, is the consistent finding that the distance to the technological frontier matters for innovation. Innovation behaviour changes depending on the distance to the international technological frontier. Companies in sectors in technologically less advanced countries are more likely to rely on technological transfer and non-R&D related modes of innovation than companies in the same sector in technologically advanced countries. R&D in less advanced countries is carried out primarily to absorb new technologies, not to develop them further. Firms in advanced countries in turn are more likely to rely on R&D based innovation modes, where the role of R&D is to create new technologies and products. In principle this means that the conditions for successful innovation vary for the same sector between countries depending on the stage of development. As a consequence, when designing innovation policies, be they sector specific or multi-sector, policy makers need to account for the stage of local economic development; innovation drivers differ within sectors as a function of the distance to the frontier. Table 9 on page 50 provides a first estimation of which countries are on the technological frontier and which are not. The clear message here is that one size does not fit all.

In short, a key message of this project is that an R&D based high-tech definition of innovation is far too narrow to capture the rich variety of innovation. Our first question should not have been whether high-tech is the right strategy, but rather whether high-innovation intensity is the right strategy for European competitiveness. We have seen that innovation capabilities of certain sectors change if we expand our view of drivers of innovation in each sector. The answer to the new question is yes.

We have also argued that a high-innovation intensity strategy is likely to fail in countries that have an unfavourable innovation environment and an industry structure dominated by sectors that are not very knowledge intense, i.e. that do not rely on company specific R&D or high levels of imported R&D. In these countries it would be advisable to foster technology transfer, increase absorptive capacities through R&D and adequate training, and improve basic institutional
conditions that encourage growth. On the other hand, in countries where industries already rely on knowledge intensive foreign imports, innovation policy should support a gradual move from knowledge acquisition to knowledge production. Obviously the number of science and technology graduates, vocational training, and good applied research at universities become increasingly important. Finally, in countries that are on the frontier or close behind, the creation of basic conditions that are conducive to more and better research within companies but also at universities should be at the core of innovation and science policies.

These recommendations are necessarily bold. More research is needed to understand better which institutions and policies are best at each level of local development and best for each industrial structure. The literature on innovation-based economic growth and development clearly shows that innovation policy cannot be looked at in isolation. It is also important to get the framework conditions as they are widely conceived right (see e.g. Rodrik et al 2004, Acemoglu and Robinson 2006). As a country moves towards the technological frontier there will be more emphasis on competition and market entry, on investment in higher education and world class research, on more efficient financial markets, and on macro-economic stability. This is reflected in the top challenges across and within sectors identified in Chapter 4.

This leads to the second question we have set out to answer: is there a need to promote innovation at the sector level through sector specific innovation policy measures? It was not and it could not have been the goal of the SIW project to provide clear-cut answers to this question. Detailed recommendations would require a precise understanding not only of the challenges for innovation in each sector and across sectors, but a good understanding of the policy landscape at the regional, national and EU levels. Especially this last aspect goes well beyond the scope of the original aims of the SIW project. Nonetheless, in order to develop adequate policies it is necessary to identify clear challenges for which the SIW project is a good starting point.

Sector specific technological regimes and modes of innovation highlighted in the SIW project represents a point of departure to study sector specific innovation policies. In order to institute such policies it is necessary to describe causes for market failures or system failure at the sector level. Ideally these failures are to be found exclusively in a sectoral innovation system. However, they may also originate from market distortions and systemic deficiencies at the national or supra-national level. In fact, the observed heterogeneity of innovation challenges across sectors and countries make it generally difficult to focus our question. In our research we have observed that:

1. a number of challenges affect all sectors in most countries. These are the lack of human capital, the need to promote more R&D as well as technology transfer, and financial constraints. That these problems are observed across most countries and because of their inherent complementarity they likely reflect a major failure of the different National Innovation Systems, and would call for policy measures taken in a coordinated fashion by member states or at the EU level — in which case, needless to say, a sector perspective is not needed.

2. some challenges on the other hand are very sector specific. For instance, social acceptance of new technologies is a major issue for biotechnology firms, but affects innovation choices in the machinery and equipment industries little. This challenge could have its roots in a failure related to the interaction among actors in the innovation system, and would therefore represent a system failure at the national and supra-national levels. However, not all national industries are affected equally. Indeed, our results show that the variation of innovation drivers and challenges within each industry across countries is very
high. This suggests that sector specific innovation policy measures should be developed and implemented at the national level.

3. there are very strong interaction effects between innovation behaviour at the sector level and national policies and institutional conditions. As our previous discussion has shown, the drivers of innovation are very different for a specific sector and depend on the distance to the world technological frontier. On the other hand, even if distance is similar between countries, sector specific innovation patterns still strongly depend on the prevailing national situation. Hence system or market failures may also be caused by distortions on the national level. This would call for horizontal or sector specific policies at the national level, depending on whether only one or several sectors is affected.

4. the policy mapping exercise in chapter 4.4 has shown that innovation support measures at the sector level are rather heterogeneous and fragmented across countries and sectors. This policy mapping exercise will continue; however, we are inclined to think that due to their fragmented nature many of these measures are less than satisfactory, and hint at a policy failure. If this is true, sectoral innovation policy measures become a challenge of themselves and are not a solution to problems of insufficient investment in innovation.

This short list of observations based on results of the SIW project shows that it is time well spent to assess the need for innovation policies targeting individual sectors at either the national or the supra-national level. However, the SIW project has shown that there is a wide variety of innovation behaviours between sectors and across countries. The project has also provided evidence that the innovation performance of countries differs chiefly because of their industrial specialisation patterns. These insights alone make a case for adding a sectoral dimension to the design and implementation of innovation policies. Such a perspective can reinforce the effectiveness of horizontal or multi-sector innovation policy measures and bridge the gap to science policies and industrial policies (see Reid and Peter 2008).

The results of the SIW project are a point of departure for developing innovation policies. Future research should assess how well existing policy measures address the innovation challenges identified in this project. This will make it possible to determine whether there is a need to improve existing policies or to develop new ones.
References


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* These are references cited in this summary report only. It also includes project reports of the SIW project. A complete list of all reports and other outputs produced by the SYSTEMATIC consortium is given in the appendix.
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APPENDIX I: Overview of the Sectoral Innovation Watch – SYSTEMATIC project

Detailed insights into sectoral innovation performance are essential for the development of effective innovation policy at regional, national and European levels. The SIW project\(^*\), which ran from November 2005 to May 2008, analysed the factors and institutions impacting innovation performance, and the prevailing situation influencing innovation potential in nine selected sectors (food/drink, machinery/equipment, textile, chemicals, ICT, space and aeronautics, automotive) and three horizontal topics: biotechnology, eco-innovation, and gazelles (fast growing SME’s). SIW aimed to provide policy-makers and stakeholders with a comprehensive, holistic understanding of sectoral innovation performance and challenges across the EU25.

Project Structure

The SYSTEMATIC Consortium

\(^{*}\) See http://www.europe-innova.org for further information on the project and related initiatives.
Research team (researchers in alphabetical order by partner)

Labein (Workpackage lead WP5; Sector lead Textile):
Alberto Calderero, José María Lázaro, Eguzkiñe Saenz De Zaitegi, Igone Ugalde

Logotech (Workpackage lead WP11):
Margarita Argyriadou, Chara Papadakaki, George Strogylopoulos, Mariana Vari

NIFU STEP (Workpackage lead WP 7; Sector lead: Energy):
Heidi Wiig Aslesen, Tor Borgar Hansen, Aris Kaloudis, Mark Knell, Trond Einar Pedersen, Martin Srholec

SPRU - University of Sussex (Workpackage lead WP 8; Sector lead Biotech, Chemicals):
Gustavo Crespi, Michael Hopkins, Anabel Marin, Lionel Nesta (SPRU/OFCE-DRIC), Pari Patel, Caroline Paunov

Technopolis (Workpackage lead WP3, WP6, WP10; Sector lead Eco-innovation):
Nelly Bruno, Katrin Männik, Michal Miedzinski, Viola Peter, Alasdair Reid, Miriam Ruiz Yaniz

UNU-Merit (Sector lead ICT, Aerospace):
Anthony Arundel, Adriana van Cruysen, Theo Dunnewijk, M. Abraham Garcia-Torres, Hugo Hollanders, Can Huang, Daniel Vertesy, René Wintjes

WIFO (Workpackage lead WP4, WP12; Sector lead Textiles, Gazelles):
Michael Böheim, Martin Falk, Klaus Friesenbichler, Werner Hödl, Hannes Leo, Michael Peneder, Andreas Reinstaller, Fabian Unterlass

ZEW (Workpackage lead WP 9; Sector lead Automotive, Machinery):
Thomas Cleff, Sandra Gottschalk, Christoph Grimpe, Nina Leheyda, Bettina Peters, Christian Rammer, Anja Schmiele, Wolfgang Sofka, Alfred Spielkamp
APPENDIX II:
Project outputs of the Sectoral Innovation Watch SYSTEMATIC Project

Workpackage Reports

Workpackage 3

Workpackage 4

Workpackage 5

Workpackage 6
Männik, K. (2008), Innovation Leaders Showcase, Europe Innova Sectoral Innovation Watch deliverable Workpackage 6

Workpackage 7
Workpackage 8


Workpackage 9


Workpackage 10


Workpackage 12

Sector reports

Aerospace:

Automotive:

Biotechnology:

Chemicals:

Eco-Innovation:

Energy:

Food:

Gazelles:

ICT:

Machinery:

Textiles:
Background papers for the WP 4 report

**Sector level studies:**


**Firm level studies:**


# Case studies for the WP 6 report

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* Due to confidentiality requirements the company name is not given but the results of the survey are used for the analysis at aggregate level.
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