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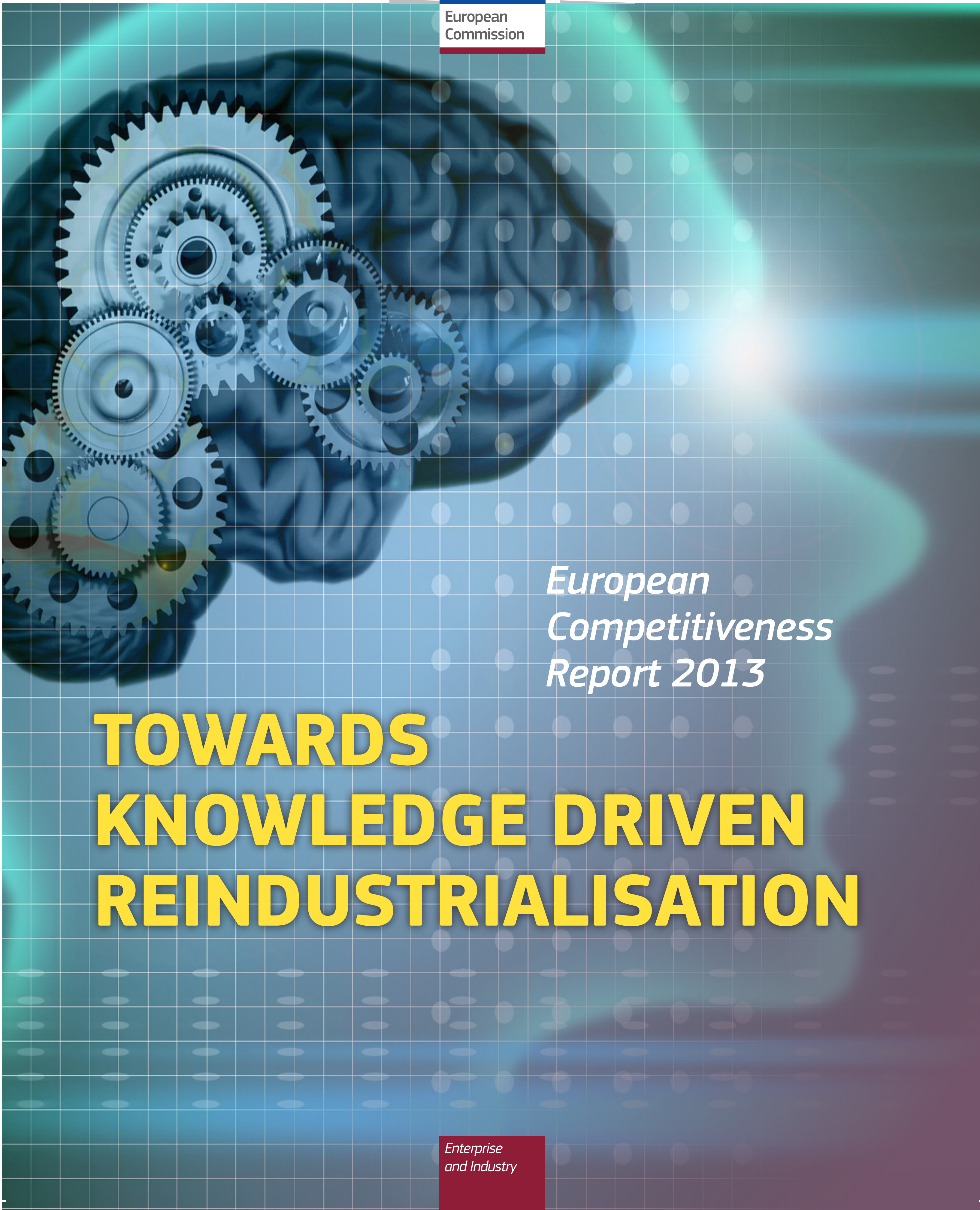

European Competitiveness Report 2013

TOWARDS KNOWLEDGE DRIVEN REINDUSTRIALISATION

Enterprise and Industry

European Competitiveness Report

2013

TOWARDS KNOWLEDGE-DRIVEN REINDUSTRIALISATION

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The report partly draws on background studies prepared by a consortium led by WIFO (see back of report for a full list of background studies). It was put together by a team consisting of Mats Marcusson (Chapter 1), Neil Kay (Chapter 2), Anastasios Saraidaris (Chapter 3), Mats Marcusson, Anastasios Saraidaris and Marshall Hsia (Chapter 4), Tomas Brännström (Chapter 5), Luigi Cipriani (Statistical annex and support), Marieta Todorova, Elizabeth Catzel and Patricia Carbajosa-Dubourdieu (administrative support). The team was led by Tomas Brännström, Project Manager, and Konstantin Pashev, Head of Unit.

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http://ec.europa.eu/enterprise/policies/industrial-competitiveness/competitiveness-analysis/index_en.htm

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FOREWORD

Daniel Calleja Crespo

Director General, DG Enterprise and Industry

Dear Reader

This year's European Competitiveness Report coincides with the first preliminary signs that Europe is finally joining the rest of the world on the path to steady recovery, leaving the worst years of the crisis behind. The report is dedicated to the role of manufacturing in making this growth path irreversible and sustainable in the long term.

Despite its declining share of EU GDP, manufacturing is widely acknowledged as the engine of the modern economy. This is due to its lead contribution to overall productivity; to its input to research and innovation, which is four times higher than its input to GDP; and to its multiplier effects on growth in the rest of the economy.

The volume and power of this engine, however, is declining vis-à-vis the overall weight it carries, including private and public service sectors.

The declining share of manufacturing in EU GDP is not a new phenomenon. Part of the explanation is related to long-term structural change. With the growth in personal incomes, advanced economies tend to consume more services than manufactured goods. Secondly, services have been relatively shielded from price competition as they are less 'mobile' than manufactures. This keeps their relative prices higher, with more attractive and often faster returns than manufacturing. Thirdly, some services have low price elasticities: households cannot react to high prices by reducing consumption (e.g. health, education or legal services); in the same way firms cannot freely adjust their consumption of compliance-related services (accounting, audit, reporting, conformity assessments, legal services, other professional business services, information to consumers and authorities, etc.) and other business related services. Finally, with the increasing specialization of manufacturing and the high share of small businesses, a growing share of the above mentioned services are bought in the market rather than produced in-house, thus pushing further the structural shift to a service-dominated economy. These trends have been observed and empirically established for quite some time.

What is new however is that in the last decade the shift away from manufacturing in Europe has accelerated, reaching a critical threshold below which the sustainability of the European economic and social model might be at risk. This is partly due to the financial and construction bubbles prior to the crisis; and partly to the faster decline of manufacturing relative to services during the crisis. But the report also shows that a large part of this phenomenon is related to growing competitive pressures from emerging industrial powerhouses, and this is not only in the low-tech homogenous products where competition is mainly on price. If the EU economy is to return to the path of sustainable and inclusive growth and find solutions to the pressing societal challenges of the 21st century, we need a larger and more powerful manufacturing engine to take us there.

The crisis has left little doubt in this regard. The report documents that the recovery has been driven mainly by exports of manufactures, benefiting from the EU's preserved and upgraded comparative advantages in high-end products. Despite the crisis, the EU has a comparative advantage on the world markets in about two thirds of the manufacturing sectors, which account for ¾ of EU manufacturing value added. The report also finds that these comparative advantages are concentrated in products with a high degree of sophistication and knowledge intensity. Additional evidence of the sophistication and resilience of the EU industrial base is its higher domestic content of exports relative to its competitors. And this is not because EU enterprises are less integrated in the global value chains: EU content in US, Chinese and Japanese exports is higher than other foreign content in these countries' exports. Taken together, this evidence shows that the EU can rely more on local supply chains for high-tech inputs than our major competitors. These are strengths and advantages which provide a firm ground for further gains and upgrades of EU industrial competitiveness, and for increasing the volume and power of the manufacturing engine of the EU economy.

The report, however, reveals a number of challenges which call for an urgent and well-targeted policy response. In the high tech sectors, the EU has comparative advantage in pharmaceuticals but lags behind in the rest of this broad category (computers, electronics, optical equipment, as well as electrical equipment). Even in the medium high-tech sectors, EU comparative advantage is lower than for the US and Japan. More importantly, China and the other emerging industrial powerhouses are quickly gaining ground in the knowledge intensive sectors and rather than merely assembling high-technology products they are now producing them.

The report looks at the EU-US productivity gap and finds that after a short period of narrowing prior to the crisis, it is widening again. A decomposition of US higher productivity gains vis-à-vis the EU shows that they are accounted for by a higher contribution of investment in ICT and by higher total factor productivity gains. The report looks as well at the contribution of the technical efficiency gap to EU productivity underperformance and derives the relevant implications for industrial policy. Business expenditures on R&D in the EU remain considerably below the US. More importantly, the report provides evidence that this is not due to a difference in industrial structure, but to a lower level of R&D spending across all sectors. Finally, the report sheds light on the slower market uptake of research results in the EU.

These are important issues which mark the transition in our policy agenda from crisis management to smarter, longer-term and more coherent governance of EU industrial competitiveness, which will bring us back on the road of sustainable and inclusive productivity growth. They will be at the centre of the EU industrial policy debate in the run-up to the elections of the new European Parliament in May 2014. Your voice, the voice of private and public sector experts, academia, entrepreneurs, consumers and employees in this debate is more important than ever. Therefore I would invite you to participate in our discussions (including online), and share with us your thoughts and ideas about the future of European manufacturing. I hope that the empirical evidence and analysis presented here provide interesting and inspiring pointers in this debate.

Daniel Calleja Crespo

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EXECUTIVE SUMMARY

MAIN FINDINGS OF THIS REPORT:

- Although the weight of manufacturing in the EU economy is decreasing in favour of services, manufacturing is increasingly seen as a pivotal sector. However, critical mass in the form of a minimum production base is needed. Industrial policy supporting innovation and external competitiveness can play a role to reverse the declining trend.
- To this end, EU industrial policy needs to steer structural change towards higher productivity in manufacturing and better positioning of EU enterprises in the global value chain based on comparative advantages in knowledge and technology intensive products and services.
- This is a must and a challenge for two reasons. First, the EU is lagging behind in productivity gains relative to emerging industrial powerhouses and some of its major competitors. The EU-US productivity gap, for instance, is growing wider again after years of narrowing. It is linked to a production efficiency gap caused by regulations, lower investment in ICT and intangible assets. In some sectors there is also a 'commercialisation of research gap' between the EU and the US. Policies targeting not only creation of new technologies, but also knowledge diffusion through measures to stimulate the supply of skills on the one hand, and demand for R&D on the other can help bridge such gaps.
- Second, structural change is slow, path-dependent and needs to build on existing strengths, but can be stimulated by having the right institutional framework in place, covering education, research, technology and innovation policies but focusing also on the general quality of governance.
- On the positive side, the report documents that the existing strengths of EU manufacturing are substantial. The revealed comparative advantage of EU manufacturing is linked to complex and high-quality product segments. By gradually increasing the complexity of their products, EU manufacturing industries managed to maintain their competitive position in 2009 compared with 1995. Moreover, EU manufactured exports have less embedded foreign value added than exports by third countries such as China, South Korea, Japan and USA.
- The EU is a major producer of new knowledge in key enabling technologies. Its products based on industrial biotechnology or advanced materials have higher technology content than competing North American or East Asian products. Apart from advanced manufacturing technologies, EU products based on key enabling technologies are mature and need to compete on price. Adding more innovative and complex products to the product portfolio will help manufacturers move up the value chain.

THE COMPETITIVE PERFORMANCE OF EU MANUFACTURING

This year's edition of the European Competitiveness Report uses a number of traditional and advanced indicators of industrial competitiveness to provide insights into the strengths and weaknesses of EU manufacturing and draw implications for EU industrial policy. It shows that the EU has comparative advantages in most manufacturing sectors (15 out of 23) accounting for about three quarters of EU manufacturing output. They include vital high-tech and medium-high-tech sectors such as pharmaceuticals, chemicals, vehicles, machinery, and other transport equipment (which includes aerospace).

EU MANUFACTURING VALUE CHAINS CAN SUPPLY HIGH-TECH INTERMEDIATES FROM THE HOME MARKET

Furthermore, the report evaluates industrial competitiveness by looking at trade in value added to analyse the place of EU manufacturing in the global supply chains. The domestic and foreign content of a country's exports provide information on whether that country develops or merely assembles high-technology products. Analysis of manufacturing exports from China, the EU, Japan, South Korea and the US from 1995 to 2009 shows that foreign value added embedded in EU manufacturing exports – the part of value added coming from inputs imported from other parts of the world – is lower than for other countries. Conversely, EU added value in the exports of emerging industrial powerhouses increased more than that from other parts of the world. Between 1995 and 2009, when Chinese exports increased dramatically, EU industries managed to increase their value added content in Chinese manufacturing exports more than industries from other parts of the world. Japanese, South Korean and US value added content shares of Chinese manufacturing gross exports decreased during the same period. Summing up, the report finds that the EU has a higher share of domestic content of exports than established and emerging industrial competitors, while at the same time has a higher share of its intermediates in other countries' exports. This is evidence of a strong industrial base which allows EU enterprises to source most of their high-tech inputs (goods and services) domestically, while also supplying them to the rest of the world.

EU MANUFACTURING EXPORTS HAVE HIGHER DEGREE OF COMPLEXITY

A further evidence of the industrial strengths of the EU is the analysis of the sophistication (knowledge intensity) of EU exports of products with comparative advantages. This is an advanced indicator of non-cost competitiveness which shows that manufacturing industries in the EU have a higher degree of complexity. The report documents that EU exports have preserved their advantages thanks to developing sophisticated, knowledge-intensive products to address the cost advantages of emerging industrial powers. By gradually increasing the complexity of their products from 1995 to 2010, EU manufacturing industries managed to maintain their competitive position. By contrast, products from BRIC countries (Brazil, Russia, India, China) underwent major changes in the same period – goods produced by firms in wood industries, radio, TV and communication equipment industries, medical, precision and optical instruments industries, and furniture industries in BRIC countries have considerably improved in terms of their average complexity – but the majority of industries in BRIC countries still produce less complex products than EU industries. As a consequence, in 2010 the EU exported around 67% of products with revealed comparative advantage, while China had comparative advantage in 54% of its exports, the US in 43% of its products, and Japan in 24%.

A ROLE FOR INDUSTRIAL POLICY

The report however documents trends and developments which call for urgent and well-targeted industrial policy measures to build on the identified strengths and upgrade the competitiveness of EU manufacturing.

Of the 15 sectors with comparative advantages mentioned above, about two-thirds are in the low-tech and medium-low tech manufacturing groups. On a positive note though, even in those sectors EU competitiveness is based on high-end innovative products.

In the high-tech sectors, the EU has comparative advantages in pharmaceuticals but lags behind in computers, electronics and optical equipment as well as in electrical equipment, while in the medium-high tech industries its comparative advantages are lower than in the US and Japan. China and other emerging industrial powerhouses are also quickly gaining ground in the international competition in the knowledge-intensive sectors, successfully upgrading their exports from assembly of high-tech products to their design and development.

With a view to identifying the drivers of non-cost competitiveness, the report looks at indicators of skills and investment in physical capital and intangibles to draw the relevant policy implications for upgrading EU comparative advantages towards knowledge-intensive products and services.

US private spending on R&D (as a share of GDP) is almost 1.5 times that of the EU (2.7% in the US; 1.85% in the EU). A sector breakdown indicates that this is not a result of differences in industrial structures or US specialisation in knowledge-intensive sectors, but due to an overall underperformance of EU sectors in terms of R&D investment across all sectors. The output of research is new products, new technologies, new materials and processes. A rough indicator of this output is patents. The report documents that in a number of high and medium-high technology industries (such as pharmaceuticals, optical equipment, electrical equipment, medical and surgical equipment, telecom and office equipment, radio and TV and accumulators and batteries), the EU is lagging behind in terms of patenting. As the RCA (revealed comparative advantage) indicators show, EU export performance depends crucially on some of these sectors. It may be hard to preserve current EU comparative advantages in these industries if the EU loses its technology lead (as indicated by patent data). Another problem is the transmission of research results from the laboratory to the market, which seems to be difficult in the EU relative to its major competitors.

What the study of the complexity of EU export products suggests is that targeting only high-tech sectors might be less rewarding than increasing the share of knowledge-intensive products in all tradable sectors, including medium-low tech sectors. Moreover, some of the labour-intensive sectors with lower knowledge intensities may be better positioned to tackle the EU's unemployment challenges than the high-tech sectors. About 40% of EU manufacturing employment is in low-tech sectors. Therefore the policy priority attached to key enabling technologies which lead to new materials and products in all manufacturing sectors has a strong potential to upgrade EU competitiveness not only in the high-tech sectors but also in the traditional industries.

LONG-TERM DYNAMICS OF STRUCTURAL CHANGE

Almost all countries follow a broadly similar pattern of structural change. As economic development gets under way, the share of agriculture in national employment and value added falls, and there is a rapid increase in the share of manufacturing and services. The resource reallocation process associated with structural change shifts economic activities from agriculture to industry and services.

DRIVERS AND IMPACT OF STRUCTURAL CHANGE

There are two central, largely complimentary theories of the observed patterns of structural change. The first, supply-side, explanation highlights the differential patterns of technical change between sectors. Here, structural change can be viewed as a consequence of differential productivity growth rates across agriculture, industry and services, where technological progress is the main driving mechanism behind productivity growth. The second, demand-side, theory relates structural change to different income elasticities of demand between products and services of different sectors. These different elasticities provide a sorting mechanism on the development of sectors.

The increasing contribution of the service industry, at the expense of manufacturing, can also be partly explained by an increasing service content of manufacturing final output. This content reflects the total value of the services required for the development, production and marketing of a modern manufacturing product. The service content of manufacturing has been growing in the EU and elsewhere in the world. Currently about a third of the price of a manufacturing product in the EU is associated with integral services. Whilst manufacturing products too are used for producing services, the manufacturing content of services produced in the EU is only around 10 per cent.

The gradual rise in services and reduction in the manufacturing share of valued added do not mean that manufacturing can be ignored. It is still seen as a pivotal, though heterogeneous, sector with important production and demand linkages that play a significant role in the process of economic development.

The analysis in Chapter 2 confirms that the structural change across economies produces more diverse country profiles in manufacturing sectors than in services sectors. Wider tradability of manufactured goods leads to more variability.

Analysis also confirms that structural change is gradual and path dependent based on the specific capacities and capabilities of individual economies, which are important determinants of sector growth.

Structural change can generate both positive and negative contributions to aggregate productivity growth. On average, structural change appears to have only a weak impact on aggregate growth over short time periods.

THE ROLE OF INSTITUTIONS IN STRUCTURAL CHANGE

Institutions can positively affect structural change in a number of ways. For example, differences in the patterns of technology diffusion are considered to account for a sizable part of the divergence in incomes between rich and poor countries. Educational attainment can also be linked to product specialization patterns, with a positive correlation between high knowledge intensity and product complexity. Microeconomic evidence also suggests that credit market imperfections are important sources of differences in productivity across countries. Market frictions can also hinder structural change due to the existence of regulations and administrative burdens that inhibit the reallocation of resources across sectors and firms. Many factors can be identified such as certain types of taxes, labour market regulation, size-dependent policies or trade barriers in addition to regulations and costs of doing business in the formal sector.

STRUCTURAL CHANGE: POLICY IMPLICATIONS

Structural change is thus dependent on progressive policies and institutions that allow an efficient allocation of resources within economies. Policies and institutions that hinder such reallocation are a source of inefficiency and impede economic development.

International trade is an important determinant of the development of sectoral shares in countries. The successful catch-up stories of Germany in 19th century, and Japan and South Korea in the 20th century, cannot be explained without taking into account international trade, comparative advantage in tradable goods and specific competencies and capabilities in the production of new and high-value added products. Here it is important to acknowledge that structural change that shapes economic development of countries is highly path-dependent and cumulative. Any change is rooted in present knowledge bases and constrained by existing specialisation patterns. Complementary capabilities need to be built up. Thus policies to support structural change should always start by taking into account the existing production structures of countries and regions, as well as the knowledge base of supporting institutions. Countries seeking to shift their industrial production up the technology ladder are likely to also need to increase and improve education and business services.

The centrality of institutions and policies in the process of structural change leads to a view that the general quality of institutions is important to structural change. Policies that foster structural adjustments should therefore be conceived in a broad way and cover such different areas as education, research, technology and innovation policies, while also focusing on the general quality of governance.

DIFFERENCES IN PRODUCTIVITY GROWTH BETWEEN THE EU AND THE US: EVIDENCE FROM A GROWTH ACCOUNTING ANALYSIS

In the late 1990s and early 2000s, the US productivity lead resulted from a first mover advantage in ICT as is illustrated by the relevant growth accounting analysis. EU movements in Total Factor Productivity (TFP) have followed US productivity developments, but with a time lag.

Prior to the financial and economic crisis of 2007-2008, the debate on the European productivity slowdown focused on the slower adoption of new technology as the main reason behind the EU's relative productivity under-performance. Moreover, industry-based studies revealed that the US productivity advantage was found in a few market services sectors, mainly trade, finance and business services.

The initial hypothesis was that the EU was lagging behind the US merely in the adoption of ICT but would eventually benefit from the same productivity gains. Chapter 3 reveals that high investments alone are not sufficient to boost economic growth and to guarantee a better productivity performance.

The EU is not only still lagging behind the US, but the productivity growth gap has recently increased.

THE CHANGES IN THE EU-US PRODUCTIVITY GAP FROM A SECTORAL PERSPECTIVE

The European failure to match the US acceleration in output and productivity between 1995 and 2004 has largely been attributed to developments in market services. The analysis reveals that the sector which contributed most to amplify the US productivity advantage was wholesale and retail trade, due to its strong productivity performance and its relatively large share in the economy. Other service sectors with sizeable contributions included professional, scientific, technical, administrative and support services, plus finance and insurance activities.

Throughout the period 2004-2007, two factors contributed to the reduction of the EU-US productivity gap, the acceleration of productivity in most EU manufacturing industries, and a robust performance of many EU services sectors.

In the US wholesale and retail sector, labour productivity slowed significantly between 2004 and 2007 compared to the exceptional performance observed in the previous period. On the other hand, the EU performance in the same sector improved substantially, reaching 3% productivity growth, nearly double the rate achieved in previous periods. In most EU services, labour productivity improved, particularly in professional, scientific, technical activities, and community, social and personal services. Overall, between 2004 and 2007, those sectors that contributed to narrowing the EU productivity gap relative to the US were the same ones which had caused EU productivity to stagnate in the previous decade.

During the financial crisis (2007-2010), labour productivity stalled in the EU, while in the US it continued to improve. The majority of manufacturing sectors in the EU experienced a fall in productivity levels, probably reflecting a higher exposure to global demand fluctuations than the services sectors. Manufacturing productivity as a whole, decreased by more than 1% annually, with chemicals down by more than 4%. In the US, manufacturing productivity grew by over 4% a year during 2007-2010. One of the few sectors to experience a worsening in productivity levels was chemicals. The majority of services activities though, experienced robust growth, particularly telecommunications, finance, insurance, IT and information services.

The sectors where the US productivity advantage increased are electrical and optical equipment and the majority of manufacturing sectors, as well as construction, and telecommunications. On the other hand, service sectors such as financial activities, business services, accommodation, food and some public services are among the EU sectors that helped narrow the gap during the most recent years. In the EU manufacturing sector, TFP was the main driver of the output growth up to 2007 but it was also the main cause of the declining productivity thereafter. In services, the picture is more heterogeneous. In the US, substantial TFP gains explain the productivity acceleration relative to the EU in the late 1990s. The finance and insurance sector in the US also experienced considerable ICT-driven productivity growth in the late 1990s and early 2000s.

TFP improvements in the EU wholesale and retail sector took place with some years' delay and contributed to closing the gap in the period just prior to the financial crisis. Since the crisis, the EU finance and insurance sector has also shown a considerably better performance than in the US.

THE ROLE OF KNOWLEDGE TRANSFER, ABSORPTIVE CAPACITY AND INSTITUTIONS FOR PRODUCTIVITY GROWTH

In the EU, too little has been invested in the skills and organisational changes necessary to reap the benefits of ICT technologies. Lower investments in intangible assets (R&D, human capital, etc.) are likely to explain a portion of the US-EU productivity gap as these factors affect a country's absorptive capacity, i.e. its ability to take advantage of technology developed elsewhere (international technology transfers). Given that the bulk of technological innovations is concentrated in a few leading countries, improvements in the absorptive capacity will be needed in order to assimilate foreign technologies.

DETERMINING THE EU-US EFFICIENCY GAP

Understanding why industries vary in their ability to use resources effectively, and identifying suitable policies to improve efficiency performance, requires the analysis to look into factors that cause industries to lose productivity and hence widen efficiency gaps.

The empirical results show that ICT plays a key role in reducing inefficiencies in the use of resources. In addition, more upstream regulation significantly increases the efficiency gap. In other words, administrative restrictions imposed on service market competition have widespread negative effects on production efficiency.

These results provide strong support for the hypothesis that a more competitive business environment reduces the efficiency gap. More flexible product market regulations, largely concentrated in key service-providing industries, are likely to raise efficiency levels across the whole economy. Regulatory changes in the labour market should also be tailored to restore the necessary balance between regular and temporary workers.

A few market service sectors were the main cause of the EU productivity disadvantage compared to the US during the emergence of ICT technologies (in the late 1990s). However, in the years leading up to the financial crisis, the EU experienced strong ICT-related labour productivity growth in these sectors, mirroring earlier developments in the US, and thereby reaching the US productivity levels. Since the crisis, the EU-US productivity gap has widened again.

Chapter 3 examines two main channels for raising productivity growth potential and closing the gap with the technology leaders. The first is the role of absorptive capacity and knowledge-base (intangible) assets (R&D and human capital) in activating international technology transfers. This mechanism has been found in the literature to be highly conducive to TFP growth through spillovers. However, its growth-enhancing effect is heterogeneous; the ability to accommodate the inflow of new technological knowledge by re-allocating factors or expanding new product lines is required.

The second channel is via production efficiency as a possible factor behind the widening productivity gaps between the EU and the US. There is evidence that technical efficiency is significantly higher in countries with less restrictive product market regulations or employment protection laws. Investments in ICT assets, on the other hand, help in reducing the gap with the most efficient country and/or industry.

Intangible assets (e.g. R&D, human capital, organizational change, etc.) are important sources of TFP growth and sustained long-run competitiveness. In this context, initiatives which stimulate investments in these areas may be particularly useful.

Similar measures may also be put in place to increase the number of qualified staff per firm. These measures could facilitate the hiring of highly qualified workers or promote workforce training. Other policies could be directed towards enhancing inputs such as ICT which can assist in the reorganisation of production. Specific ICT applications, such as enterprise software systems, increase productivity at firm level. These measures would also be viable for smaller firms which do not always have the necessary financial and human resources to undertake R&D activities and for that reason, seek alternative ways of increasing their competitiveness.

As regards the key role of financial resources on productivity performance, policies which increase access to finance for SMEs are needed. The above measures should be conceived and applied within an appropriate regulatory framework that will safeguard the stability of market regulation and facilitate the reduction of productivity and efficiency gaps.

A 'MANUFACTURING IMPERATIVE' IN THE EU — DECLINING MANUFACTURING SHARES OF VALUE-ADDED AND EMPLOYMENT

There are at least two well-documented reasons for the declining share of manufacturing value-added in GDP.

Firstly, the higher productivity growth in manufacturing implies that in the longer term prices of manufactures will decline relative to services, leading to a lower share of manufactures in value-added in nominal terms. Therefore, a declining value-added share of the manufacturing sector per se is not a reason for concern, but rather the logical consequence of a European manufacturing sector that is constantly becoming more efficient.

Secondly, demand structures characterised by low price elasticities of demand and high income elasticities for some services like education, tourism, health and cultural activities change the composition of demand as income increases. These elasticity differentials (discussed above in the context of structural change) compound the effect of the declining relative importance of manufacturing in value-added terms.

These two factors driving the downward trend of a manufacturing sector in relative terms can be countered by increased external competitiveness of the manufacturing sector and industrial policies working towards this end, as set out in Chapter 4.

ARGUMENTS FOR THE MANUFACTURING IMPERATIVE

Fears have been raised that the declining manufacturing share of GDP entails loss of manufacturing capabilities which, once lost, are hard to recover. Manufacturing capabilities specific to particular industries – even if they are low-technology industries – may at a later stage become important inputs for fast-growing new products.

There are at least three arguments for a ‘critical size’ of the manufacturing base:

- Manufacturing still accounts for a major part of the innovation effort in advanced economies and this translates into above-average contributions to overall productivity growth and thus to real income growth.
- There are very important ‘backward linkages’ from manufacturing to services which provide important inputs for manufacturing (in particular business services). Manufacturing has a ‘carrier function’ for services which might otherwise be considered to have limited tradability. This operates through international competitive pressure and has an added stimulus effect for innovation and qualitative upgrading for service activities. Another linkage is increased ‘product bundling’ of production and service activities in advanced manufacturing activities.
- Lastly, and related to the first argument, is the higher productivity growth in manufacturing which is important because the sector of origin of productivity growth may not be the sector which benefits most from the productivity growth.

THE EXTERNAL COMPETITIVENESS OF EU MANUFACTURING

There are also structural changes within the manufacturing sector, as explained in Chapter 2 above. These go in the direction of a mild but persistent shift towards more technology-intensive industries (chemicals, machinery, electrical equipment and transport equipment) which also tend to be less labour-intensive.

This mild trend towards advanced manufacturing industries reflects international specialisation patterns of EU Member States because in general technology-intensive industries offer more possibilities for building comparative advantages by product differentiation and quality aspects. At the same time, low-technology-intensive industries still accounted for almost 40% of EU manufacturing employment in 2009.

Traditionally, EU manufacturing has faced competition in more technology-intensive segments from producers in Japan, Korea or the US. However, over time competition from producers in BRIC countries is gradually changing and increasing.

Given the structural upgrading in emerging economies, competitive pressures from these countries are not limited to low-technology-intensive industries but are also felt in advanced manufacturing industries. Brazil, India and China all increased considerably their market shares in global value added exports of manufactures over a period of 15 years. It is especially the outstanding performance of Chinese producers, whose market share quadrupled between 1995 and 2011, which drove this change.

All in all, EU manufacturing seems to have managed to defend its positions on world markets. In general, the EU manufacturing sector is seen as rather well-diversified. Over time, the EU manufacturing sector has succeeded in upgrading product quality by engaging in R&D&I. The challenge is more demanding for low-tech and medium-low-tech industries for which this may require a higher degree of specialisation and entering or creating niche markets. Existing evidence suggests that many European firms follow such a 'premium strategy' within their respective industry. European firms typically operate in the top quality segments.

R&D in manufacturing is key to maintaining or expanding market shares for knowledge-intensive goods. It is therefore worrying that EU manufacturing has a lower R&D intensity per firm than the US and Japan. The R&D intensity in seven EU Member States, for which data are available, is only 62% of that of the United States.

R&D and innovation are not the sole ingredients for a highly productive and internationally competitive manufacturing sector. In order to differentiate products and charge higher price-cost mark-ups, manufacturing firms depend increasingly on sophisticated services inputs.

The ever tighter inter-linkages between the manufacturing sector and the increasingly dominant services sector in the EU economy work in two ways:

- Increased use of services inputs and services embedded in manufacturing products can increase the EU manufacturing sector's competitiveness
- Through this increased interdependence, manufacturing can increase the tradability of services.

INDUSTRIAL POLICY AND THE EXTERNAL COMPETITIVENESS OF EU MANUFACTURING

Sectoral aid does not show any significant effects on extra-EU exports or value added per capita for export oriented firms. On the other hand, internationalisation measures are horizontal and have significant and positive effects on extra-EU exports.[1]

Other effective horizontal aid measures seem to be regional aid and aid for training of the employees.

An industrial policy providing funds to different parts of the innovation process have positive and significant effects on R&D intensities and patent application propensities for manufacturing firms in the EU-15 and EU-12 irrespective of firm size and technological intensity of the firm.

The effects on output of the innovation process, of the amount of the innovative sales or of public funding differ according to the geographical location of the firm, its size and its technological intensity. Public funding has positive and significant effects, in particular for EU-15 firms. Further positive and significant effects are found for high-tech and medium-high-tech and for SMEs.

These results suggest that there is potential to improve the targeting of public support and to make it more effective. Especially in the EU-12, and irrespective of the actual objectives of

[1] For the purposes of this report, internationalisation measures mean horizontal measures aimed at supporting internationalisation of commerce. (Export aid is generally prohibited under EU State aid rules).

the support programmes, governments end up providing innovation support more often to larger firms than to their smaller competitors. Given that small firms in particular face considerable financial problems due partly to asymmetric information flows, they should be the primary target of public funds.

The special targeting of grants is one way to improve the allocation of public funds to SMEs. Other initiatives could include information campaigns about credits, cost-deductions and subsidised loans for new entrepreneurs. As financial problems occur mainly in the commercialisation phase, fostering venture capital investment would be another starting point.

RESEARCH COMMERCIALISATION

The EU is usually perceived as less effective at bringing research to the market when compared to its main competitors such as the US, Japan, and South Korea. The relative underperformance in research commercialisation in the EU has been attributed to a number of factors including the absence of an entrepreneurial culture and a less developed venture capital sector. The discussion about the main factors explaining the European innovation gap is related to the so-called European innovation paradox which suggests that Europe does not lag behind the US in terms of scientific excellence, but lacks the entrepreneurial capacity of the US to effectively commercialise inventions and step thereby on an innovation-driven growth path.

Analysis on the specific innovation-related factors and types of public funding on commercialization performance focused on the commercialisation of R&D efforts at firm level. In particular, the actual R&D performed internally and/or acquired from external sources, the research collaboration activities with different players such as customers, suppliers, public research institutions and other firms, and the firm's use of particular types of public funding for innovation were examined, using the Community Innovation Survey (CIS) micro-data. Focusing on the commercialisation of R&D efforts, innovation output was analysed in terms of innovative sales of companies.

The results of the analysis suggest that the impact of the R&D efforts on commercialization is positive for both manufacturing and non-manufacturing firms. It is observed that the firms which, in addition to their own R&D, also acquire R&D services externally tend to have higher share of turnover from innovative products. This external acquisition of R&D results can take place as a pure purchase of services, but also can be acquired in the framework of the inter-firm R&D cooperation.

Concerning the different forms of R&D cooperation activities the results are mixed across different groups and classes of firms. It can be seen that vertical cooperation (i.e. R&D cooperation with suppliers and/or customers) is positively associated with higher commercialization performance in firms coming from different size classes and different technology intensity groups.

The effects of public funding on the commercialization performance of firms appear to be positive in most classes and groups of firms considered. The relationship between the use of local public R&D support and the commercialisation performance shows positive across all different technology intensity domains. Public R&D support at the national level is positively related to the share of innovative turnover. Firms appear generally to have higher commercialisation performance when making use of EU-level public R&D support, with a consistently strong and positive effect of public funding being found especially for firms in medium-high and high-tech industries.

Bringing the most important findings together suggests a number of conclusions regarding the general patterns of innovation and commercialisation performance of European firms. When observing the behaviour of individual firms, the link between the R&D effort and the commercialisation performance is rather pronounced and a positive relationship is observed in number of cases, not only the R&D itself, but also its origin and the patterns of R&D cooperation among firms play a role.

In particular, the results suggest that local R&D support does positively affect firm commercialisation performance in all technology intensity and size classes. The effects of national and EU funding are positive and significant for all firms and manufacturing firms only, but mixed results are found for smaller subsamples. Overall, public funding has consistently positive effects on innovative sales for medium-high and high-tech sectors firms, while this statement is true to a lesser extent for firms in lower tech industries.

PRODUCTS AND TRADE BASED ON KEY ENABLING TECHNOLOGIES

Every two to three decades, an innovative concept or material comes along with the potential to bring about fundamental change throughout the economy. Silicon arrived in the 1940s, paving the way for the ICT revolution. In the 1970s, gallium arsenide made lasers ubiquitous in DVDs, CDs and modern telecommunications. The late 1980s witnessed the interconnection of several existing computer networks to create the internet. In the 1990s there was gallium nitrite, which revolutionised photonics and in particular solid state lighting. Right now the world is exploring the potential benefits of graphene, isolated as recently as 2004 and subsequently acknowledged by the 2010 Nobel Prize in physics, as well as by the European Commission which recently launched a ten-year flagship programme with a budget of EUR 1 billion to develop graphene technology. Decades from now, with the benefit of hindsight, people may look back at graphene as another game-changing discovery.

The stakes and potential gains are high. In 2011, the European Commission’s first High-Level Group on Key Enabling Technologies (KETs) presented its final report which estimated the market for key enabling technologies to be worth USD 1,282 billion by 2015 (photonics 480 bn; micro and nanoelectronics 300 bn; advanced manufacturing systems 200 bn; advanced materials 150 bn; industrial biotechnology 125 bn; nanotechnology 27 bn). As 2015 approaches, it is of course crucially important to ensure that EU manufacturing is ideally placed to benefit as much as possible from this potentially huge and growing market. To that end, it is not enough for the EU to produce state-of-the art research results in key enabling technologies, there must also be mechanisms in place to bring those results to market in the form of commercial products, and there must be demand for the products. This was one of the key conclusions of the first High-Level Group’s report. This report develops that theme by assessing the position of the EU in the production of and international trade in certain products based on key enabling technologies, including changes in EU competitiveness over time. Chapter 5 goes on to examine the specialisation of Member States in the production of, and trade in, products based on key enabling technologies.

EUROPE IS A MAJOR PRODUCER OF NEW KNOWLEDGE IN KEY ENABLING TECHNOLOGIES …

In terms of knowledge production, Europe appears to be doing well. Measured by its share of the global number of patent applications in each of the six key enabling technologies, Europe is maintaining a similar share as North America (US, Canada, Mexico) in most key enabling technologies, while East Asian patent applicants tend to be more productive than their European and North American counterparts. Unlike North American applicants though, European patent applicants have lost little or no ground in recent years: Europe’s shares of global patent applications are similar to those reported in the 2010 edition of this report (EC 2010), whereas North American applications have fallen back. It is also important to underscore that in absolute terms, European patent applications are increasing from year to year in most key enabling technologies.

… BUT IS NOT ALWAYS IN A POSITION TO BENEFIT IN THE FORM OF PRODUCTS

But knowledge production is not synonymous with job creation and growth. In order to turn patents into marketable products based on key enabling technologies, manufacturers need to be well positioned in terms of the technology content of their products and in relation to the competition they face on the global market. Unit value analysis indicates that EU products based on industrial biotechnology and advanced materials have a higher technology content than North American or East Asian products in the same fields, while in advanced manufacturing technologies for other KETs the technology content is similar to North American but higher than East Asian products. In nanotechnology and micro- and nanoelectronics on the other hand, EU products have a relatively low and generally decreasing technology content.

The technology content should be seen against the backdrop of the competitive situation in which EU manufacturers have to sell their products. The analysis presented in Chapter 6 suggests that in all key enabling technologies except advanced manufacturing, EU manufacturers are predominantly up against price competition, and in three technologies – industrial biotechnology, nanotechnology and advanced materials – they are able to compete on price. This finding is new and runs counter to the generally held view that production costs are too high in the EU to enable manufacturers to compete on price. In photonics and micro- and nanoelectronics, where price competition prevails as well, EU manufacturers tend to have little or no price advantage and therefore struggle to compete with North American and East Asian manufacturers. This does not mean that EU manufacturers in those fields should exit the market or that policies to strengthen competitiveness should not be pursued. It simply reflects the fact that historically EU manufacturers have not had a price advantage on a market where price competition prevails.

The only key enabling technology in which quality competition dominates is advanced manufacturing technologies for other key enabling technologies, where EU manufacturers are able to compete with North American and East Asian rivals thanks to the superior quality of their products. The impact of the high technology content of EU products manifests itself in a possibility to compete with high-quality products even if they are more expensive than competing products made in North America or East Asia.

MOVING TO THE HIGHER END OF THE VALUE CHAIN

Having to compete mainly on price (in five of the six key enabling technologies) may not be an attractive growth model for EU manufacturers in the long run. Given its considerable knowledge production and the high technology content of EU products, a gradual shift away from the current portfolio of predominantly mature products – where firms compete more on price than quality – to more innovative and complex products could be an avenue to pursue. A step in that direction could be to focus on more integrated products than today, possibly combining more than one key enabling technology. Another idea could be to reinforce the cross-fertilisation of new technology developments between key enabling technologies.

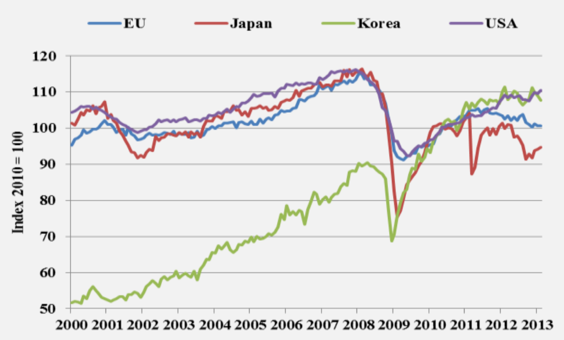
Chapter 1.

THE COMPETITIVE PERFORMANCE OF EU MANUFACTURING

This chapter reviews the competitive performance of EU manufacturing vis-à-vis established and emerging global competitors. EU industries compete on the single market and on external markets by selling their products either at a lower price or with a higher quality than competitors.[2] Their ability to compete depends on a number of "drivers". Some of these drivers are necessary in order to compete with prices while other drivers are more essential for the development of products with characteristics and qualities that differentiate the industries' products from those of their competitors.[3] The analysis relies on a number of traditional indicators of international competitiveness, such as revealed comparative advantages, labour productivity and unit labour costs, but employs as well relatively novel indicators of exports in value added and complexity and exclusivity of exports.

The chapter is organised as follows. The first section presents a brief overview of the impacts of the recession on the manufacturing sector. The second section focuses on the export performance of EU industries on world markets. The third section explains the export performance by analysing the drivers of EU price and non-price competitiveness. It looks at the dynamics of labour productivity and unit labour costs (ULC), as well as patenting and innovation output. R&D and innovation indicators however are not readily available for all the comparator economies.[4] Therefore they are used mainly for comparisons across EU industries and Member States.

Figure 1.1. EU recovery in comparative perspective

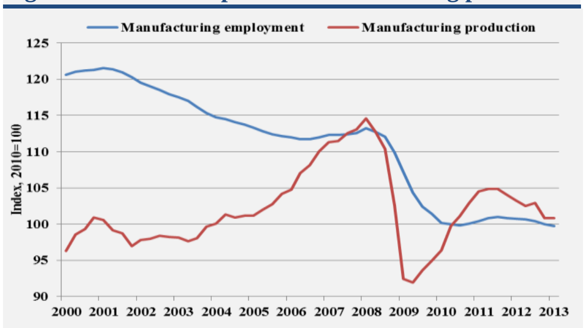


Source: Own calculations using Eurostat and OECD manufacturing output data.

1.1. DELAYED RECOVERY

The EU manufacturing output decline reached its trough in the middle of 2009. Following a short-lived recovery, manufacturing industries fell back into a double-dip recession at the end of 2011. Employment in manufacturing has been steadily declining for decades. The decline accelerated with the onset of the financial crisis (Figure 1.1).

Figure 1.2. Double-dip of EU manufacturing production



Source: Own calculations using Eurostat data.

Even though the financial crisis had global repercussions, other parts of the world have been recovering faster. While EU manufacturing hit the trough and began a rebound earlier than US manufacturing, since late 2011 the EU has been lagging behind. The recovery in the two previous recessions since 1990 was also faster in the US than the EU. Asia is also recovering faster than Europe. South Korean manufacturing, for instance, reached its pre-crisis peak in less than 18 months.[5] Similarly, the initial rebound of Japan – which was hardest hit by

[2] This is a simplification, more accurately describing the situation of firms selling just one product. Firms and industries also have other means of competing. Examples of other means to compete are combinations of goods with services, combinations of goods that are complementary to each other, establishment of distribution networks.

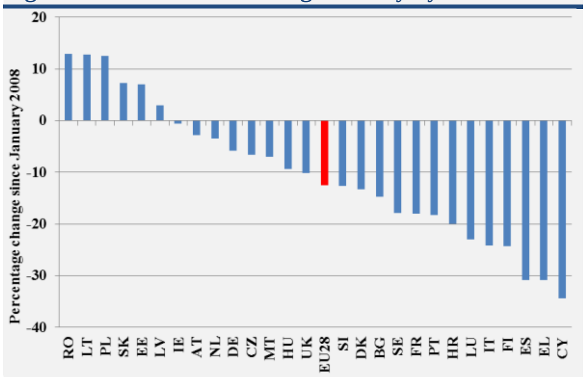
[3] See European Commission (2010a) for thorough analyses and discussions of price and non-price factors.

[4] Data for R&D expenditures, business expenditures on R&D (BERD), are unfortunately published with a long delay. At the time of drafting this report, a comprehensive data set for EU Member States and OECD countries, is not available after 2008.

[5] A sharp depreciation of the won by 31% from the first quarter of 2008 may partly explain the 10% growth in exports in 2009. Close relations with other Asian countries is another factor accelerating Korea's recovery. Especially the Chinese stimulus programme in 2009 contributed significantly as Korean exports to China accounted for 87% of the increase of exports during 2009. Other factors explaining the rebound of Korean manufacturing were strong domestic demand growth, including fiscal expansion, and a relatively limited impact of the global financial crisis on Korean financial markets (OECD 2011).

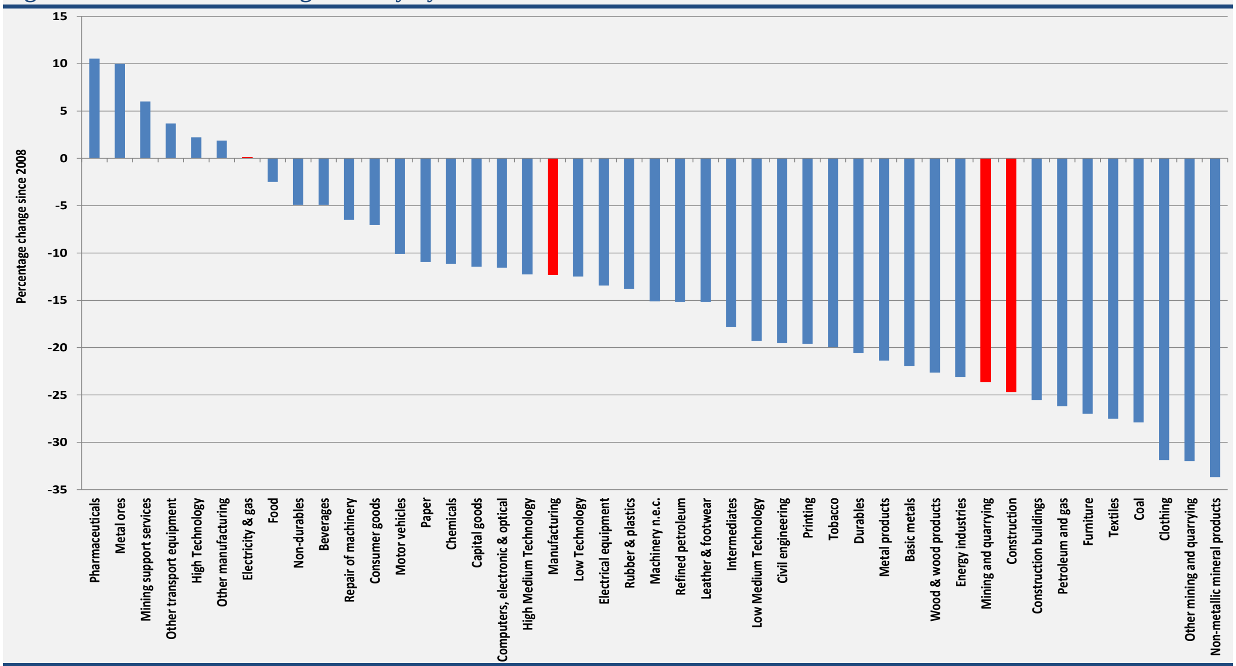
the financial crisis – was impressive, but was interrupted by the 2011 Fukushima earthquake and tsunami (Figure 1.2).

Figure 1.3. EU manufacturing recovery by Member State



Source: Own calculations using Eurostat manufacturing output data as of March 2013.

Figure 1.4. EU manufacturing recovery by sector



Source: Own calculations using Eurostat data. Developments are shown since the peak in EU aggregate manufacturing output in January 2008 to March 2013. HT, HMT, LT and LMT denote high-tech, medium-high-tech, low-tech and medium-low-tech manufacturing industries (see the Annex 1.3 for definitions)

Recovery has been much harder across the EU. While Romania, Poland, Slovakia and the Baltic states have already surpassed their pre-recession peak levels of industrial output, most of the Member States are still below, with some of those in the south still close to the trough or may have not even started their recovery (Figure 1.3).

A sector breakdown shows that few industrial sectors (among which pharmaceuticals and other transport equipment) have recovered their pre-crisis level of production (Figure 1.4). In principle, high-tech manufacturing industries were less severely impacted.

Food, beverages and non-durable consumer goods have fared relatively better than other industries since the outbreak of the financial crisis. The reason is that capital goods and intermediate goods industries are more sensitive to business cycle fluctuations than industries producing necessity goods and non-durable consumer goods, demand for which is less sensitive to variations in income.[6] Some medium-high technology industries produce capital and intermediate goods, which is why they experienced larger output decline.

Mining and construction were harder hit than total manufacturing. There is however a considerable variation within the aggregate mining and quarrying. Metal ores and mining support services have had a positive development since 2008. Some of this development is due to a high demand from the world market. On the other hand, some mining industries have been in decline for a longer period of time before the crisis. This is also true of some manufacturing industries such as furniture, clothing and textiles.

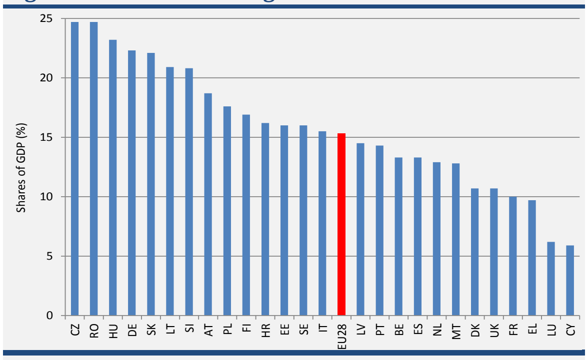
Since manufacturing was hit more severely than services industries, the shares of manufacturing to GDP fell in every Member State during the crisis.[7] Figure 1.5 presents the shares of manufacturing in

[6] See the discussion in European Commission (2009, 2011b).

[7] See for example European Commission (2013c) forthcoming on the developments of services since 2008. Total services declined by some 9% between the first quarters of 2008 and 2013 while the corresponding decline for total manufacturing amounted to some 12%. Certain services industries providing services with high income elasticities, for example transportation services and package holidays, experienced much stronger declines.

GDP by country in 2012. The declining share of manufacturing output and employment has been a long-term trend driven by a shift in domestic demand due to growth in incomes on the one hand and lower prices of manufactures due to higher productivity growth on the other (Nickell et al. 2008).[8] Increasing external demand for EU manufactured goods however can counter this trend provided that EU manufacturing industries compete successfully on world markets.

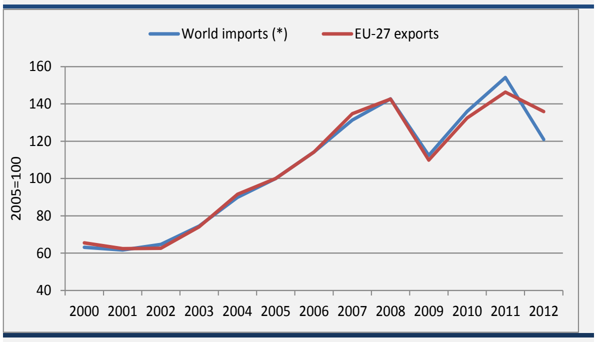
Figure 1.5. Manufacturing shares of GDP in the EU 2012



Source: Own calculations using Eurostat data. Note: 2011 value for Romania. No data available for Bulgaria and Ireland.

Following the decline in trade during 2009, world demand recovered faster than in the EU and world imports recovered quickly. A particularly strong import rise in China helped ease the recovery in East-Asian countries.[9] The rebound of world imports

Figure 1.7. World imports and EU exports from 2000 to 2012

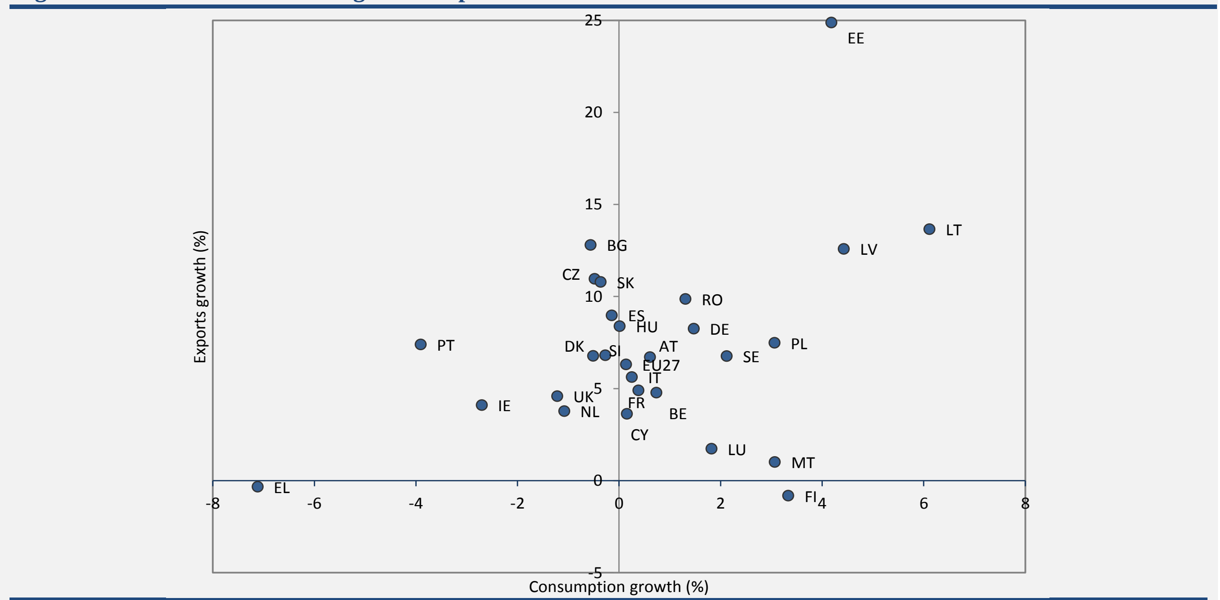


Source: UN COMTRADE Note: Trade data for 2012 is still incomplete at the time of drafting this report. Imports and exports in current value. (EU imports excluded)

starting in 2010 has boosted EU exports (Figure 1.7).

This question will be explored using an indicator for

Figure 1.6. Contribution to GDP growth in per cent 2011-2012



Source: AMECO database, Commission services.

1.2. THE PERFORMANCE OF EU INDUSTRIES ON WORLD MARKETS

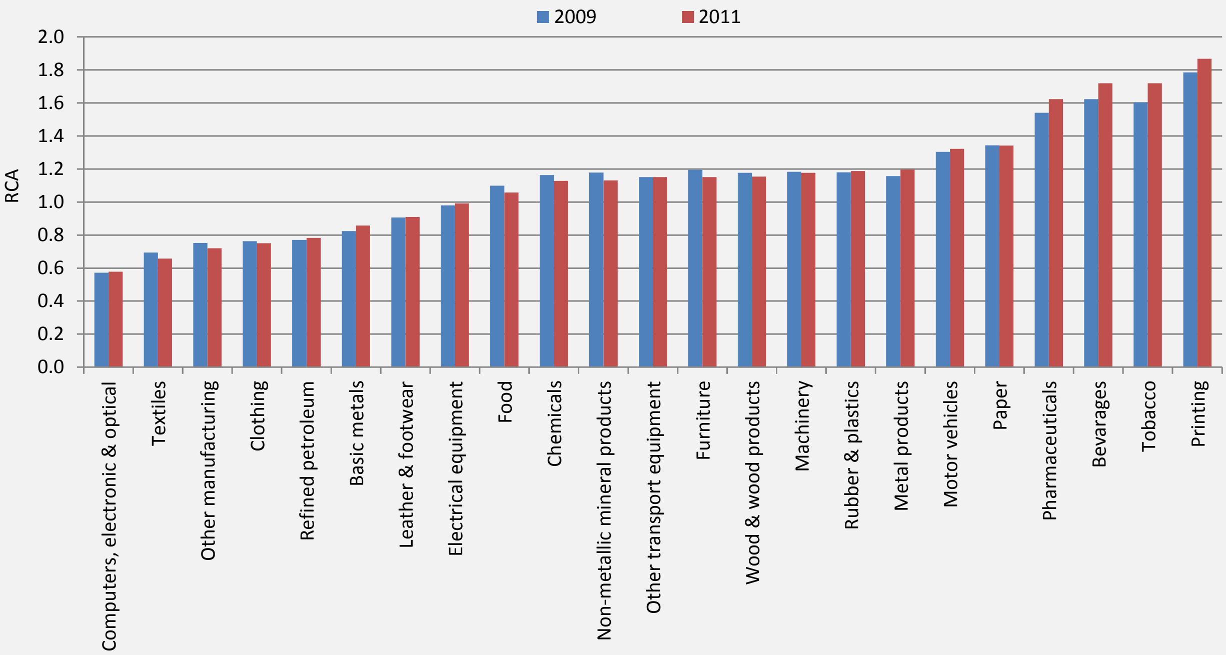
The recession which began in 2008 had a global impact. While public and private debt problems have constrained domestic demand in many Member States and delayed a full recovery from the crisis, demand for EU exports has risen. During 2010-2011, exports contributed more to GDP growth than domestic demand in most EU Member States (Figure 1.6).

competitiveness on world markets, the index of revealed comparative advantage (RCA). The RCA index compares the share of an EU sector's exports in the EU's total manufacturing exports with the share of the same sector's exports in the total manufacturing exports of a group of reference

[8] See chapter 2 for detailed analysis.

[9] European Commission (2012).

Figure 1.8. EU comparative advantages in 2009 and 2011



Source: UN COMTRADE

Table 1.1 – Revealed comparative advantages by technology intensities in manufacturing 2011

	High tech	Medium high tech	Medium low tech	Low Tech
EU	0.85	1.14	0.89	1.01
Japan	0.73	1.59	0.86	0.16
US	0.88	1.22	0.96	0.68
Brazil	0.32	0.76	0.87	2.50
China	1.56	0.72	0.85	1.29
India	0.40	0.49	1.93	1.33
Russia	0.08	0.45	2.74	0.49

Source: UN COMTRADE

countries. A value higher than 1 means that a given industry performs better than the reference group and has comparative advantage, while a value lower than unity indicates comparative disadvantage.[10]

According to the RCA indices, some 15 manufacturing industries had comparative advantages in 2009 and 2011.[11] Two thirds of these are either low-technology or medium-low-technology industries. However, the EU has comparative advantages in most medium-high-technology industries as well as the high-technology sector of pharmaceuticals (Figure 1.8)

A comparison with major global competitors (including BRIC) in sectors grouped according to technology intensities in Table 1.1, shows that EU, Japanese and US manufacturing industries have RCAs in medium-high-tech sectors. Only Chinese high-tech manufacturing has a RCA of 1.56.[12]

The indicators above are calculated from trade data. Even though the industries can be classified according to technology intensities, it is hard to measure the real sophistication of a country's manufacturing using this kind of data, for at least two reasons. **The first reason has to do with the difficulty of observing the quality or complexity of the export products of a country or an industry**. Two products in the same sector or even two products with the same customs code can have different degree of complexity. **Secondly, for any given good, trade statistics do not provide information on the share of value added produced domestically (i.e. the domestic content of a country's exports)**. That makes it difficult to tell for example if an industry in a specific country is developing high-tech products or merely assembles them. These limitations complicate measurements and comparisons of industrial competitiveness. They also require that the picture of EU competitiveness based on RCA presented in Figure 1.8 be extended to account for these two additional indicators of international competitiveness.

Concerning the quality or complexity of a product, a recent strand of literature interprets the

[10] See Balassa (1965). A disadvantage with the measure is that it can assume values between zero and infinity. See European Commission (2010a) for an alternative specification that constrains the index to range from -1 to +1 with positive values indicating revealed comparative advantages.

[11] One should note that the manufacturing industries above are represented for the two-digit level NACE classification. This is a relatively high level of aggregation which includes a great many industries.

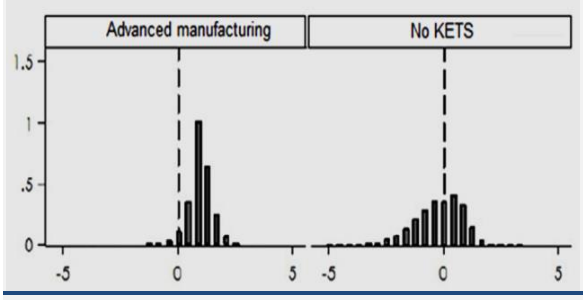
[12] These aggregates mask significant differences not only between the industries entering the aggregates but also between the different EU Member States.

competitiveness of an industry in a certain country through its ability to produce relatively sophisticated products. Two key concepts in this respect are the diversification of the export mix of a given country or industry; and the sophistication or exclusiveness of the export mix.[13] Diversification by itself does not indicate strong capabilities in an economy with complex productive structures. It could very well be that a country whose industries produce a large number of products does so because the products are at the end of their life cycles, i.e. are standardised and can be produced at low costs. Countries with more complex productive structures will have industries that are able to produce more sophisticated and exclusive products.[14] These countries have a knowledge base or critical mass large enough to produce sophisticated products.

The complexity of products can be illustrated by comparing the type of products produced by advanced manufacturing vis-à-vis the other manufacturing sectors. Figure 1.9 shows how complexity is distributed within the category advanced manufacturing technologies and in those sectors that do not belong to key enabling technologies. In the first category most products are more complex than average while the second shows a more even distribution between complex and less complex goods.[15]

Revealed comparative advantages can be calculated

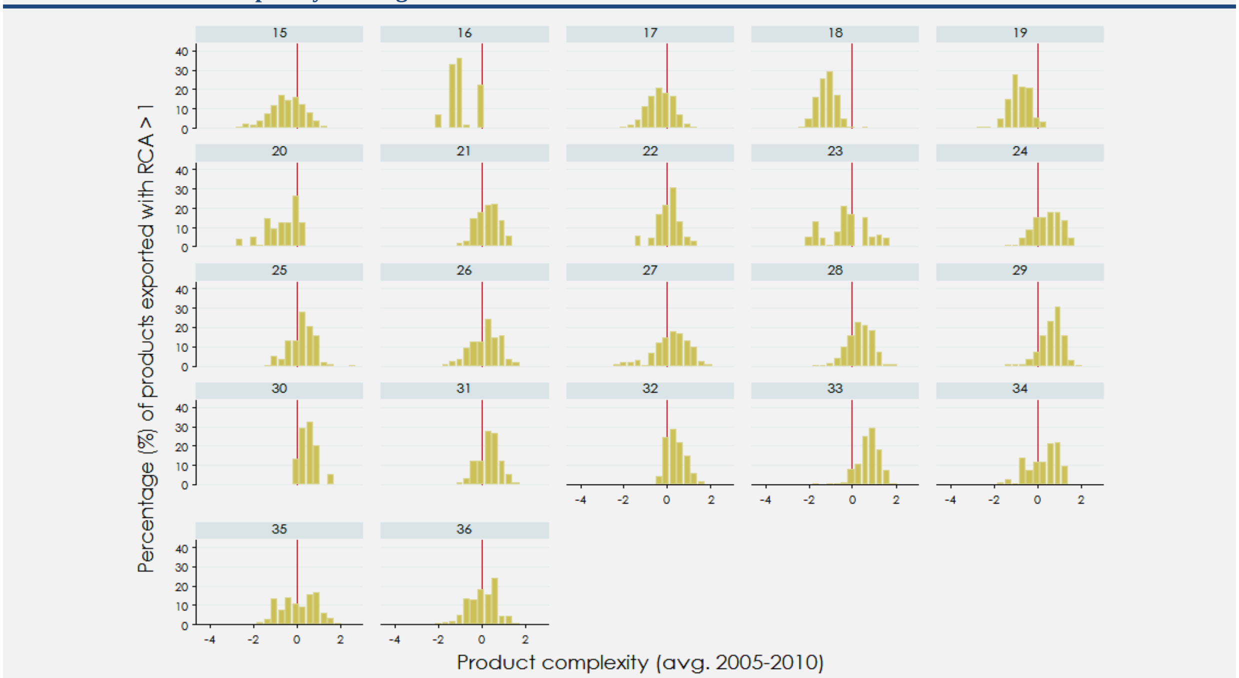
Figure 1.9. Product complexity: comparison of advanced manufacturing goods with non-Key Enabling Technologies



Note: Product complexity is the average 2005-10. More density to the right means products in that category are more complex than average.

for products of varying complexity, across EU

Figure 1.10. Percentage of total products for which EU manufacturing industries have revealed comparative advantages in different levels of complexity: averages 2005-2010 NACE Rev. 1



Source: Reinstaller et al. (2012). BACI database. Note: Products are sorted according to their complexity score on the horizontal axes. The average world market shares for each country's products are shown on the vertical axes.

manufacturing industries on average 2005-2010, to show how successful EU manufacturing industries are in competing with goods of different degrees of complexity.

The figure above focuses on EU products with revealed comparative advantages (values of RCA above 1). The results show that quite a high share of products with RCA>1 in the categories of basic and fabricated metals (NACE 27 and NACE 28),

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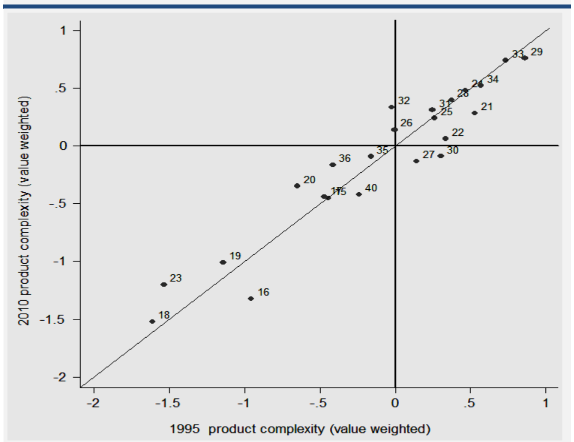
13 See Annex 1.1 for a description of the methodology for calculating complexity of products. The description is based on Reinstaller, A. et al (2012). See also Felipe et al. (2012 pp. 36-68).

14 See Hausmann and Hidalgo (2011); Hausmann, Hwang and Rodrik (2007)

15 See also the discussion in European Commission (2013a).

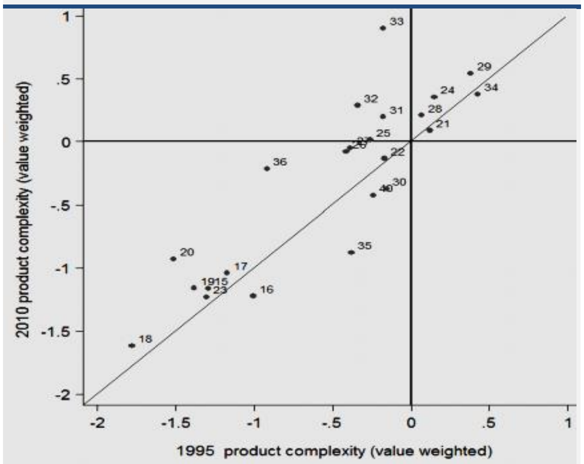
Figure 1.11. Development of product complexity at EU manufacturing industry level between 1995 and 2010 NACE Rev. 1.



Source: Reinstaller et al. (2012). BACI database. Note: Products are sorted according to their complexity scores 1995 and 2010 on the axes.

machinery and equipment n.e.c. (NACE 29), office machinery and computers (NACE 30) and motor vehicles (NACE 34) are products of higher than average complexity. For example, more than 90% of the products for which the manufacturing industry medical, precision and optical instruments (NACE 33) have revealed comparative advantages are more complex than the average products sold on world markets by the same industries in other countries.

Figure 1.12. Development of product complexity at BRIC countries' manufacturing industries' levels between 1995 and 2010



Source: Reinstaller et al. (2012). BACI database. Note: Products are sorted according to their complexity scores 1995 and 2010 on the axes.

EU manufacturing industries have revealed comparative advantages also for low complex products such as tobacco (NACE 16), clothing (NACE 18), leather (NACE 19) and wood (NACE 20) (Figure 1.10).

Given that competitiveness is a dynamic state, it is interesting to see how the EU manufacturing industries' products change in terms of complexity over time. EU manufacturers producing the most complex items: chemicals (NACE 24), machinery and equipment (NACE 29), medical, precision and optical instruments (NACE 33) and motor vehicles (NACE 34) maintained their position in 2010 compared to 1995. Industries producing electrical machinery and apparatus n.e.c. (NACE 31) and radio, TV and communication equipment (NACE 32) managed to upgrade their products, while industries producing office machinery and computers (NACE 30) were not able to upgrade their average complexity (Figure 1.11.).[16]

Larger changes have taken place over time in products supplied by BRIC countries. Products from wood industries (NACE 20), radio, TV and communication equipment (NACE 32), medical, precision and optical instruments (NACE 33) and furniture industries (NACE 36) have considerably improved in average complexity (Figure 1.12).[17]

Even though industries in the BRIC countries managed to upgrade their products considerably between 1995 and 2010, the majority of industries in these countries still produce less complex products than their counterparts in the EU. In fact, manufacturing industries in the EU have a high degree of complexity. This is further confirmed by the observation that the EU exported about 67% of products with revealed comparative advantage in 2010. In comparison, the US only has a comparative advantage in 43% of products, China in 54% and Japan in 24%.[18]

The EU is a highly diversified economic area, which is further confirmed by Figure A1.2.1 to A1.2.5 in Annex 1.2. More industries in the EU than in Japan and South Korea are able to secure big market shares for a larger number of export products. Manufacturing industries in the US are more advanced competitors in this respect. China has developed over time more industries able to produce relatively complex products. Chinese manufacturing industries are however still predominantly competitive in product categories with lower complexity.[19] Reinstaller et al (2012) show that EU exporters, together with those in the US, Japan and South Korea are more able to capture larger shares of

16 The lines crossing zero on the horizontal and vertical axes denote the average complexity of industries' products in 1995 and 2010 respectively. A dot above the 45 degree line indicates that an industry has managed to increase its average complexity between 1995 and 2010.

17 The lines crossing zero at the horizontal and vertical axes denote the average complexity of industries' products in 1995 and 2010 respectively. A dot above the 45 degree line indicates that an industry has managed to increase its average complexity between 1995 and 2010.

18 See Reinstaller et al, 2012.

19 ibid

Table 1.2. Domestic and foreign value added content of gross manufacturing exports by source country in 1995 and 2009 (%)

	EU		CHINA		JAPAN		KOREA		US	
	1995	2009	1995	2009	1995	2009	1995	2009	1995	2009
Domestic	91.1	85.6	82.7	73.6	93.3	85.4	73.3	61.3	86.9	84.5
Foreign	8.9	14.4	17.3	26.4	6.7	14.6	26.7	38.7	13.1	15.5
EU	–	–	2.8	5.1	1.2	1.8	4.4	5.2	3.7	3.3
CHINA	0.3	2.3	–	–	0.4	2.4	1.7	6.7	0.4	2.5
JAPAN	1.0	0.7	3.8	3.3	–	–	6.3	4.7	2.2	0.9
KOREA	0.3	0.4	2.0	1.8	0.5	0.5	–	–	0.6	0.4
US	2.3	2.4	2.0	3.4	1.4	1.6	5.1	3.8	–	–
AUSTRALIA	0.2	0.2	0.5	1.3	0.3	0.9	1.1	1.8	0.1	0.2
BRAZIL	0.2	0.4	0.1	0.6	0.1	0.2	0.3	0.4	0.2	0.3
CANADA	0.4	0.4	0.4	0.5	0.3	0.3	0.7	0.5	1.8	2.0
INDONESIA	0.1	0.2	0.5	0.4	0.3	0.6	0.6	1.2	0.1	0.1
INDIA	0.1	0.3	0.1	0.3	0.1	0.1	0.2	0.3	0.1	0.3
MEXICO	0.1	0.2	0.0	0.2	0.1	0.1	0.1	0.2	0.7	1.2
RUSSIA	0.8	1.5	0.3	0.7	0.1	0.4	0.4	1.0	0.2	0.3
TURKEY	0.1	0.3	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.1
TAIWAN	0.2	0.2	1.8	1.8	0.3	0.4	0.6	0.9	0.5	0.3
Rest of world	2.8	5.0	2.9	7.1	1.7	5.2	5.4	11.9	2.4	3.8

Source: WIOD

the world market by offering more exclusive products which rely on a broader knowledge base.[20]

The analysis of export complexity and exclusivity feeds into the broader discussion of the upgrade of a country's productive structure and comparative advantages. It is discussed in the context of the differences in structural change across countries in chapter 2 of this report.

The issue of separating the domestic content of production from foreign content is related to the increased international fragmentation of production which gives rise to increased intra-industry trade in intermediate goods. In traditional trade statistics the value of imported intermediate goods is included in the export value of the final product that is exported. One possibility is to adjust gross export flows for imported intermediates by means of global input-output statistics. The resulting exports only capture the value added which is generated domestically in the production of goods destined for export (see Johnson and Noguera, 2012; Stehrer, 2012) but exclude foreign value added associated with imported intermediates. Value added exports also exclude the part of value added which is created domestically but used in domestic production.[21]

A related concept is value added content in trade. This concept measures the domestic and foreign value added embodied in a country's gross exports. The measure provides information on how much value added from the exporting and other countries is embodied in a country's gross exports. A large share of foreign value added content in a country's exports is indicative of a less sophisticated part of the production process, such as the assembly of a product.[22] Figure 1.13 compares foreign value added of exports from China, the EU, Japan, Korea and the US from 1995 to 2009. It shows that foreign value added embedded in EU manufacturing exports is lower than that of the other global competitors.

The effects of the financial crisis on trade and global value chains are visible in the figure as the shares of foreign value added content ceased to increase after 2007. An exception is Korea which hosts a large number of Japanese multinational firms.[23]

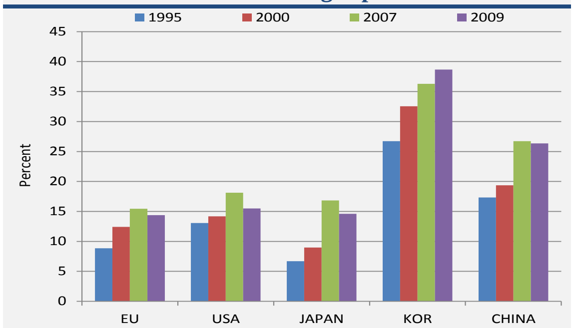
20 Regression analyses show that increases of product complexity of EU manufacturing products are positively associated with increases of world market shares, employment and value added growth in the EU manufacturing sector. See Reinstaller et al, (2012 pp 32-33).

21 See chapter 4 in this report.

22 See Stehrer (2012) for an extensive discussion of these two concepts.

23 OECD (2011). See also previous OECD Economic surveys for Korea.

Figure 1.13. Lower extent of foreign value added embedded in EU manufacturing exports



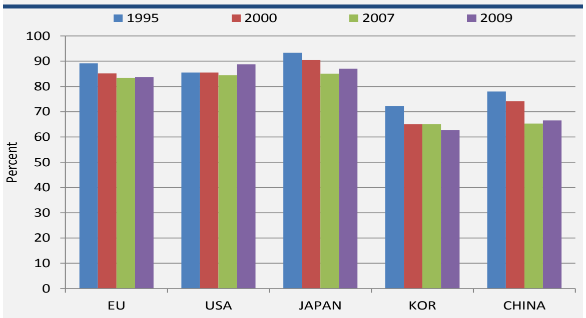
Source: WIOD.

Foreign value added embedded in gross exports can be broken down by source. This will show whether countries and their industries succeed in selling intermediate inputs to be used in the gross exports of other countries. The value added content of manufactured gross exports by source is closely related to the measure of vertical specialisation (Hummels et al, 2001). Between 1995 and 2009 when Chinese exports increased dramatically, EU value added in Chinese manufacturing exports increased more than that of industries from other parts of the world (Table 1.2). Japanese and Korean value added in Chinese manufacturing exports decreased during the same time. The increased presence of inputs from the rest of the world in Chinese, Japanese and Korean manufacturing gross exports suggests that there is a strong inter-Asian production network masked in this aggregate.

One reason for a relatively lower foreign content of EU manufacturing gross exports is that most of the value chains in which EU firms participate are regional, i.e. within the EU. The manufacturing aggregate masks differences across industries. The value chains involving EU industries producing chemicals, electrical equipment and transport equipment are more global, with a higher foreign content of manufactured exports.

Another reason for a lower foreign content of exports can be that the ability to produce most of the value added content of high-tech production – and exports – within a country can be an indication of complex productive structures. A look at the domestic value added content embedded in manufacturing high-tech exports reveals that the EU, Japan and the US are better able than Chinese or Korean counterparts to source most of the input factors necessary for high-tech production at home (Figure 1.14).

Figure 1.14. Lower extent of domestic value added content in high-tech manufacturing exports from China and Korea



Source: WIOD.

The analyses in European Commission (2011b) show that Chinese exports of high-tech manufacturing depend to a large extent on high-tech intermediate imports from other countries. This is evidenced by relatively low values per unit of high-tech exports against relatively high values per unit of imported intermediate goods.[24]

1.3. Drivers of sectoral competitiveness

This section assesses sectoral performance looking at drivers of external competitiveness. The development over time of cost and price competitiveness is analysed first. This is followed by an analysis of indicators of determinants of non-price competitiveness.

Labour cost and productivity

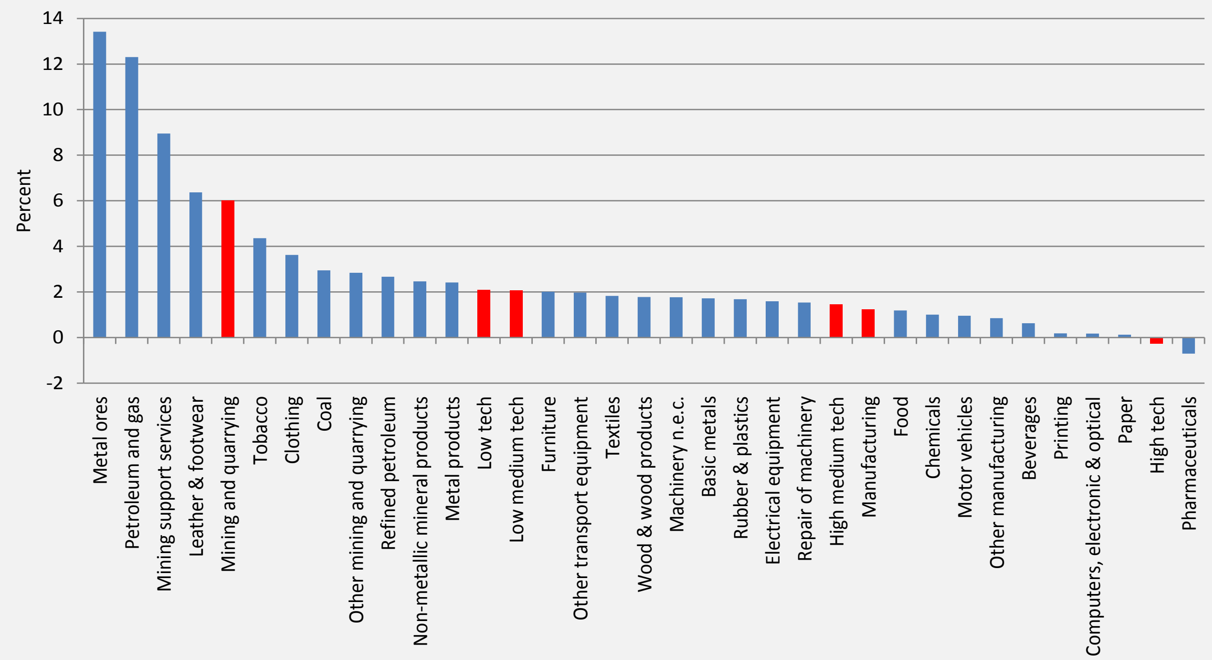
Developments in labour costs should be assessed in relation to labour productivity. A common measure is unit labour cost (ULC), which is defined as the ratio of labour compensation to labour productivity.

Labour compensation and labour productivity can be measured either relative to the number of workers or the number of hours worked. Increases in labour costs exceeding labour productivity growth imply lower profits on markets where the competition is intense and where firms are price takers. Developments in ULC can therefore be regarded as measures of cost competitiveness on markets of non-differentiated products. It should be noted that at given labour costs, ULC developments are heavily influenced by business cycle fluctuations impacting labour productivity growth through larger variations in production than in employment or hours worked.

For firms which produce homogenous goods and face strong competition from low-cost countries, labour costs are an important means to remain competitive. ULC may however not be a good indicator for firms which produce differentiated goods with some

[24] High-tech industries here include NACE 30 to 33, i.e. also the medium-high-tech group NACE 31, as it is based on the 2-digit NACE Rev. 1.1 classification and the aggregation of industries in the World Input-Output Database (WIOD).

Figure 1.15. More favourable developments of unit labour costs in high- and medium-high-tech industries 2001-2012



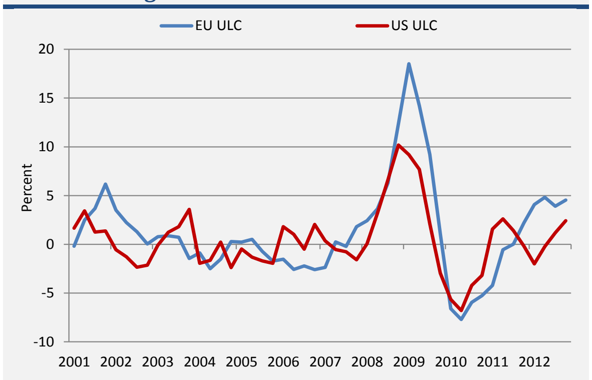
Source: Own calculations using Eurostat data.
Note: Annual growth 2001-2012 in ULC based on employment (%). HT, HMT, LT and LMT denote high-tech, medium-high-tech, low-tech and medium-low-tech manufacturing industries respectively.

characteristics that allow the firms some room of manoeuvre to set the prices themselves. Such firms producing goods with higher value added are more frequently found in high-tech and medium-high-tech manufacturing industries. Their goods are often combined with some kind of services aiming at satisfying demand for differentiated goods in high-income segments of different markets. Labour normally constitutes a smaller proportion of total costs and input factors for such firms, rendering the ULC less useful as a measure of competitiveness.

ULC based on the number of employees in manufacturing and mining industries are compared in Figure 1.15. High-tech and medium-high tech industries display lower ULC growth rates. ULC growth rates for manufacturing are considerably lower than for mining for the whole period and for different sub-periods.

Comparisons of different industries in the EU provide some insight into the competitiveness of these sectors. It is however more meaningful to compare developments of indicators of EU competitiveness with the same indicators for industries from other parts of the world which compete with EU firms.

Figure 1.16. Similar developments of ULC in EU and US manufacturing industries

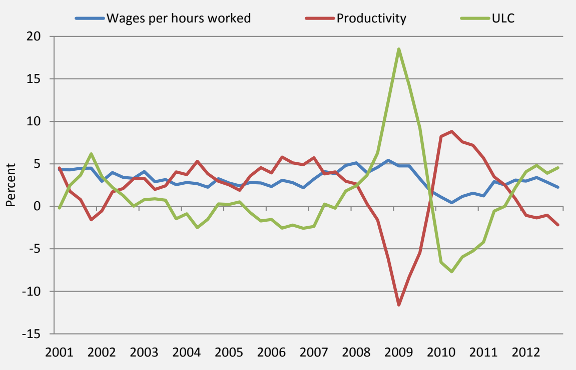


Source: Own calculations using Eurostat and Federal Reserve data.
Note: Growth rates in percent. ULC based on hours worked.

ULC developments for aggregate EU and US manufacturing are compared in Figure 1.16.[25] US unit labour costs advantages are driven mainly by labour productivity (cf. Figure 1.19). As can be seen below, a larger fall in EU labour productivity growth following the outbreak of the crisis is reflected in higher growth of unit labour costs (Figure 1.16).

[25] It would be more interesting to compare ULC developments between different types of EU and US manufacturing industries. It is however hard to make these comparisons, because of different industrial classifications.

Figure 1.17. Fluctuations in EU ULC are mainly caused by variations in labour productivity growth



Source: Own calculations using Eurostat data. Note: Growth rates in percent. ULC based on hours worked.

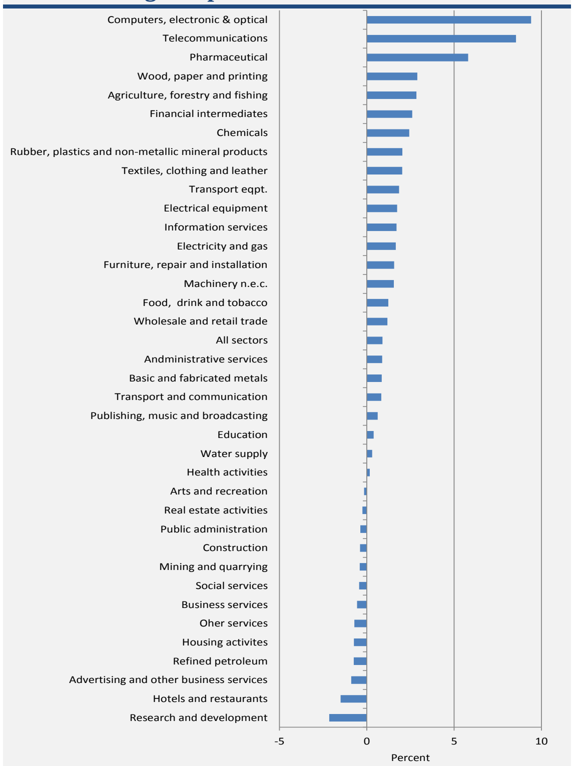
Most of the recent variations in EU manufacturing unit labour costs are due to fluctuations in labour productivity growth. Taking the analysis one step further, a faster decline of output relative to employment during the slump accounts for most of the losses in labour productivity in the EU at the start of the crisis. Between the first quarters of 2008 and 2009, production decreased by 19% while hours worked fell by 8% (Figure 1.17). This can partly be explained by labour market rigidities in Europe on the one hand and labour hoarding on the other (e.g. enterprises avoid the higher cost of recruiting and retraining when demand picks up by keeping skills in-house).

Growth of labour productivity is important both for price and non-price competitiveness. Labour productivity, and especially multi-factor productivity, is often seen as indicator of technical progress. Increased labour productivity means more output is produced with less labour, which can be due to technological or organizational improvements and other non-observable factors. Labour productivity growth is often used as an indicator of price or cost competitiveness as firms can lower their prices at given labour costs.

Between 2000 and 2011, labour productivity, measured as value added per employee, grew faster in high-tech manufacturing and the knowledge-intensive ICT sector. Some low-tech and medium low-tech industries such as textiles and rubber and plastics also performed relatively well and above the manufacturing average. The lowest productivity growth rates are observed in labour intensive services (Figure 1.18).

The relationship between labour productivity growth and market share gains is not straightforward. Firms in industries facing tough competition from low-cost producers (e.g. textiles and other low-tech sectors) are forced to rationalize their production in order to survive. Productivity growth in such a case may occur together with a declining share of the world market.[26] Therefore it is more informative to compare productivity growth rates with these of EU major competitors.

Figure 1.18. Highest labour productivity growth in ICT manufacturing and pharmaceuticals



Source: Own calculations using Eurostat data. Note: Annual growth in productivity per person employed 2000-2012 (%).

Labour productivity growth in US manufacturing in 2000-2011 was 3.5% on average, against 2.4% in EU manufacturing.[27] Large part of this difference occurred in the beginning of the millennium, even though a larger decline of labour productivity in the EU between 2008 and 2010 contributed to it too. Figure 1.19 shows that during recessions, manufacturing employment (in hours worked) tends to decline more in the US than in the EU. Therefore at a similar decline of demand and output, manufacturing labour productivity declines more in the EU.

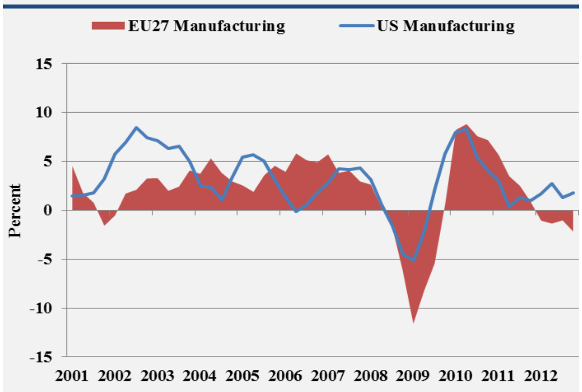
The remainder of this section examines non-price competitiveness of EU manufacturing. Accounting for the determinants of non-price competitiveness however, is a challenging task. There is a rather large

[26] In the worst case, firms are forced to close down non-profitable plants and reduce the labour force in order to rationalize. This would, all other factors equal, bring about an increase in industry productivity growth.

[27] Measured as changes from a quarter in one year relative to the same quarter in the previous year.

spectrum of factors which determine the good's quality and its value for the customer.[28]

Figure 1.19. Manufacturing labour productivity in the EU and US



Source: Own calculations using Eurostat and OECD data. Note: Annual growth in labour productivity per hour worked (%).

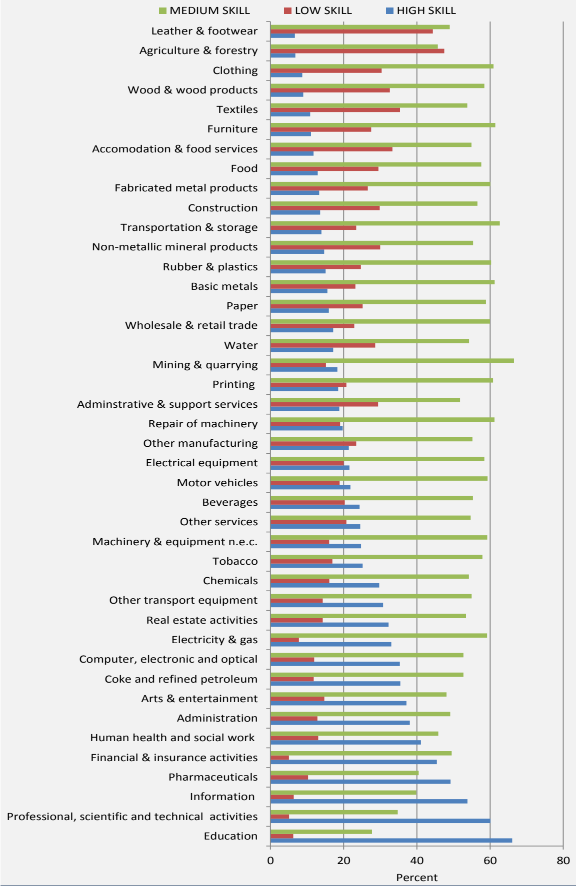
Innovation activities of firms resulting in product and process innovations as well as marketing and organization innovations are often regarded as non-price competitiveness factors. The discussion in European Commission (2010a) also addresses the quality and variety of inputs such as intermediate goods, service inputs, or the framework conditions under which firms operate. The analyses here will focus on human capital, physical capital, R&D and innovation and the use of services inputs.[29]

Skills

Labour and skills are not perfectly mobile, i.e. they cannot be moved across sectors without cost. The labour force consists of individuals possessing different types of skills and levels of education. This heterogeneity makes hiring and firing costly as they entail search and transactions costs. Highly educated labour with a certain set of skills can be difficult to find within any given period of time. This makes firms reluctant to make that kind of labour redundant during recessions. Adding to this reluctance are the sometimes firm specific skills that the labour force acquires within the firm.

These characteristics of the labour force mean that it is necessary to discuss **skills and human capital** as an input factor which can explain differences in growth between countries. Human capital is not easily measured. An often used proxy for accumulated knowledge is educational attainment. It is an imperfect measure since it is not capable of taking into account the whole stock of knowledge built up by skills and experience acquired after school from vocational or on-the-job training and learning by doing.[30] This indicator has however the advantage of being easily available. It is used here to analyse the distribution of employment by education across sectors based on the International Standard Classification of Education (ISCED)[31].

Figure 1.20. Skill and knowledge intensities (% of total employment)



Source: Own calculations using Eurostat's labour force survey data.

The market and non-market services sectors of education, information and communication, and financial activities are the most human-capital intensive. Manufacturing industries which produce goods that require a relatively high share of high-skilled labour are pharmaceuticals, refined petroleum products and computer, electronic and optical industries. Around 50% of the labour force in pharmaceutical firms has tertiary education. The smallest share of low-skilled workers is found in

28 See the discussion of how to define and measure the quality of goods in NUTEK (1997).

29 Some of these, and other non-price competitiveness factors are analysed by means of regression analysis in European Commission (2010a).

30 For a discussion of proxies for human capital in empirical studies, see Greiner, Semmler and Gong (2005). On different ways of measuring the stock of human capital, including a discussion on the limitations of educational attainment as a proxy for human capital, see OECD (1998).

31 ISCED identifies levels of education from 0 to 6 and is used to measure the proportions of low-skilled, medium-skilled and high-skilled labour for each sector (see Annex 1.3 for definitions).

financial services where only 5% of the labour force have no educational qualifications beyond primary level. More than 25% of the workforce in manufacturing industries producing chemicals, other transport equipment and tobacco are also classified as high-skilled.

Low-technology manufacturing sectors like textiles, clothing and leather have small shares of highly skilled labour, as do labour-intensive service sectors such as hotels and restaurants and agriculture and forestry (Figure 1.20).

Investment

Investment in physical capital increases the output capacity of firms and their labour productivity. It also improves total factor productivity by bringing technology, innovation and intangibles, thereby facilitating reorganisation and adaptation of the production process to shifts in consumer demand. Conversely, lower investments today impact negatively not only on current growth performance, but also on future growth prospects through a lower capital stock and lower future innovation and productivity growth, as much R&D and innovation is embedded in physical capital.[32]

The investment ratios presented in Table 1.3. below are defined as the ratio of **gross fixed capital formation** (GFCG) to value added.[33] Sectors with a high share of large capital intensive firms such as transport equipment, electricity and gas, water supply, transportation and storage as well as real estate activities have high investment ratios. The statistical classification with aggregation of sectors sometimes distorts the picture. The tobacco industry, which is capital intensive and dominated by large firms, is grouped together with food and beverages industries.

That lowers the average investment ratio for this aggregation of sectors. The investment ratios are relatively stable over time with some significant exceptions. Following the financial crisis, production in petroleum industries fell by some 40% in 2009 while investments were higher than the previous year. Possible reasons for maintaining a high investment against a drop in demand could be that the downturn was perceived as temporary, that the prices of investment goods declined, or the investment cycle in extracting industries has a longer-term time horizon and is less responsive to short-term fluctuations of demand, or for other strategic reasons. In any case, the investment ratio in this industry increased to 0.61 in 2009. It should be noted that data on gross fixed capital formation are not complete. Table 1.3 is based on data for only 20 Member States,[34] of which 2011 data is missing for eight Member States.[35]

R&D and innovation

R&D and innovation are indicators of non-price competitiveness, describing attempts by producers to increase their competitiveness by improving supply side conditions as well as trying to influence demand for their products. R&D expenditures can improve supply by introducing technology which improves the production process and lowers production costs. Outcomes of R&D can also be innovations in the form of new, improved or differentiated products which can increase the competitiveness of firms by making demand for their products less price elastic.[36]

The adoption and use of technology determines how efficiently input factors are combined in order to achieve growth in the long run. The indicators below describe the technology in the EU industries from different angles. The indicators represent different stages of the R&D&I process. R&D expenditures can be regarded as input indicators while patents and firms introducing new and/or improved products to a higher extent measure outputs of the R&D&I processes.

Due to insufficient coverage of R&D statistics across sectors and countries since 2007, the discussion in this section cannot include more recent data. This may not be as serious a drawback as it seems. The process from investing in R&D to developing new products can be very long, especially in industries such as pharmaceuticals where the process also includes rigorous and carefully regulated testing of the products. It may therefore be that the data represented in the figures below accurately describes the situation today. Data on R&D today should be seen as an indication of future technology and innovation results.

EU R&D expenditures represented 1.85% of GDP in 2007 against 2.7% in the US. The bulk of the difference between the EU and the US is found in private enterprise R&D. An EU aggregate has been formed in order to analyse R&D intensities by sectors (R&D expenditures relative to value added). The aggregate represents more than 80% of total R&D expenditures in the EU. The analysis focuses on business enterprise R&D expenditures (BERD) by economic activity. Public expenditures in terms of sectoral R&D are not reflected in the data.

[32] See for example the discussion in European Commission (2010a).

[33] Fixed assets; buildings, machinery and equipment, transport equipment, office machinery and hardware, software and intangible fixed asset are included in this aggregate.

[34] BE, CZ, DK, DE, EL, ES, FR, IT, CY, LT, LU, HU, NL, AT, PL, PT, SI, SK, FI and SE.

[35] DE, ES, CY, NL, AT, PL, PT and SI.

[36] See European Commission (2010a), p 123, and related references for a discussion of firms' attempts to differentiate products in order to increase their competitiveness.

Table 1.3. Investment ratios in 20 Member States

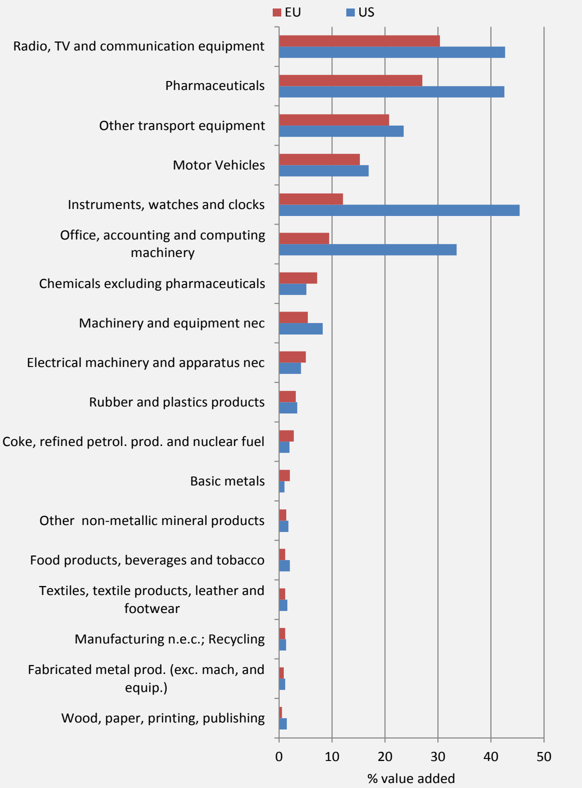
		2007	2008	2009	2010	2011
TOTAL	**Total**	**0.25**	**0.24**	**0.22**	**0.22**	**0.22**
A	Agriculture, forestry and fishing	0.37	0.39	0.39	0.34	0.35
B	Mining and quarrying	0.25	0.22	0.28	0.24	0.27
C10-C12	Food, drinks and tobacco products	0.19	0.20	0.17	0.17	0.21
C13-C15	Textiles, clothing, leather and footwear	0.12	0.12	0.10	0.11	0.15
C16-C18	Wood, pulp and paper and printing	0.20	0.21	0.17	0.17	0.21
C19	Refined petroleum products	0.35	0.36	0.61	0.41	0.27
C20	Chemicals	0.19	0.21	0.19	0.16	0.26
C21	Pharmaceuticals	0.15	0.15	0.14	0.13	0.18
C22-C23	Rubber and plastics	0.20	0.20	0.16	0.16	0.21
C24-C25	Basic metals and metal products	0.18	0.19	0.18	0.17	0.21
C26	Computers, electronic and optical products	0.18	0.18	0.18	0.19	0.28
C27	Electrical equipment	0.13	0.13	0.12	0.11	0.14
C28	Machinery and equipment n.e.c.	0.12	0.13	0.12	0.10	0.13
C29-C30	Transport equipment	0.20	0.23	0.23	0.18	0.32
C31-C33	Furniture, repair and installation of machinery and equipment	0.11	0.11	0.10	0.11	0.13
D	Electricity and gas	0.37	0.36	0.38	0.39	0.37
E	Water supply	0.49	0.48	0.45	0.46	0.43
F	Construction	0.16	0.15	0.10	0.11	0.10
G	Wholesale and retail trade	0.12	0.12	0.10	0.10	0.10
H	Transportation and storage	0.37	0.39	0.36	0.37	0.37
I	Accommodation and food service activities	0.12	0.12	0.10	0.10	0.12
J58-J60	Publishing, motion picture and broadcasting	0.23	0.23	0.21	0.22	0.26
J61	Telecommunications	0.29	0.29	0.25	0.27	0.28
J62-J63	Computer programming and consultancy activities	0.16	0.17	0.15	0.16	0.18
K	Financial and insurance activities	0.11	0.14	0.12	0.11	0.10
L	Real estate activities	0.73	0.68	0.61	0.60	0.58
M69-M71	Legal and accounting activities and architectural and engineering activities	0.09	0.09	0.08	0.08	0.10
M72	Scientific research and development	0.27	0.26	0.26	0.28	0.29
M73-M75	Advertising and market research, other professional services, scientific and veterinary activities	0.09	0.09	0.08	0.09	0.12
N	Administrative and support service activities	0.35	0.34	0.26	0.28	0.31
O	Public administration and defence	0.27	0.27	0.27	0.25	0.21
P	Education	0.09	0.09	0.09	0.09	0.09
Q86	Health care	0.12	0.12	0.11	0.11	0.10
Q87-Q88	Residential care activities and social work activities	0.13	0.12	0.11	0.11	0.07
R	Arts, entertainment and recreation	0.35	0.34	0.33	0.31	0.21
S	Other service activities	0.09	0.09	0.08	0.08	0.07

Source: Own calculations using Eurostat data.

This aggregate for EU manufacturing sectors is compared with US manufacturing (Figure 1.21). The comparison shows that the R&D intensity in US manufacturing is higher, due not to differences in industrial structures but to an overall smaller investment in R&D in the EU across all sectors.

Patent statistics are often used to compare countries' and industries' knowledge output. Even if indicators of patenting and the underlying statistics are subject to uncertainty and even bias, the information is of interest.[37]

Figure 1.21. US firms spend more on R&D in almost al sectors



Note: The EU is represented by 17 countries: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Poland, Portugal, Spain, Sweden and the UK. The industries are classified according to ISIC Rev 3.1.

Patent statistics reflect the output of the research process undertaken by firms. The statistics provide information on a large number of manufacturing sectors and the coverage over time allows trends and correlations with other economic developments to be analysed. As data are available for many countries, it is possible to calculate the performance of an EU sector relative to say, global performance. The measure is calculated in the same way as RCA indices for manufacturing exports (see Annex 1.3 for a complete definition of the measure).

Values larger than 1 indicate that the EU industry has a 'patent specialisation' relative to the world. The indicator shows that EU manufacturing industries perform better than the world in a number of industries. However, many high and medium-high-technology industries such as pharmaceuticals, office machinery and electrical equipment industries perform relatively worse than the rest of the world (Figure 1.22)[38].

Other things equal, lower-than-average patenting by EU manufacturing firms implies that EU industries are less able to develop new and/or improved products or production processes. This could translate into future losses of competitiveness.

Firms engage in product innovation in order to develop new or improve existing products. The purpose is to produce products with certain qualities that differentiate them from their competitors. If they succeed, they will face less elastic demand, be more able to set their own prices and be less reliable on labour costs and input prices to compete. By engaging in process innovation, firms aim at implementing new production processes that increase their productivity and/or lower their production costs. Firms also engage in organisational and marketing innovations to the same end.

EU manufacturing industries are more prone to engage in **innovation** activities than services industries. This is confirmed by the number of innovative enterprises by sector as well as by the number of innovations according to data from the Community Innovation Survey (CIS). Firms producing pharmaceuticals, tobacco, computers, chemicals and beverages have relatively higher shares of innovative enterprises in all enterprises in the 2010 CIS. Pharmaceutical, ICT and chemical firms were most successful in bringing new or improved products to market between 2008 and 2010 according to the Community Innovation Survey. It should however be noted that innovation comes easier for firms in some industries than others. Improving a beverage or tobacco product by introducing a new flavour is probably easier and less costly than developing a new car model. [39]

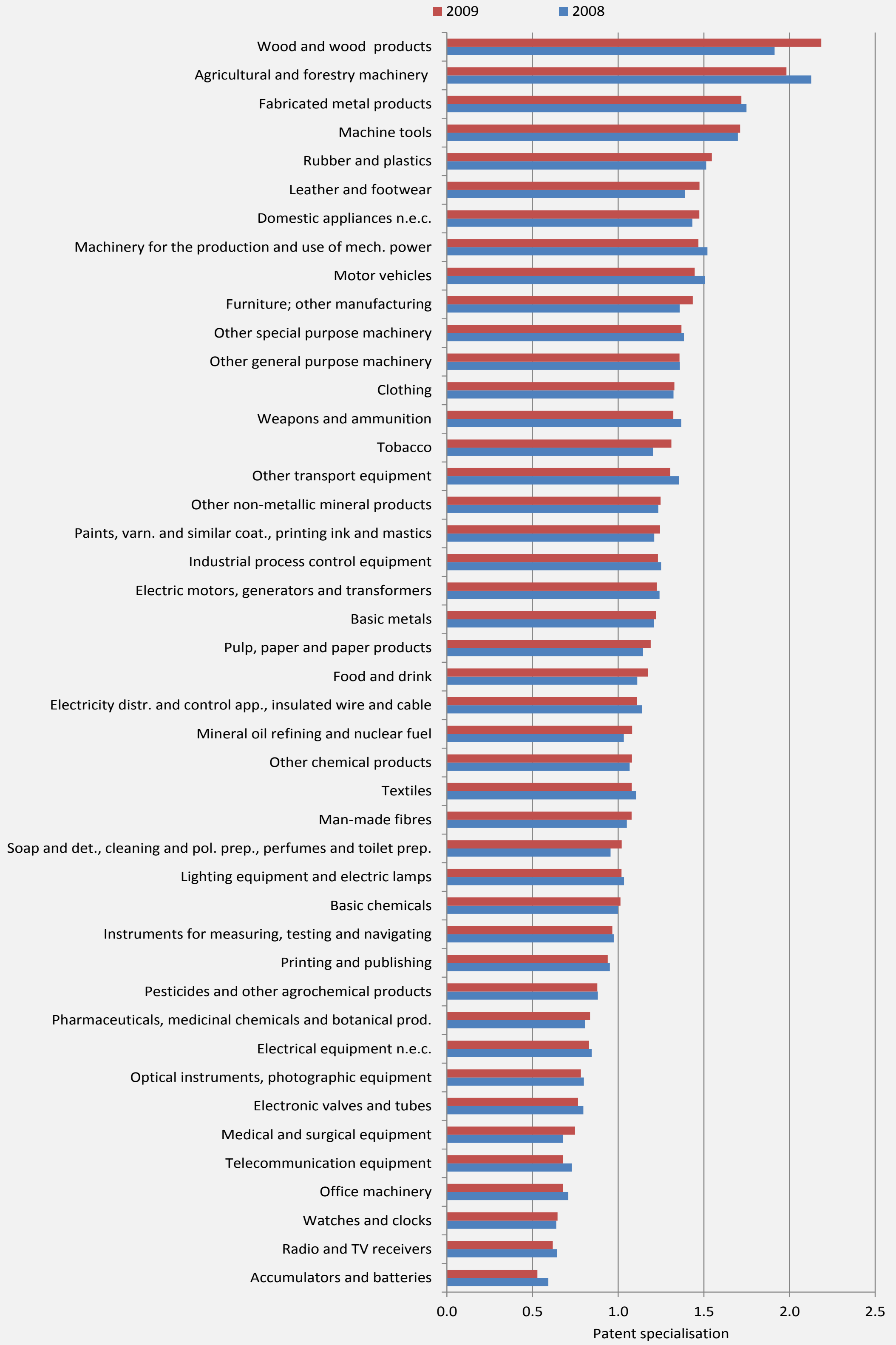
Few firms in low-tech manufacturing industries such as clothing, wood and leather, construction industries and in service industries (administration, hotels and restaurants) are engaging in innovative activities (Figure 1.23).

[37] Griliches (1990) discusses a number of issues related to patents, including the advantages and drawbacks. See also Pavitt (1985), Silverman (2002) and Griliches (1984).

[38] It should be noted that the indicator is based on patent applications to the EPO. The indicator might therefore be biased in favour of EU manufacturing industries as there is a tendency for non-EU industries to patent relatively less frequently at the EPO than at the USPTO. Triad patent families for industries which could take this bias into account were not available at the time of drafting of this report.

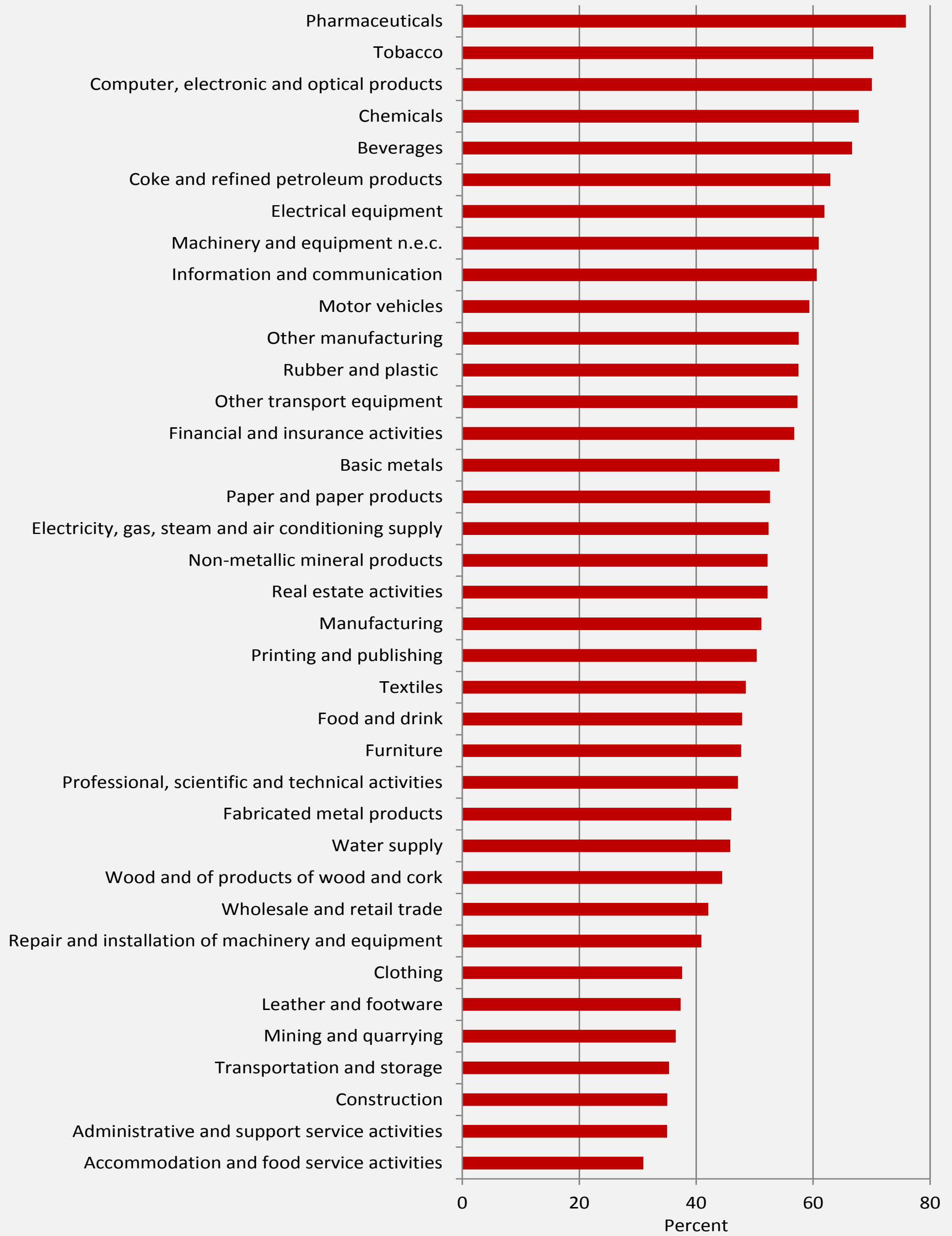
[39] The figures are calculated as averages for different sectors across the EU countries. The interpretation of the figure should be treated with caution since there are gaps in the dataset. The averages for tobacco, administration, accommodation and food and real estate activities are based on ten or fewer observations.

Figure 1.22. Relatively lower patenting by EU high-tech industries



Source: Own calculations using Eurostat data. Note: The aggregate "World" includes Iceland, Lichtenstein, Norway, Switzerland, Turkey, Russia, South Africa, Canada, the US, Mexico, Brazil, China, Japan, South Korea, India, Israel, Taiwan, Singapore, Australia and New Zealand.

Figure 1.23. More innovative enterprises in manufacturing industries than in mining and service industries



Source: Own calculations using Eurostat data. Innovative enterprises as a percentage of total enterprises in the 2010 CIS innovation survey.

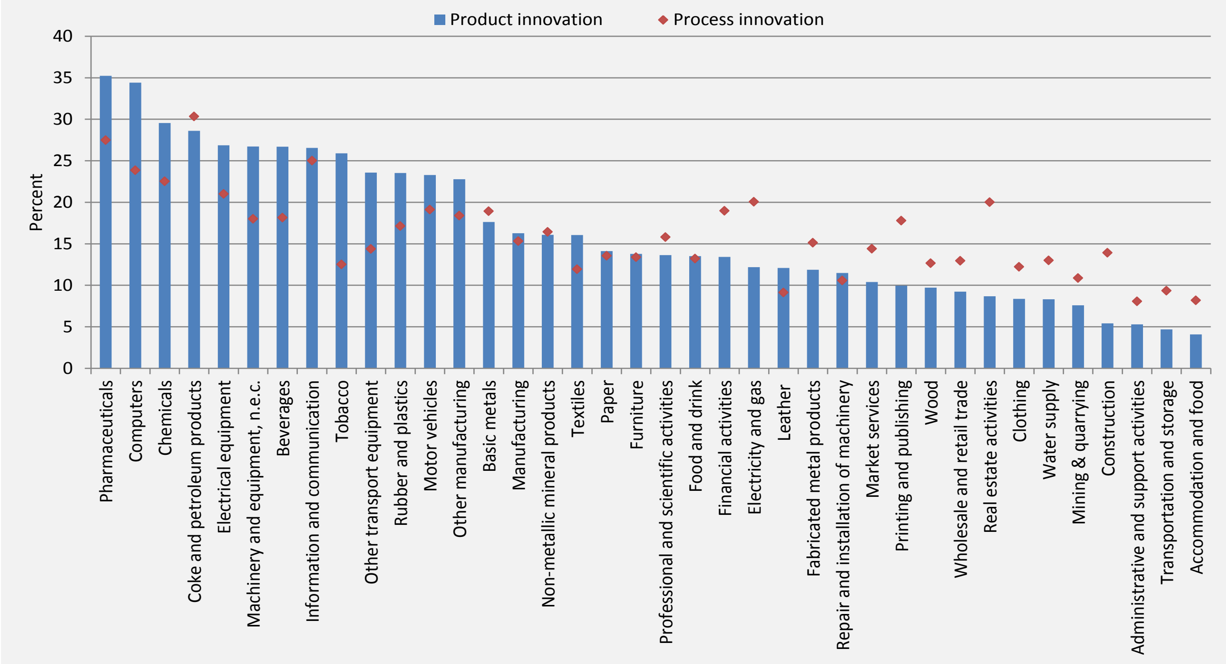
Services industries engage in process innovation to a higher extent than product innovation. Market services engage in process innovation almost to the same extent as manufacturing firms (Figure 1.24).

The use of services in manufacturing

Manufacturing firms have increasingly used services over time. This shows up on the input side as well as the output side. They have increased their services intensity in order to increase their productivity and thereby also their competitiveness. Manufacturing firms use services to differentiate their products from their competitors.

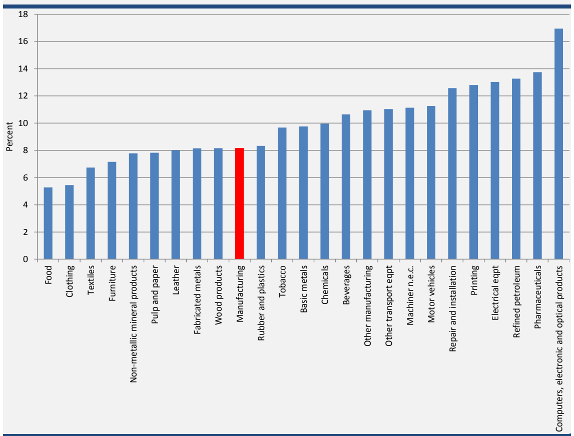
On the input side, manufacturing firms' use of intermediate services has increased over time. The increase has been most pronounced for services provided by knowledge-intensive business services firms (European Commission 2010b). But manufacturing firms are also producing more of the services in-house. This is reflected in the increased share of employees with services-related occupations over time. Having access to this kind of labour makes it easier for manufacturing firms to provide their physical goods with services characteristics and to engage in services innovations. High-tech manufacturing firms producing pharmaceuticals, ICT and electronic and optical equipment are the most

Figure 1.24. Pharmaceutical and ICT firms more successful in innovation



Source: Own calculations using Eurostat data. Data from the 2010 Community Innovation Survey.

Figure 1.25. Manufacturing firms' services innovation in 2010



Source: Own calculations using Eurostat data. Note: Manufacturing enterprises that developed services innovations as percentages of total enterprises in the CIS innovation survey 2010. Data are not available for Denmark, Germany, Greece and the UK.

frequent innovators in EU manufacturing. But firms in the refined petroleum and coke sectors are also responsible for a relatively high level of services innovations.[40] Low-technology industries engage in services innovation much less than the EU manufacturing average (Figure 1.25).

On the output side, services have increased over time as a share of manufacturing output (European Commission 2011b). But manufacturing firms not only produce more "pure" services than previously. The contents of manufacturing goods have also changed as more and more services are embedded in physical products.

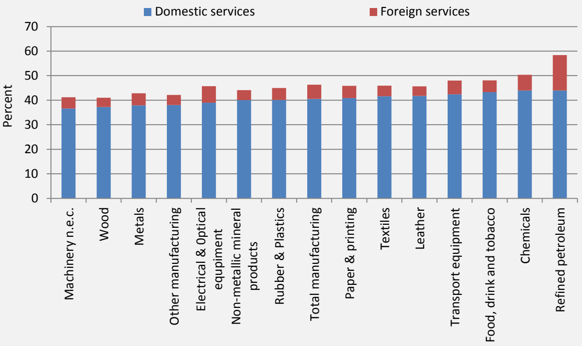
The latter trend is a natural consequence of manufacturing firms trying to differentiate their products. This is a response not only to intensified competition from low-cost producers in emerging countries but also an attempt to satisfy increased demand for more varieties of goods as incomes rise. Upgrading the products may also make customers willing to pay a premium for them if the products are perceived to be of high enough quality.

This makes demand for these products less price elastic. EU manufactured exports consist to an increasing extent of embedded services. Domestic services account for most of the services value added – around 90% across all industries, except in coke and refined petroleum where 25% of services value-added is imported. The largest total share of services value added embedded in exports is also to be found in industries producing coke and refined petroleum (Figure 1.26).

One of the most prominent characteristics of increased globalisation is the way production processes are sliced up between different locations, according to their comparative advantages. Technological progress, especially in communications, and lower transportation costs are major factors behind the emergence of global value chains (GVCs). Firms participate in GVCs in order to increase their competitiveness or better satisfy demand in different foreign markets. Focusing on the first of these motives, engaging in GVCs may

[40] See also Lodefalk (2013) for an analysis of the servicification of Swedish manufacturing. The industries producing refined petroleum and coke are among the most "servicified" manufacturing industries.

Figure 1.26. Services value added in EU manufacturing gross exports 2009



Source: WIOD.

increase a firm's competitiveness by enhancing access to cheaper or higher-quality intermediate inputs (OECD 2013). Industries in OECD countries using a higher share of **imported intermediates** display on average higher productivity. The effects arise mainly in three ways. Firstly through lower prices, as more intermediate imports lead to stronger competition among intermediate producers. Secondly, by increasing the supply of varieties of intermediates as imports grow. Finally through increased productivity as new imported intermediates may be more suited for the technology of final goods destined for the foreign markets. Gaining access to foreign knowledge by using imported intermediates may also lead to higher innovation as the firms' knowledge bases increase (OECD 2013).

Conclusions and policy implications

This chapter uses a number of advanced indicators of international competitiveness to provide insights into the strengths and weaknesses of EU manufacturing and draw implications for EU industrial policy. It finds that the EU has comparative advantages in most of its manufacturing sectors. These sectors include such vital high and medium-high tech sectors as pharmaceuticals, chemicals, vehicles, machinery, other transport equipment (which includes aerospace), but also low and medium low tech sectors such as food, beverages, tobacco, paper and plastic. On the downside, in high-tech sectors Europe has comparative advantages only in pharmaceuticals while EU electrical equipment and computer, electronic and optical products lag behind in international competitiveness.

The EU has a comparative advantage in the broad category of medium-high tech industries (1.14), but its advantage is smaller than that of Japan (1.59) and the US (1.22). The development of RCA over time shows that China is quickly gaining ground. China has a comparative advantage in the aggregate broad category of high-tech industries (1.56), leaving far behind in high-tech export specialization the US (0.88), the EU (0.85) and Japan (0.73).

This is the state of play of competition in broad categories of industries grouped according to technology intensities. Taking the analysis further down to product level, however, presents Europe in a much better position globally. In 2010, 67% of European exports had revealed comparative advantages, while China had comparative advantages in 54% of products, and US and Japan export 43% and 24% respectively of their products with a comparative advantage.

Indicators of revealed comparative advantage (RCA) are derived from trade data. They do not provide information about the sophistication of the exported product and how much of it is produced in the exporting country (the domestic share of export value added). Looking at the complexity of EU exports shows that the sectoral comparative advantages of EU industries in the medium-high tech group are based on higher complexity (knowledge intensity) of exports than the average. For instance, in medical precision and optical instruments 90% of products with RCA>1 are more complex than the average products exported by other countries. The analysis shows that the present comparative advantages of EU industries are the result of maintaining and upgrading the sophistication of EU exports over the last 15 years. At the same time, the emerging industrial powers (e.g. BRIC) have achieved a much faster upgrade of their exports, but are still lagging behind the EU industries in terms of sophistication of exports. Even though China has RCA>1 in the high-tech category, it is still based on products with lower complexity.

The analysis of exports in value added provides new insights into the international performance of EU manufacturing. It shows that advanced economies have higher domestic content of exports; thanks to their strong industrial base they can afford to supply domestically competitive terms most of the inputs needed for their exports. Thus the domestic value of the exports of EU, US and Japan is around 85 %, while that of China is 73.6% and that of Korea is 61.3%. Chinese high-tech exports, for instance, seem to rely heavily on high-tech imports of intermediates. In electrical equipment, for example, China's market share in gross exports is 9 percentage points higher than its market share in exports in value added.[41] This is evidenced by the relatively low values per unit of finished high-tech exports against the relatively high unit values of imported high-tech inputs.

About 20% of the foreign inputs in Chinese exports comes from the EU, which is higher than for the US and Japan (about 13% each). This is a result of faster growth of the EU share during the last 15 years of the Chinese export boom.

[41] See Chapter 4 for details.

The indicators present the EU position in the global competition in manufacturing goods. They cannot, however, inform policymakers about the reasons for the EU position, nor about how to improve the position. Therefore the analysis looks at factors that can explain industrial performance and, if properly targeted by policy, improve it. Competitiveness is above all the result of productivity gains. Accordingly, the analysis departs from labour costs and productivity of EU manufacturing, but goes further to explore such determinants of total factor productivity as the input of skills, R&D and innovation intensities, fixed capital formation and the contribution of services to manufacturing competitiveness.

It shows that between 2000 and 2011, labour productivity in the US has grown by 3.5% on average, against 2.4% in the EU. This is largely explained by the fact that during downturns, the US seems to do better in terms of labour productivity growth. One reason is that employment in the US adjusts faster than in the EU to shrinking demand for goods and services. Productivity is the major driver of the US superior performance vis-à-vis Europe in terms of unit labour cost (ULC), which is one of the common explanatory indicators of cost and price competitiveness. A possible implication of this comparison is that the EU labour market needs to gain flexibility in order to allow faster and more efficient adjustment of labour to shifts in demand. Labour market rigidities are often explained by employment protection. During the slump however, employment adjustment lagged behind the drop in demand not just because employers could not lay off workers, but because in the technology-intensive sectors they chose to keep them to avoid the cost of re-hiring and re-training when demand picks up. Therefore shortages of skills and hoarding of labour may be additional reasons why the labour demand response to a decline in output is more sluggish in Europe than in the US. Chapter 3 looks in more depth at the efficiency and productivity deficits of EU manufacturing and the relevant policy responses.

Labour costs have a decreasing weight in EU manufacturing competitiveness for two reasons. First, the analysis shows that EU exports rely mainly on knowledge-intensive products rather than low-tech labour intensive products. On the other hand, emerging economies are catching up fast, not only in the level of technology but also in terms of wages. Therefore what is more important for Europe's competitiveness in the global supply chains is total factor productivity (TFP). It accounts for the part of GDP growth which cannot be attributed to measurable factor inputs, and is explained by skills, technology and process innovation, and investment in intangibles.

US private spending on R&D (as a share of GDP) is almost 1.5 times that of the EU (2.7% in the US vs. 1.85% in the EU). A sector breakdown indicates that this is not a result of differences in industrial structures or US specialization in knowledge-intensive sectors but of an overall underperformance of EU sectors in terms of R&D investment across all sectors.[42] The output of research is new products, new technologies, new materials and processes. A rough indicator of this output is patents. The chapter documents that in a number of high and medium-high technology industries (such as pharmaceuticals, optical equipment, electrical equipment, medical and surgical equipment, telecom and office equipment, radio and TV and accumulators and batteries), the EU is lagging behind in patenting. As the RCA indicators show, the EU export performance depends crucially on some of these sectors. It may be hard to preserve current comparative advantages in these industries if it loses its technology lead, as indicated by patent data. Another problem is that the transition of EU research to the market seems to be more difficult than for major competitors. This is an important problem which deserves a more detailed study. This report is trying to look for explanations in Chapter 4 and Chapter 5.

The implications of EU exports' complexity for industrial policy is that targeting only high-tech sectors might be less rewarding than increasing the share of knowledge intensive products in all tradable sectors, including medium-low and medium-high tech sectors. Moreover, some of the labour intensive sectors with lower knowledge intensities may be better suited to tackle the EU's unemployment challenges than high-tech sectors. About 40% of EU manufacturing employment is in low-tech sectors. Therefore the policy priority attached to key enabling technologies which leads to new materials and products in all manufacturing sectors has a strong potential to upgrade EU competitiveness not only in high-tech sectors but also in traditional industries. Chapter 5 of this report analyses EU performance and prospects in the competition with products based on key enabling technologies.

[42] See Chapter 4 of this report for further details.

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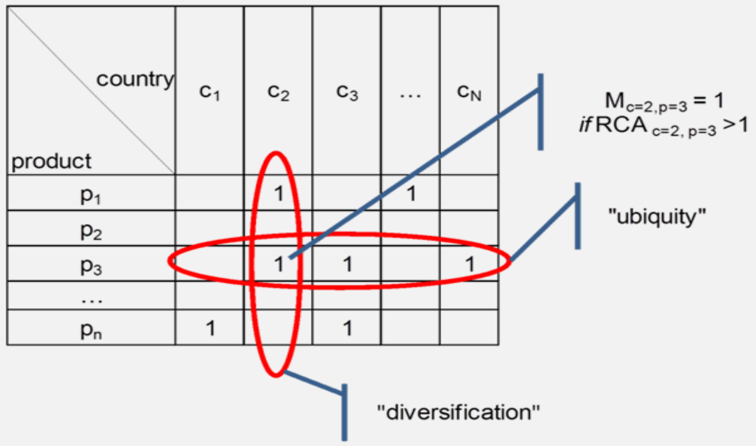
ANNEX 1.1.
DIVERSIFICATION AND UBIQUITY OF PRODUCTS

The analytical approach is based on Hidalgo et al. (2007) and Hidalgo and Hausmann (2009). This approach uses trade data to construct measures for the diversification of an economy and the sophistication of the products it exports. Data from the *Base pour l'Analyse du Commerce International* (BACI) database developed at the Centre d'Études Prospectives et d'Informations Internationales (CEPII) have been used. The dataset contains data for 232 countries and 5,109 product categories classified using the Harmonized System at the 6-digit level. The data cover the years 1995 to 2010. The methodological approach aims to capture, in a few indicators, the productive capabilities of an economy.[43] Figure A1.1 shows how these indicators are constructed. A country is linked to a product if it has revealed comparative advantage in this product. The implicit assumption is therefore that a country disposes of capabilities or factor endowments that convey a competitive advantage in this product.

Figure A1.1. Diversification and ubiquity of countries and products



If the matrix shown in the figure above is summed up **column-wise** over products p, one obtains a measure for the diversification of a country c.

$$k_{c,0} = \sum_{p} M_{c,p} \cdots \text{diversification} \quad (1)$$

Where k is the measure of diversification. M is an indicator which assumes the value of one (1) if RCA >1 for a country c exporting a product p.

If on the other hand the matrix is summed up **row-wise,** one obtains a measure for the ubiquity of comparative advantage in the trade of a specific product p. This measure tells us how many countries c have a comparative advantage in trading this product.

$$k_{p,0} = \sum_{c} M_{c,p} \cdots \text{ubiquity} \quad (2)$$

By combining these two indicators, it is possible to calculate through recursive substitution how common products are that are exported by a specific country,

$$\rightarrow k_{c,n} = \frac{1}{k_{c,0}} \sum_{p} M_{c,p}\, k_{p,n-1} \ldots \text{for } n \geq 1, \quad (3)$$

and how diversified the countries are that produce a specific product

$$\rightarrow k_{p,n} = \frac{1}{k_{p,0}} \sum_{c} M_{c,p}\, k_{c,n-1} \ldots \text{for } n \geq 1. \quad (4)$$

[43] A short and intuitive description of the methodology is available in European Commission (2013a) http://ec.europa.eu/enterprise/policies/industrial-competitiveness/competitiveness-analysis/index_en.htmhttp://ec.europa.eu/enterprise/policies/industrial-competitiveness/competitiveness-analysis/index_en.htm.

n in (3) and (4) denotes the number of iterations in the computations. See also Table A 1. If formula (3) goes through an additional iteration, the indicator now tells us how diversified countries are that export similar products as those exported by country c. An additional iteration for formula (4) then tells us how ubiquitous products are that are exported by product p's exporters. Table A1.1 gives an overview on how the indicators can be interpreted.[44] Only the first three iterations of the indicator are presented below. The indicators k_(p,max) and k_(c,max) provide for any product p, (k_(p,max)), its level of complexity, and for any country c, k_(c,max), the level of complexity of the productive structures of its economy.

These two indicators are calculated by going through as many iterations necessary until the ranking of the countries and the products in terms of the k_(p,max) and k_(c,max) values do not change anymore. The number of iterations necessary to obtain this convergence may thus vary from year to year.

Table A1.1. Interpretation of the indicators calculated using the Method of Reflections, first three pairs

n	country	product
0	$k_{c,0}$: number of products exported by country c, diversification → "How many products are exported by country c?"	$k_{p,0}$: number of counries exporting product p, ubiquity → "How many countries export product p?"
1	$k_{c,1}$: average ubiquity of products exported by country c → "How common are the products exported by country c?"	$k_{p,1}$: Average diversification of the countries exporting product p → "How diversified are the countries exporting product p?"
2	$k_{c,2}$: Average diversification of countries with a similar export basket as country c → "How diversified are countries exporting similar products as those exported by country c?"	$k_{p,2}$: Average ubiquity of the products exported by countries exporting product p → "How ubiquitous are the products exported by product p's exporters?"

Source: Abdon et al. (2010), p. 8, following Hidalgo - Hausmann (2009), Supplementary material p.8

The assumption underlying this analytical framework is that countries need a large set of complementary and non-tradable inputs. Hausmann and Hidalgo refer to this as capabilities (see also Hausmann and Hidalgo 2011). If countries differ in these capabilities and products differ in the type of capabilities that are needed to produce and successfully trade them, countries with more capabilities will be more diversified. On the other hand, products that require more capabilities will be successfully exported only by those countries that have these capabilities, and as a consequence they will be less ubiquitous.

The indicators therefore capture on the one hand the variety of goods produced by an economy and to what extent this product mix represents a unique source of comparative advantage for the economy. They do so by conceiving these relationships as a network and by expressing the properties of each node in the network as a combination of the properties of all its neighbours. This approach therefore exploits information from the global trade network to construct indicators that capture important aspects of the level of economic development and the competitiveness of economies by exploiting the fact that the economic fortunes of countries are intertwined via trade, foreign direct investment, and financial capital flows.

The supply of products in one country is highly dependent on economic activities in multiple foreign countries and changes in production networks spread across countries and continents. When countries and regions transform as a result of economic, technological, political, or institutional change, the nature of foreign trade changes as well, and trade data therefore capture such changes.

[44] Higher iterations than those presented in the table are increasingly difficult to interpret.

ANNEX 1.2
WORLD EXPORT SHARES AT PRODUCT LEVELS OVER PRODUCT COMPLEXITY BY NACE, EU-27 AND COMPETING COUNTRIES

Figure A1.2.1. World export shares at the product level over product complexity by NACE sector, EU 27

Source: Reinstaller et al. (2012). BACI database

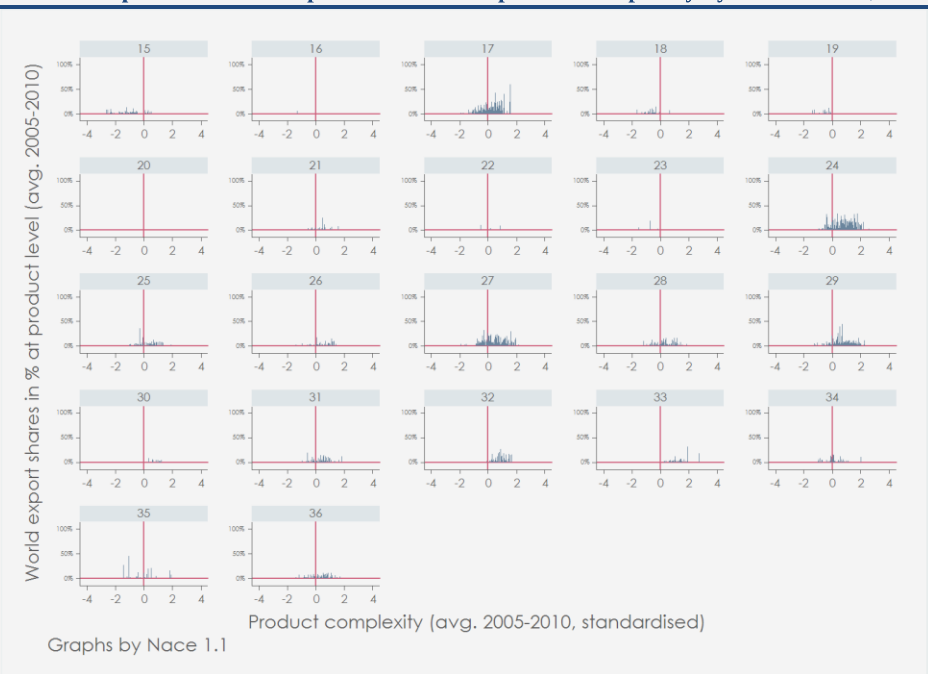
Figure A1.2.2. World export shares at the product level over product complexity by NACE sector, US

Source: Reinstaller et al. (2012). BACI database

Figure A1.2.3. World export shares at the product level over product complexity by NACE sector, Japan

Source: Reinstaller et al. (2012). BACI database

Figure A1.2.4. World export shares at the product level over product complexity by NACE sector, Korea



Source: Reinstaller et al. (2012). BACI database

Figure A1.2.5. World export shares at the product level over product complexity by NACE sector, China

Source: Reinstaller et al. (2012). BACI database

ANNEX 1.3
DEFINITIONS OF MEASURES AND CLASSIFICATIONS USED

The number of patent applications of a given EU manufacturing industry relative to total EU manufacturing patent applications are compared to the number of patent applications of the same industry in the world relative to the number of total patent applications in manufacturing in the world. The indicator, PAT, measures the EU manufacturing industries' relative patenting performance:

$$PAT = \frac{PAT_i^{EU} / \sum_i PAT_i^{EU}}{PAT_i^{World} / \sum_i PAT_i^{World}}$$

where:

PAT_i^{EU}: number of patents filed by EU industry 'i'

$\Sigma i\ PAT_i^{EU}$: number of patents filed by all EU manufacturing industries

PAT_i^{World}: number of patents filed by World industry 'i'

$\Sigma i\ PAT_i^{World}$: number of patents filed by all manufacturing industries in the World

Box A1.3.1: Using International Standard Classification of Education to define skill categories

The International Standard Classification of Education (ISCED) differentiates seven levels of education.

Level 0: pre-primary

Level 1: primary education

Level 2: lower secondary

Level 3: upper secondary

Level 4: post-secondary non-tertiary

Level 5: first stage of tertiary education

Level 6: second stage of tertiary education.

The publication has aggregated the levels in three categories so that total employment in each sector can be broken down in three skill categories instead of seven:

Low skilled: Level 0, Level 1 and level 2

Medium skilled: Level 3 and level 4

High-skilled: Level 5 and level 6

Manufacturing industries classified according to technological intensity (NACE Revision 2)

High-technology manufacturing

21 Manufacture of basic pharmaceutical products and pharmaceutical preparations

26 Manufacture of computer, electronic and optical products

Medium high-technology manufacturing

20 Manufacture of chemicals and chemical products

27 to 30 Manufacture of electrical equipment, Manufacture of machinery and equipment n.e.c., Manufacture of motor vehicles, trailers and semi-trailers, Manufacture of other transport equipment

Medium low-technology manufacturing

19 Manufacture of coke and refined petroleum products

22 to 25 Manufacture of rubber and plastic products, Manufacture of other non-metallic mineral products, Manufacture of basic metals, Manufacture of fabricated metal products except machinery and equipment

33 Repair and installation of machinery and equipment

Low-technology manufacturing

10 to 18 Manufacture of food products, beverages, tobacco products, textiles, wearing apparel, leather and related products, wood and products of wood, paper and paper products, printing and reproduction of recorded media

31 to 32 Manufacture of furniture, other manufacturing

Chapter 2.

STRUCTURAL CHANGE

Economic development is linked to major changes in the structure of economies. Changes in technology and skills enable economies to produce the same goods at higher levels of productivity, and to develop new products and services. At the same time, consumer demand and derived demand for intermediate goods and services shift to different sets of goods. This process of long-lasting changes in the set of goods and services produced and in the composition of capabilities – the physical and human capital base as part of the factors of production – is called structural change. This long-term process should be distinguished from shorter-term changes in the structure of economies that may, for example, be induced by economic bubbles and their collapse. In this regard, the chapter does not focus on sector changes occurring during the current financial crisis.

Structural change is not only related to changes in the composition of economies associated with economic development. The growth potential of economies is also affected by the sectoral composition of output and employment. Some sectors experience higher long-term growth than others, leading to shifts in the shares of these industries in the economy. However, it is important to note that the structure of the economy can also change with no positive impact on economic growth, if structural change increases the share of sectors with low growth potential. Thus, the structural composition of economies and structural change are important elements to be addressed by economic policy making in order to ensure that the positive growth enhancing structural change is facilitated. For this reason, this chapter deals with the pattern of structural change observed over recent decades. The driving forces of structural change are technological change and its impact on productivity, as well as changes in the structure of demand associated with changes in the prices of goods and aggregate income. These determinants are interrelated and difficult to disentangle, but they explain a large part of the observed trends in structural change.

The primary aim of this chapter is to explore broad patterns of structural change and its determinants with a look at the policy relevance of structural change for European policymaking. Europe is currently experiencing an economic crisis the impact of which on individual EU Member States varies. Within this context, the importance of economic structure is amplified when international trade and the sectoral distribution of employment and output across the production of tradable and non-tradable output are taken into account. International trade can modify, deepen and relax patterns of structural-change across countries (McMillan and Roderick 2011).

The chapter covers the main trends of structural change, the drivers, and the role of policies and institutions in the process.

Broad trends of structural change are associated with economic developments that are quite robust and homogenous over time in the countries under consideration. The share of agriculture is declining, while the share of manufacturing displays a hump-shaped pattern and the share of services is increasing for almost all industrialized countries. The primary drivers are productivity improvements based on technical change and innovation, and changing patterns in demand due to income effects and price changes. International trade also has an important influence on differences in economic structure across countries.

Growth-enhancing structural change is associated with the upgrading of capabilities, as well as with a process of "creative destruction". This process can be observed by analysing a country's export basket. In more advanced economies, industries producing more sophisticated and complex products are replacing other industries. However, more sophisticated and complex products require specific knowledge-bases and specialisation patterns. The process of reconfiguring capabilities and the range of products produced by an economy is thus an important part of the interaction between structural change and the international division of labour.

The analysis of the relationship between broad policies and institutions within the process of structural change reveals that policies can guide structural change, but that there are also important limits to the impact of policies due to the existing structure of economies. Because of international trade and the associated specialisation patterns, economies have different industrial structures. Therefore, policy intervention should aim to support growth-enhancing structural change by developing and building upon existing strengths, rather than taking a completely open approach.

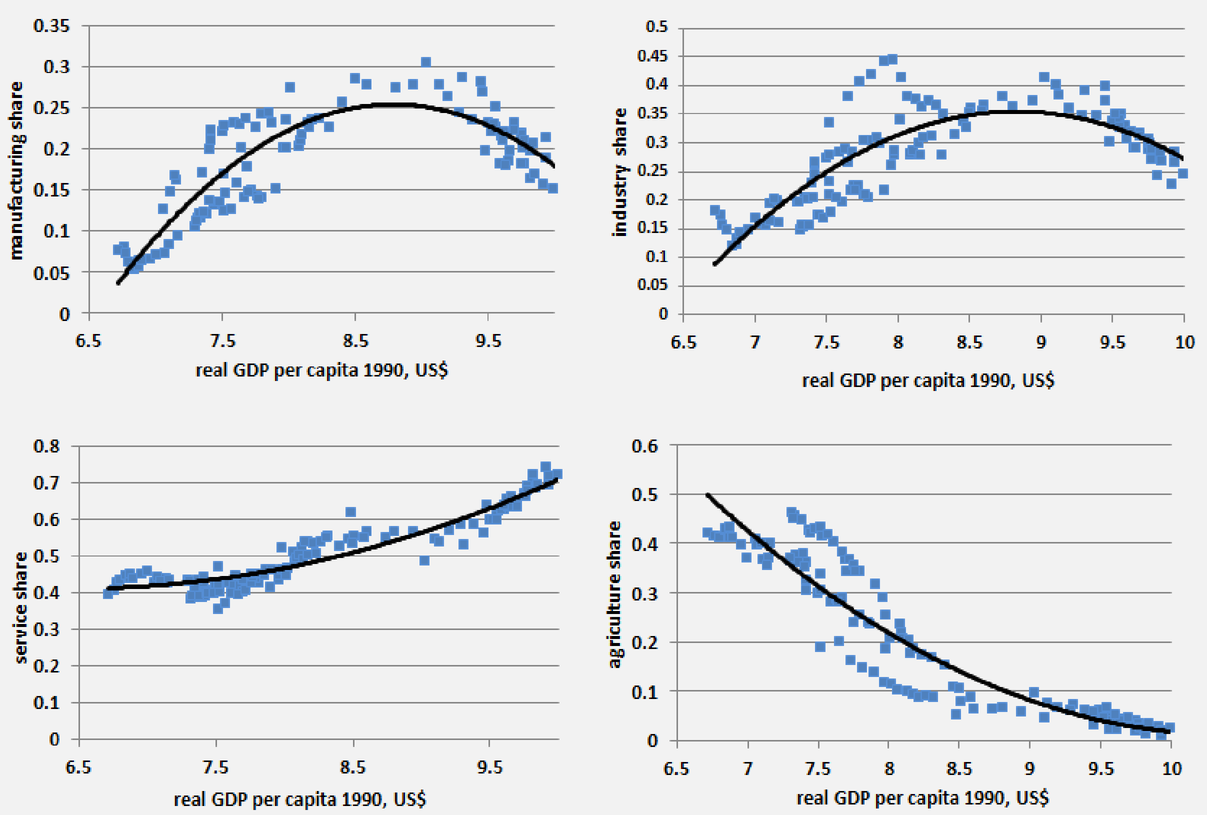
2.1. BROAD TRENDS IN STRUCTURAL CHANGE

Structural change originates from microeconomic changes which affect economic sectors in different ways and with different magnitude. The changes at the microeconomic level are important at the aggregate level, because they are systematic and affect the long-run performance of economies. The result is that some sectors experience higher long-term growth rates than others, leading to shifts in the shares of these industries in the aggregate. This process unfolds over longer periods of time. This chapter looks at the long-run changes between sectors. These changes are best outlined using a simple sectoral disaggregation which breaks down the economic aggregates into three sectors:

1. Agriculture, fishery and forestry;
2. Industry in a broad sense covering manufacturing, mining, construction and public utilities, and
3. Services, covering the different business, personal and public service sectors.

In presenting the broad trends, results are given for the manufacturing sector as a whole, as much discussion of industrial policies focuses on the manufacturing sector. In a subsection of the chapter, services are examined in greater detail, as services have become the dominant sector in terms of employment and production in all advanced economies.

Figure 2.1. Structural change in a historical perspective: Value-added shares for six European countries



Source: WIFO calculations based on data from University of Groningen and EU Klems

The broad trends in structural change are quite similar across countries in the course of their economic development. As economic development gets under way, the share of agriculture in national employment and value added falls, while there is a rapid increase in the share of manufacturing and services. The resource reallocation process associated with structural change shifts economic activities from agriculture to industry and services.

This pattern can be easily identified using historical value-added shares for six European countries (Belgium, Finland, France, Italy, Netherlands, Spain and Sweden) over the 19th and 20th centuries. Unfortunately, information is only available for these six countries. Figure 2.1 plots the current value added shares over the past 150 years. In order to make the patterns comparable across countries, nominal sectoral shares (nominal value added of a sector in proportion to total nominal value added) are plotted against the level of economic development measured as the logarithm of per capita GDP in 1990 dollars (Bolt and van Zanden 2013). The line in the figure is a polynomial prediction that does not take into account country weights. The prediction provides a better perspective of the association of the sectoral value-added shares with economic development (measured in GDP per capita at constant prices).

This historical pattern is quite similar to the pattern identified in the cross section of a large number of countries. Indeed, the historical patterns of structural change would be of much less interest if findings for the broad patterns of structural change were very different for countries that are currently becoming wealthier, in which case information on historical patterns of structural change would not be very useful for policymaking today. Figure 2.2 shows that the patterns are quite similar if a very different dataset is used, which has broader country coverage and comparatively short time coverage. The National

Accounts Dataset collected by the United Nations Statistics Division provides information on value added shares for 164 countries over the period from 1960 to 2010.

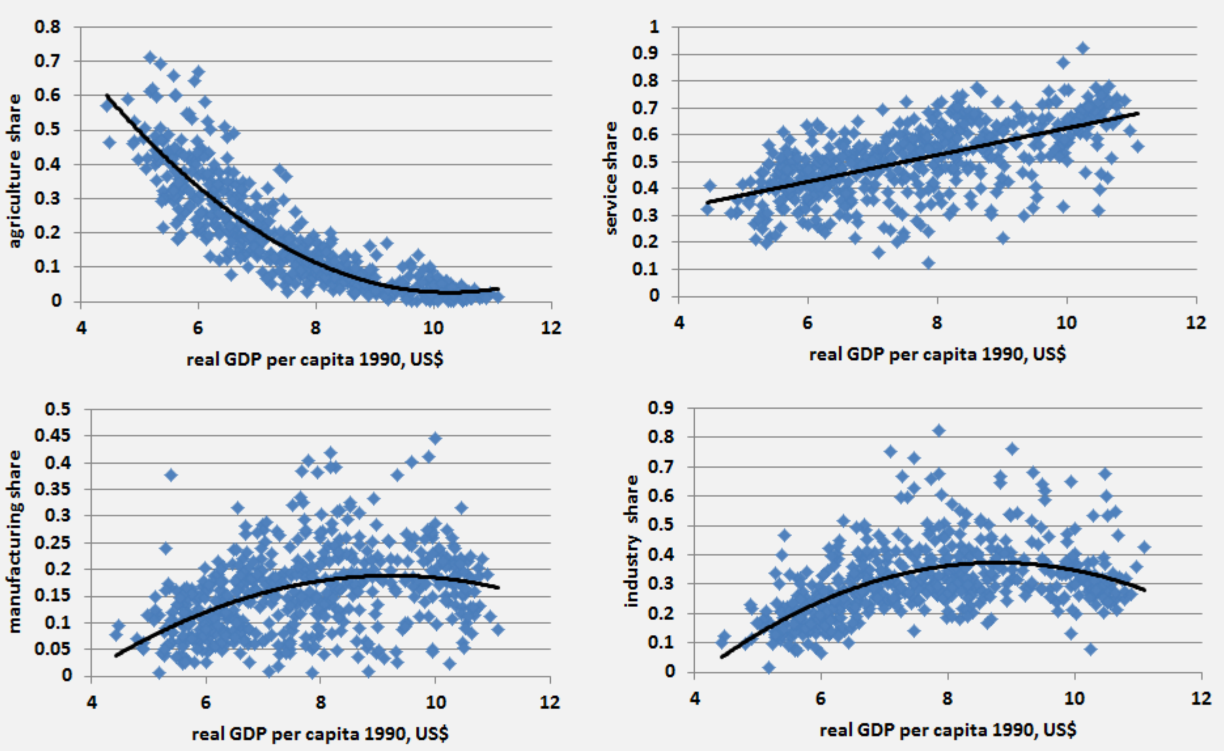
Figure 2.2 plots the current sectoral value added shares against GDP per capita from the UN National Accounts dataset. The sectoral breakdown is again agriculture, manufacturing, industry (manufacturing, mining, utilities and construction) and services. The line in the Figure 2.2 corresponds to a polynomial prediction without country weights. The prediction makes it possible to see the point estimate of the association between sectoral value added shares and economic development (measured in GDP per capita in constant prices) which is independent of individual countries.

Figure 2.2 confirms the basic regularities for structural change found in the historical data. However, the country coverage is much more heterogeneous in terms of sector development. There are countries in the sample that have a share of agriculture of around 80% at very low levels of economic development. A few countries even have service shares as low as 10% of GDP. In addition, there are countries that have very high value added shares in manufacturing and industry. The results for industry are often driven by countries with important natural resources and a high share of mining in GDP, such as oil-producing countries.

A visual inspection of the figures for manufacturing shows that at a value of log real GDP per capita in 2005 of around 9, which corresponds to USD 8,100 in 2005 prices, the manufacturing share begins to decline on average. This is broadly in line with the evidence from the historical time series.

Figure 2.2 reports the results from a more rigorous test using regression analysis. The sector share in nominal value added is regressed on log real GDP per capita (RGDP)[45] using a fixed-effects regression in order to control for unobserved, country-specific factors affecting the composition of country shares. Real per capita GDP of USD 8,100 (in 2005 prices) is used to divide the country-year observations into two sub-samples. For agriculture, it is observed that the negative relationship between the agricultural share and economic development is less strong for the sub-sample covering the country-year observations with a real GDP per capita above US$ 8100. This may be related to the fact that for these countries, the value added share of agriculture is already very small (4% on average) for the more developed economies in the upper sub-sample while it is still substantial (an average of 23%) for the sub-sample covering the poorer countries. For the service sector, an

Figure 2.2. Structural change in the cross section: evidence from value added shares for 164 countries, 1960–2010



Source: WIFO Calculations based on national accounts statistics from the UN.

[45] Whilst Figure 2.2 displays a degree of non-linearity for certain sectors, a linear relationship was modelled to illustrate the direction and strength of the relationships in the two sub-samples.

Table 2.1. Value-added share regressions for cross-section data, UN National Accounts data for 164 countries, 1960–2010

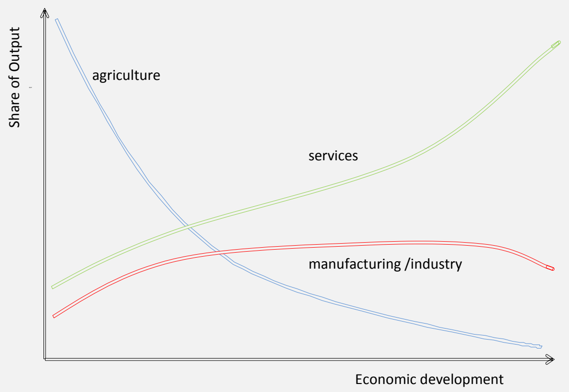
	all observations	y<US$8100 sample	y>=US$8100 sample	all observations	y<US$8100 sample	y>=US$8100 sample
	Agriculture share			**Service share**		
RGDP	–0.0869***	–0.117***	–0.0623***	0.0543***	0.0655***	0.106***
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.007)
Observations	5872	4505	1367	5830	4463	1367
R^2	0.866	0.835	0.758	0.690	0.651	0.691
	Manufacturing share			**Industry share**		
RGDP	0.00816***	0.0257***	–0.0828***	0.0343***	0.0553***	-0.0436***
	(0.001)	(0.001)	(0.003)	(0.002)	(0.002)	(0.006)
Observations	5838	4471	1367	5872	4505	1367
R^2	0.720	0.738	0.821	0.644	0.689	0.723

Source: WIFO Calculations
*Note: Standard errors in parentheses. *** denotes significant estimate.*

acceleration of the service share value-added for the second sub-sample (country-year observations with a real GDP per capita above USD 8100) can be seen. This finding corresponds to the stylised facts reported by Buera and Kaboski (2012a) for historical time series covering a larger set of countries. Different relationships are found for the manufacturing and industry shares in the two sub-samples. There is a positive relationship for the first sub-sample (real GDP per capita below US$ 8100) and a negative relationship for the second sub-sample (real GDP per capita above USD 8100) is observed. The negative relationship between economic development and the manufacturing share in the second sub-sample is stronger than the negative relationship between the industry share and economic development for the same sample. This is partly due to oil-exporting countries which have a high industry share and a high level of real GDP per capita with a low manufacturing share (e.g. Saudi Arabia, Kuwait, United Arab Emirates) and partly due to the fact that utilities and construction – which are also part of the industry share – do not show a very strong association with the level of economic development as services and the manufacturing sector.

It is important to note that these patterns are not restricted to nominal value-added shares but also show up in employment shares. Figure 2.3 shows this process in a stylised way. It shows that economic development has consisted of a gradual shift from agriculture to manufacturing and services, followed by a shift from manufacturing towards the service sector. In other words, when the market economy first emerged, a vast majority of workers were employed in agriculture, which accounted for the largest share of production. The production of goods was limited to handicrafts while market services played even less of a role. Successive industrial revolutions, exemplified by the creation, diffusion and use of new technologies, led to a gradual increase in productivity in both the primary and secondary sectors. The share of income spent on food decreased and employment in the primary sector declined relative to the other sectors. In manufacturing the increase in productivity has led to lower prices. In the course of economic development this has resulted in lower factor demand (demand for labour, for instance) once productivity outstrips the growth in demand for manufactured goods. Over time, the tertiary sector has gained in importance, both in terms of employment and output, as enterprises have demanded support services and consumption patterns have shifted towards services, and productivity gains in manufacturing have become much higher than those in service sectors.

Figure 2.3. Stylised broad patterns of structural change



Source: WIFO

2.2. PRODUCTIVITY IMPROVEMENTS AND CHANGES IN DEMAND AS DRIVERS OF STRUCTURAL CHANGE

The need to understand the mutual interdependency between economic growth and structural change requires analyses that enrich the general one-sector macroeconomic perspective with multi-sectoral perspectives, in order to understand the main economic mechanisms that drive broad patterns of structural change.

There are two central, possibly complementary, explanations of the observed patterns of structural change in the literature. The first explanation relates to differential patterns of technical change between different industries. The second explanation relates to the different income elasticity of demand between products of different sectors. From a conceptual standpoint, the potential significance of these mechanisms in explaining the broad trends of structural change has long been recognized. For instance, a pioneer in the theory of structural change, Fourastié (1949), explained economic development based on the combination of differential productivity growth rates across agriculture, industry and services, and the differential income elasticity of demand. Technological progress was the main driving mechanism behind structural change in his theory, while the income elasticity of demand provides something like a sorting mechanism that gave new weights to the sectors. Fourastié maintained that in the long run, the sorting mechanism of demand dominates supply-side forces in shaping the economic structure of countries. As income rises, the demand for primary products will become saturated first, followed by the growth of demand for manufactured goods, which become eventually saturated, and an increase in demand for products in the tertiary sectors take place. Fourastié's vision of the three-sector hypothesis is one of the most elaborate theories of structural change, but his explanation of why products from industry can become saturated neglects the role of intermediate inputs from industry that are used in all sectors of the economy. A decline in the demand for consumer goods in manufacturing does not necessarily imply a declining share of the secondary sector in total value added.

Other economists held such views at the time. For example Kaldor (1981, 1996) argued that expanding domestic and international markets engendered a process of cumulative causation in which manufacturing growth played a central role as many growth-enhancing learning activities such as R&D and the mechanisation of activities are closely related to manufacturing. This allows a higher rate of productivity growth in the manufacturing sector. Today manufacturing is an important sector, but it is also recognised that manufacturing industries are heterogeneous, and that there are important production and demand linkages which play a significant role in the process of economic development. More recently, the theoretical literature has examined the conditions under which the two determinants of different productivity growth (e.g. Ngai and Pissarides 2007) and differential income elasticities of demand (e.g. Echevarria 1997, Kongesamut et al. 2001) can lead to an aggregate balanced growth path. Herrendorf et al. (2013) claim that the conditions under which these theories can simultaneously generate balanced growth and structural change are rather strict. Theories of balanced growth, which constitute the workhorse of growth theory, may not provide the right analytical tools to explain the broad set of empirical regularities of structural change.

2.2.1. Interaction of supply and demand factors

Pasinetti (1981, 1993) emphasised the importance of the interaction of supply and demand side influences in determining the outcome of the process of structural change. Pasinetti stresses the influence of income elasticity on the pattern of demand – Engel's law[46] – and technological progress as the main drivers of structural change and long-term economic growth. Hölzl and Reinstaller (2007) identify two mechanisms linking the inter-industry and intra-industry dynamics: sorting and selection. Sorting is based on the idea that the industrial composition of demand varies with income growth. This captures the observation that the consumption of agricultural products rises proportionally less than aggregate income. Consumer preferences and the demand derived by other firms for intermediate goods have an impact on the relative growth patterns of sectors within an economy. Selection in turn reflects price competition within and between sectors: firms or sectors able to produce the best value for money will be able to increase their demand and grow faster.

Pure demand-side explanations of structural change emphasise that changes in consumption associated with income effects are a central driving force behind the process of structural change. Rising income leads to demand shifts from necessities towards manufactured goods and then towards services (e.g. Echevarria 1997, Kongsamut et al. 2001). However, pure demand-side explanations do not take into account the observed persistent differences in technical change and productivity across sectors. Baumol's (1967) theory of imbalanced economic growth is perhaps the most important supply-side explanation for why the tertiary sector will gain in importance over time. Baumol divides the economy

[46] Strictly speaking, Engel's law refers to the low income elasticity of food but in the literature on structural change Engel's law is used to refer to structural change driven by nonlinear income effects that affect demand for all types of goods (e.g. Pasinetti 1981, 1993, or Iscan 2010).

into two types of activities: '*technologically progressive activities in which innovations, capital accumulation, and economies of large scale all make for a cumulative rise in output per man hour and activities which, by their very nature, permit only sporadic increases in productivity*' (Baumol 1967, p. 415-416). Baumol contends that productivity growth in progressive activities drives wage growth in the economy as a whole, causing relative costs in non-progressive activities to rise. This leads to a fall in the relative weight of the non-progressive sectors or, if the relative outputs are maintained, to a slowing of the aggregate growth rate, as an increasing proportion of resources must be channelled into these activities.

Little is known about the relative importance of these two mechanisms in the process of structural change and economic development from the empirical perspective. Part of the difficulty in understanding the relative importance of the supply-side and demand-side drivers of aggregate growth is the paucity of data on the services sector. There are still significant measurement issues with service sector output, value added and productivity growth. It is also very difficult to establish the importance of preference parameters governing the income elasticity of demand for services in a rigorous way.

A closer look at the empirical broad patterns of structural change reveals that both processes are relevant. The gradual shift in value added and employment shares from agricultural to manufacturing and onwards to the services sector seems to be mainly due to changes in market demand. However, this account of the shift of demand also needs to take into account big productivity improvements in agriculture over the past decades. Thus the mechanics of Engel's law –that as income rises, the proportion of income spent on a good falls, even if actual expenditure on it rises – needs to be complemented by an account of productivity improvements. Up to now, there is no clear evidence as to whether technological progress or changes in demand is the driver of structural change. Baumol et al. (1989) and more recently Nordhaus (2008) provide empirical evidence favouring the technological explanation. In contrast, Dietrich and Krüger (2010) find empirical evidence for the demand story for the rise of the service sector in Germany. Additionally, results by Curtis and Murthy (1998), Rowthorn and Ramaswamy (1999) and Peneder et al. (2003) suggest that the income elasticity is greater than unity for most service branches as well as for aggregate services, and below unity for manufacturing branches.

Table 2.2. Dynamics in value added shares 1975 to 2005 between EU-15 Member States and the US

	Agriculture	Industry	Services
EU-15 avg. value added share 2005	2.3	26.2	71.5
US avg. value added share 2005	1.8	23.8	74.4
EU-15 change in share 1975-2005	–5.3	–11.1	16.5
US change in share 1975-2005	–3.7	–7.8	11.5
EU-15 change in inequality 1975-2005	1.6	1.9	–1
US change in inequality 1975-2005	–5.6	2.1	–1.4

Source: WIFO calculations, EUKLEMS for the EU-15, Bureau of Economic Analysis (BEA) for US states.
Note: Differences in the industry classifications limit the comparability of the data across regions (EU-15 and US). For European data NACE 1 is used, while US data follow the NACIS classification. The change in shares between 1975 and 2005 refers to the difference in the value added shares between the two periods. Inequality is measured using the Gini coefficient within the broad regions (US, EU-15).

Productivity and growth decompositions generally lead to a view that structural components appear to be largely dominated by the intra-industry and intra-firm effects of productivity growth (Isaksson 2009). The empirical literature confirms that the broad patterns of structural change are driven by both demand-side and supply-side dynamics. It confirms that structural change can generate both positive and negative contributions to aggregate productivity growth. If structural change reallocates resources towards sectors with higher potential of productivity growth, structural change is growth-enhancing, and if structural change shifts resources and employment towards sectors with below-average productivity gains, structural change may be growth-reducing. In many cases the effects of structural change net out, and structural change on average appears to have only a weak impact on aggregate growth over short time periods. Hence, if certain types of industries achieve higher rates of productivity growth and expansion in output than others, structural change in favour of specific industries might still be conducive to economic growth. However, this might not be seen at the aggregate level. The comparison between patterns of structural change in the EU-15 and in the US shown in Box 2.1 confirms that structural change has been quite similar. Both have experienced a dramatic growth in the value added share of services across all constituent EU countries and US states, and this shift towards services has been associated with a relative decline in industry and agriculture.

Box 2.1. A comparison between patterns of structural change in EU-15 Member States and US states

The fact that the majority of industrialized economies experienced a shift from manufacturing to services in recent decades illustrates the similarity in the change in contributions of agriculture, manufacturing and service sectors to total value added in the US and the EU. Between 1975 and 2005, the shares of services saw double-digit increases in both the US and the EU-15. The increase of the services sector has taken place largely at the expense of industry (mining, utilities, construction and manufacturing). On average across the US states, the share of services has increased by 11.5 percentage points. This shift has been even more pronounced in the EU, where the share of services increased by 16.5 points to 71.5 % in 2005. During this time, some member states (notably Greece, Spain and Portugal) experienced a substantial catch-up. The share of industry in the EU fell by 11.1 percentage points on average. The decline has been slightly less (7.8 percentage points) in the US states. The comparatively small shares of agriculture decreased further, more so in the EU than in the US.

One important question is whether structural change leads economies to become more similar over time or magnifies regional and interregional disparities in the composition of aggregate output. This question is important for several reasons. The tradability of agricultural and manufacturing commodities coupled with positive agglomeration effects in their production foster regional specialisation, yet there are limits to specialisation in the production of some services, which may not be tradable. Increasing structural disparities between the regions together with stark differences in productivity developments across the three sectors have the potential to reduce or increase income inequality within the regions. Economic policies aimed at attaining or maintaining a certain composition of output also need to take into account regional inequalities and the underlying specialisation trends.

To answer this question in a simplified way, the inequality of the shares of agriculture, manufacturing and services between the 15 EU Member States and the 50 US states relative to their aggregate economies (US and EU-15) is considered. The preferred measure of structural cohesion is the difference between the values of the ubiquitous Gini coefficient of inequality, calculated across the member states and federal states of both regions for the years 1975 and 2005 (Table 2.2).

Negative differences mean that regional (country/state) differences have decreased. This is the case for the share of services, as the nationwide rise in the contribution of services has been due in part to their low tradability and local character. On the contrary, as expected, disparities in the structure of manufacturing have increased.

An apparent difference between the 15 Member States and 50 US states lies in the evolution of the inequality in the contribution of agriculture. Regional inequality has increased in the EU-15, while it has decreased in the US. This may be related to the fact that the US has had a common agricultural market since its early days, with regional differences and specialisation in agriculture taking place long before 1975. In the EU this process started around this time. This may explain why differences appear to have decreased in the US, while they have increased in the EU. Interestingly, quite similar patterns in inequality are observed for the industry and services sectors for the US states and the EU-15. Industry shares have become more unequal across Member States and US states, and services shares (almost by nature) have become more similar across the two regions.

2.3. The expansion of the Services Sector

The analysis of broad changes has revealed that the biggest shift experienced by industrialised countries over the past decade has been the reallocation of resources and employment linked to the growth in services. All highly industrialised countries have become service economies, in terms of the share of value-added generated in the services sector and when employment shares are considered. This structural change is uneven as it has not affected all services in the same way. In fact, the rise of the services sector taken as a whole has mainly been due to the expansion of business services and some non-market services.

For a long time, the shift towards services was seen as growth-reducing structural change. The rates of productivity growth in manufacturing and services are very different and can to some extent explain the large-scale labour reallocation in favour of the services sector. However, more recent economic research clearly shows that many knowledge-intensive services are important factors in economic growth. For example, Pugno (2006) emphasises the importance of education and human capital formation for economic growth.

Buera and Kaboski (2012b) emphasise the skill intensity of many service sectors and propose a theory of the rise of the service economy based on an increasing importance of specialised highly-skilled labour at high levels of productivity. Thus the rise of the service economy is a growth in the range of services that are market-produced relative to those that are home-produced. Buera and Kaboski (2012b) provide an explanation of the rising level of skills and "skill premium" that goes in hand with the rising relative level of prices for services, which is associated with changes in demand towards knowledge-intensive services in the process of economic development. In particular, the application of modern information and communication technology to the production of services has changed the perception of services as low productivity and low skill sectors of the economy. Eichengreen and Gupta (2013) and Jorgenson and Timmer (2011) show that more traditional services like lodging, housecleaning, distribution, education and healthcare are increasingly complemented by modern services such as banking, insurance, communication and business services.

Figure 2.4 provides evidence on the heterogeneity of services sector expansion in the most advanced economies, including most EU Member States. In these figures EUKLEMS data are used and four different types of services are distinguished:

- Distribution
- Personal services
- Business services
- Non-market services (education, health and government services)

Figure 2.4 reports both the value-added and the hours-worked shares. While the share in hours worked is almost constant, the value share of distribution decreases with economic development. The expansion of business services is more dynamic in terms of valued added shares than for hours-worked shares. However, the opposite seems to be true for non-market services. This shows that the expansion of the service share is mainly driven by the expansion of two quite different service subsectors: business services and non-market services. While the pattern of expansion of non-market services – government services, health and education to name the most important – could be explained by a supply-side 'cost disease' argument, the same argument does not apply for the expansion of business services, because for many countries the increase in economic weight is more substantial in terms of value added than hours worked.

This evidence shows that services are heterogeneous and is compatible with the argument provided by Peneder et al. (2001) and Buera and Kaboski (2012b), indicating that the rise of the service economy has primarily been driven by the growth of knowledge-based services.

Even if the shift in structure towards services has reached unprecedented proportions, the understanding of the factors accounting for the shift to services is still partially contested. This is related to a number of issues. Different mechanisms have been proposed to explain the shift of economic activities towards services. The thesis of marketization or de-marketisation of home production proposed by Buera and Kaboski (2012a) is one that combines the differential development of technology with a mechanism of a shift in demand.

Schettkatt and Yocarini (2006) emphasise the importance of demand-side explanations. They argue that shifts in demand associated with income effects have been the driving force of the expansion of services employment in past decades. However, the different productivity developments between services and manufacturing are also important. Price trends in some services support this view (e.g. Schettkat and Yocarini 2006): prices of services generally rise more than prices for manufactured output. However, as emphasised by Peneder (2001) some services sectors are obviously technologically progressive. Jorgenson and Timmer (2012) clearly show that price and productivity developments in distribution sectors are very different from other service sectors.

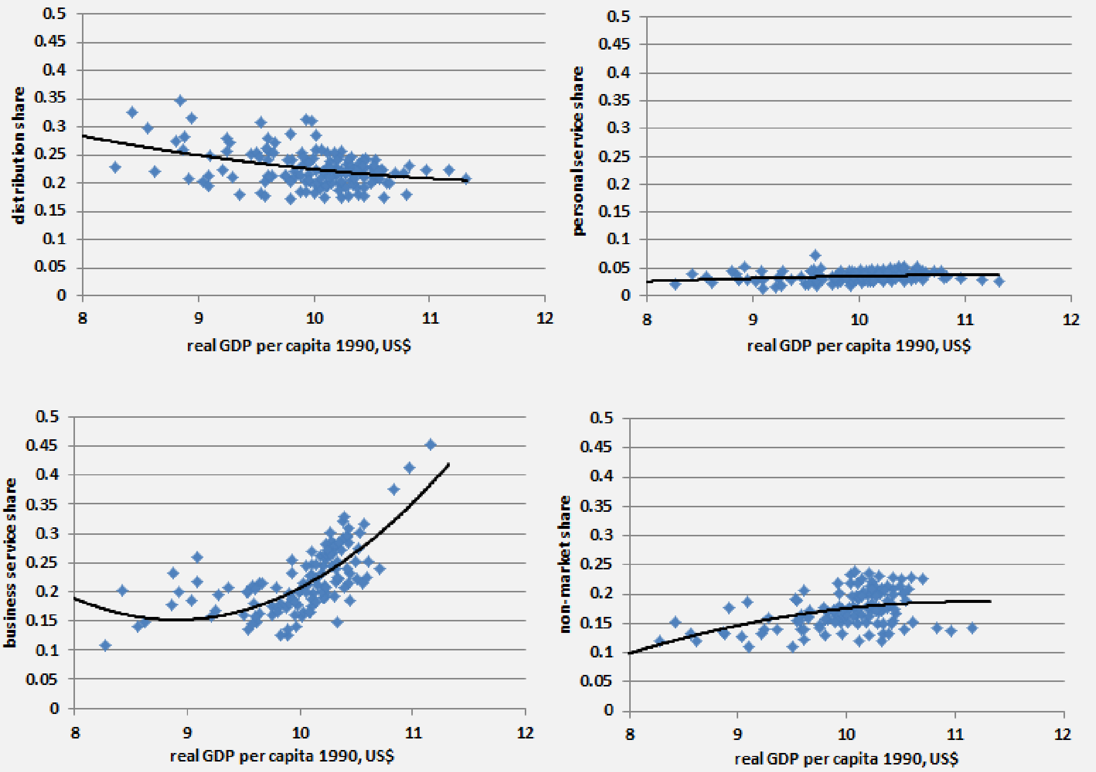
Table 2.3 gives an indication by using the relative price development of sectoral prices compared to the GDP deflator as a measure of sectoral price developments. Values below 1 indicate that price developments were below the aggregate price development (GDP deflator). Conversely, a value above 1 indicates that prices rose faster than average. The table displays average values for the EU-27 Member States and the associated standard deviations. Across Member States, agriculture and manufacturing have had a below-average price development. The price development in distribution was on average approximately the same as for aggregate prices. For personal services, business services and non-market services, an above-average price development is observed. These price trends are consistent with the view of differential productivity developments across services and manufacturing and higher productivity dynamics in manufacturing.[47] The associated standard deviations show that these differences are statistically significant. Nevertheless, it is also important to note that these price series are themselves subject to a considerable composition bias, as it is very unlikely that the structure of these quite aggregate sectors remained identical over time.[48]

47 Price developments of manufacturing products would be further below the aggregate price development if they were corrected for increases in the quality of finished products (see Cummins and Violante (2002).

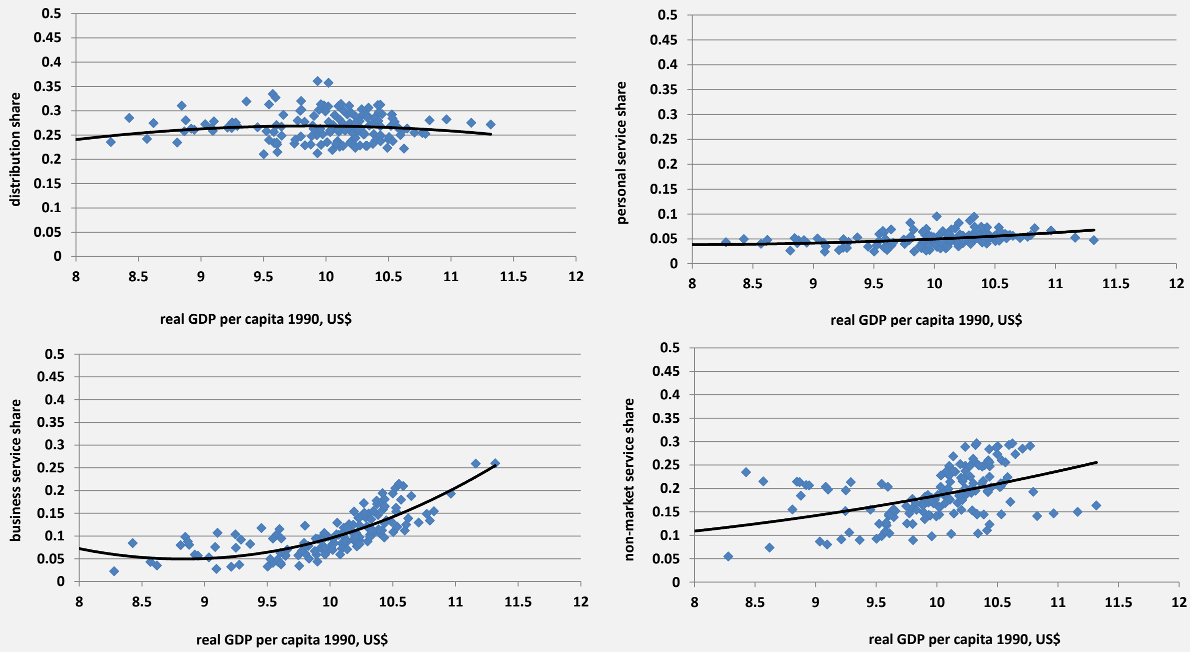
48 This remark is important for the comparison of real shares over time. Structural change is a process that changes the weights of economic activities in the aggregate. Moreover, structural change is driven by differences in demand and productivity that react to or determine prices. Therefore these data not only identify a price effect but also a quantity effect associated with the changing weights of economic activities.

Figure 2.4. Service shares and economic development

(a) Value added shares



(b) Shares in hours worked



Source: WIFO calculations, EUKLEMS

Box 2.2. Household production and structural change

It has been widely recognised that income and wealth generated by household production could introduce a bias in the measurement of the economic structure. Kuznets (1944) and Clark (1958) already indicated that the neglect of home production leads to a significant underestimation of national income in general and the contribution of agriculture, construction, and services to national income in particular. These missing activities contribute to economic welfare and can be 'marketised' to different degrees across countries, thereby affecting the measurement of sector shares, since only market services are taken into account in the official statistics.

Hill (1977) defined household production as economically productive households or do-it-yourself activities that can be provided through the market by choice. Home-produced and market-produced services are gross substitutes. Cooking and cleaning are productive activities because the market *can* provide them, whereas eating and sleeping are non-productive activities because the market cannot provide them. Unfortunately, no systematic data are available which would allow differences in structural change to be quantified across EU Member States. The results for the US suggest that incorporating the value of non-market home production increases the level of nominal GDP. Bridgman et al. (2012) estimate that in 1965 household production increased GDP by 39%, and by 26% in 2010. The relative decline in home production is almost solely due to the reduction of hours spent in home production by women. Their contribution declined from 40 to 26 hours during this period, whereas the number of hours spent by men increased from 14 to 17 hours. Thus the allocation of hours between market and home production can also be considered in the context of structural change. Yet Freeman and Schettkat (2005) and Rogerson (2008) suggest that it is not a driver of structural change but part of the increase in leisure deriving from the reallocation of labour from home production to the market production of services.

It is also important to take into account the impact of technical change on home production. A good example is the contribution of the mechanisation of home production, namely the growth of the manufacturing of household appliances. The spread of washing machines, dryers, vacuum cleaners, microwaves, and other home appliances was accompanied by declines in domestic servants, laundries and drycleaners. Buera and Kaboski (2012a) emphasise that innovations which change the scale economies of productive activities are an important determinant of the boundaries between home and market production of goods and services over time. They argue that scale economies are a driving force in the process of marketisation of services, but that this process can also be reversed if technological change and mechanisation lowers the cost of producing services and scale economies, as households value the flexibility of home production. Their result suggests that the spread of manufactured goods into the home leads to a 'demarketisation' of services and a growth of manufacturing relative to services. Technical change that leads to an increase in the economies of scale of services will lead to the marketisation and relative growth of the service sector. However, it is important to note that the empirical verdict on the importance of the thesis of the marketization and demarketisation of home production for structural change is still not settled.

It should also be noted that the de-marketization of certain activities, because they can be done at home at a low cost in terms of time, can potentially increase labour supply and reinforce the tertiarization of the economy because services are labour-intensive.

2.3.1. Interaction of manufacturing and services

Another important explanation that has been brought forward is the hypothesis of the inter-industry division of labour. It is sometimes claimed that outsourcing jobs from manufacturing to services is a primary driver of the rise of service sectors (see Schettkatt and Yocarini (2006) for a discussion). However, most of the studies using input-output analysis come to the conclusion that outsourcing from manufacturing to services took place at a very modest rate[49]. According to Gregory and Russo (2004), the rise of business services is largely explained by outsourcing from other service sectors. This shows that the trend towards an increasing services share cannot be understood without considering changes at the microeconomic level. The interaction between manufacturing and services has become more complex. Services and manufactured goods are used as intermediary inputs to produce a larger number of final products (goods and services).

The increasing contribution of the service industry at the expense of manufacturing can in part be explained by an increasing service content of manufacturing final output, reflecting the total value of the services

[49] The methodological limitations of using input-output analysis to examine the outsourcing process are discussed in Montesor and Vitucci (2007).

Table 2.3. Relative price developments at the sector level, 1995–2007

	Average	Standard deviation
Agriculture	0.77	0.18
Manufacturing	0.82	0.13
Construction	1.22	0.20
Distribution	0.97	0.09
Personal services	1.17	0.16
Business services	1.13	0.13
Non-market services	1.18	0.16

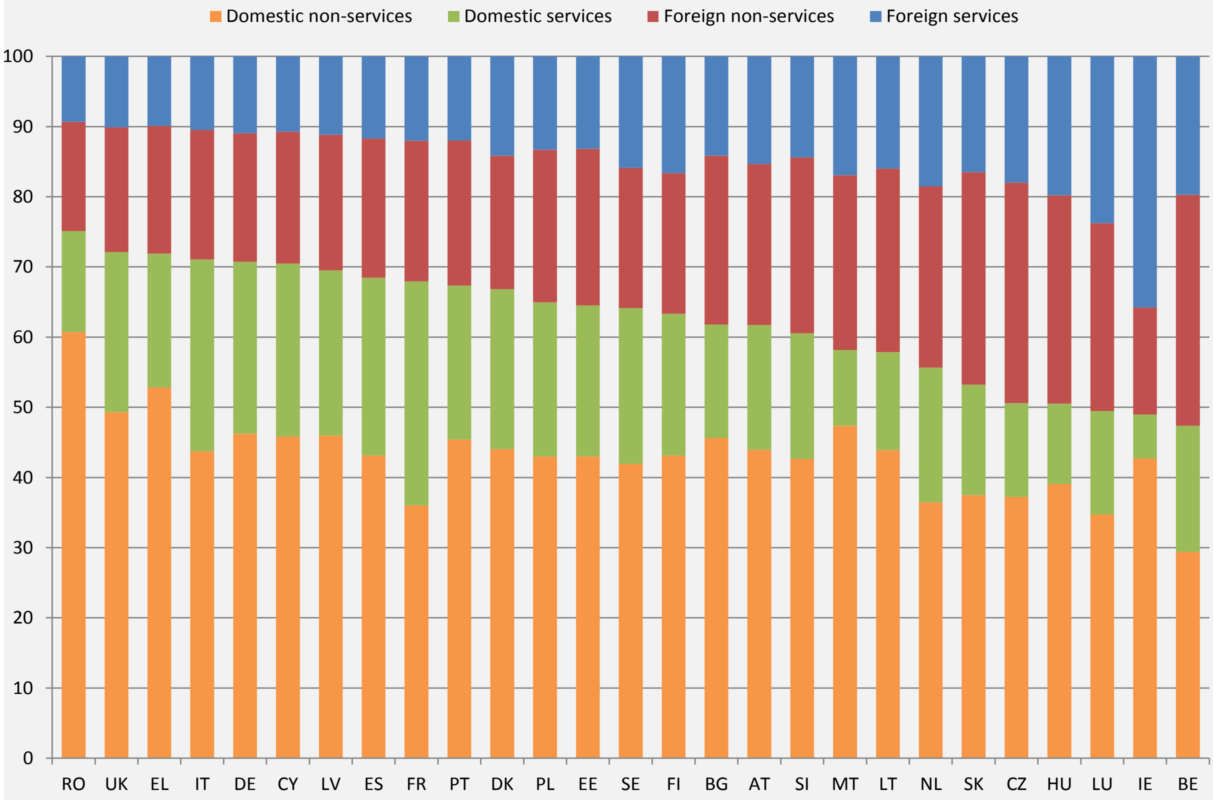
Source: EUKLEMS

required for the development, production and marketing of a modern manufacturing product. The service content of manufacturing has been growing in the EU and elsewhere in the world. In 2011, the share of value added embodied in manufacturing final output that was created in the service industry ranged from approximately 40% in Belgium, Ireland and Luxembourg to below 30% in Romania and Greece (see Figure 2.6). This means that more than a third of the value of a European manufacturing product that is sold to final users is created in the services sector. Whereas manufacturing products are also used for producing services, the manufacturing content of services is about three times smaller than the service content of manufacturing and has increased much less over time.

These results explain that there is a high degree of complementarity between manufacturing goods and services, but that this complementarity is biased towards the increasing importance of services as inputs to manufacturing. Services such as maintenance and training are very important elements in the delivery of complex manufactured products. At the same time the importance of specialised services such as financial intermediation, communications, insurance and knowledge-intensive business services (KIBS) are becoming important inputs in the production of sophisticated manufacturing output. This process is one of several explanations for the increasing contribution of services to the overall output of an economy. Figure 2.5 shows the shares of intermediate services used in modern manufacturing In general, for smaller economies more of the value added in manufacturing production is located abroad. The relocation of business processes from one country to another also affects the structure of an economy and its services share. However, the degree of offshoring and outsourcing is dependent on the particular industry and activity.

In the discussion of the rise of services, two issues have so far been neglected. The first issue relates to the quality of data on services. There are still measurement issues associated with services sector

Figure 2.5. Value added decomposition for manufacturing production in per cent, 2011



Note: Countries are ranked according to their domestic value added share (i.e. Domestic non-services + domestic services)

Source: WIOD, wiiw calculations

output, value added and productivity.[50] Griliches (1992), for example, documented that services sectors with hard-to-measure outputs, such as health services, experienced the largest labour productivity slowdown after 1973. In many services there are conceptual and empirical problems in measuring output and prices.

Therefore, there are still substantial differences in the measurement of productivity in manufacturing and in services, and thus major limits in the comparability of its growth rates across these sectors. These problems primarily affect the value added shares in GDP and the identification of productivity developments, while employment shares are unaffected by these issues. However, the importance of human capital and education for economic growth in developed economies (e.g. Lucas 1988, Pugno 2006) leaves an additional question mark concerning the usefulness of comparing sectoral productivity differences. If human capital is essential for economic growth and the educational sector provides most of the human capital used in the form of capabilities in the manufacturing and services sectors to develop new products and to improve productivity, then the reallocation of resources to a low-productivity activity such as education may be the reason why productivity improves in other sectors of the economy. Pugno (2006) explicitly takes this situation into account, concluding that not only can the expansion of business services support long-term economic growth but also the expansion of some non-market activities such as education. In this case the productivity and quality of the educational system are of primary importance. The productivity of the education system needs to be measured in terms of its quality in providing the right competences and capabilities.

2.4. Heterogeneity of structural change in Europe

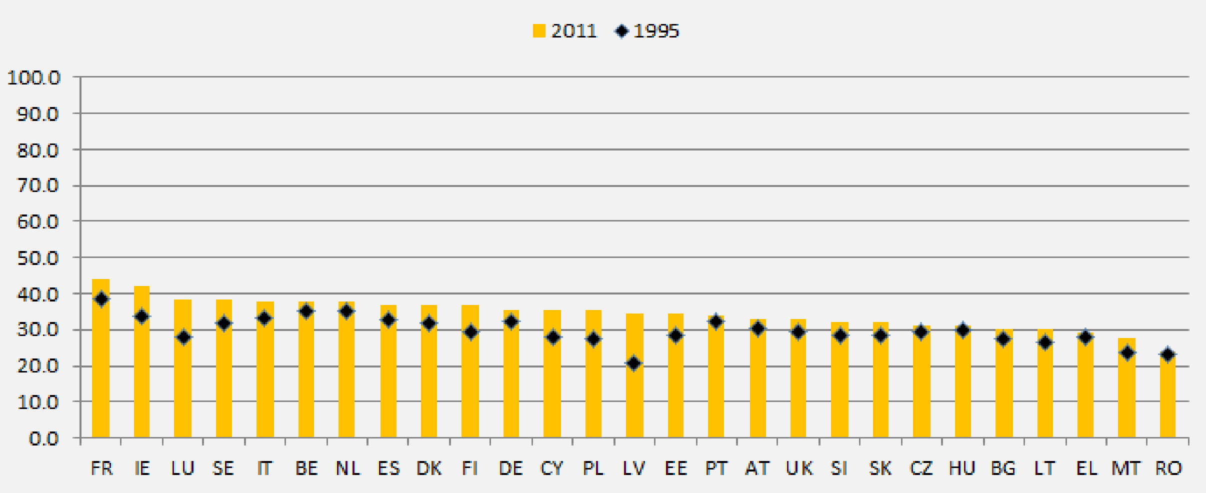
The discussion so far has shown that broad trends in structural change are quite homogeneous across countries.

Table 2.4 summarises developments between 1995 and 2011 for the EU-27 countries. There has been a decline in most production sectors, both in terms of employment shares and nominal value-added shares. The biggest reductions are for agriculture and the manufacturing sector. In the period 2005 to 2011, construction also shows a negative trend for employment as well as value- added shares, reflecting its sensitivity to aggregate downturns (cf. Hölzl et al. 2011). These declines have been offset primarily through the expansion in business services and non-market services. Overall, these results are consistent with a view suggesting that labour productivity growth has been especially strong in agriculture, manufacturing, distribution, mining and utilities.

Of greater interest is the development in the dispersion within the EU-27.

Table 2.4 provides descriptive statistics of this dispersion, in terms of Gini indices. The Gini index is a widely used measure of relative inequality. The coefficient takes values between zero and one, or, as in Table 2.4, between 0 and 100 on the percentile scale. A value of 0 corresponds to total equality. This would be the case if all sectors had equal shares. The higher the value of the Gini coefficient, the more unequal the distribution. A value of 100 expresses maximum inequality, for example if all countries had

Figure 2.6. Share of services inputs in embodied in manufacturing output (%)



Note: Services sectors are NACE Rev. 1 50 to 95.
Source: WIOD, wiiw calculations

[50] There is a literature on problems with measuring productivity in services. One of the best overviews on measurement problems in the services sector in general is provided by Triplett and Bosworth (2004). Diewert, Fixler and Zieschang (2012) cover banking services and Diewert (2011) cover public services.

different sectors. The formula for computing the Gini coefficient is:

$$G = \frac{2\sum_{i=1}^{n} i y_i}{n\sum_{i=1}^{n} y_i} - \frac{n+1}{n},$$

where y_i are the sector shares sorted in an ascending order and n the number of sectors.

Table 2.4 shows that the disparity is highest for agriculture and for mining and utilities. The lowest inequality ratings are for construction, distribution and non-market services for the employment share, and for distribution, non-market services and business services for the value-added share. The changes in inequality show that most services sectors experienced a reduction in inequality during the longer period 1995 to 2005. For the shorter time horizon inequality increased for personal services, probably due to a transitory divergence in the consumption of personal services across countries. However, for manufacturing we observe a rising disparity across the EU-27, for both the employment and value-added shares.

Table 2.5 displays the heterogeneity of structural change for the EU-15 over the longer time period between 1975 and 2005 using EU KLEMS data. The results confirm the earlier picture of the EU-15 experiencing a reduction in disparity of services shares, along with an increase in disparity for the production sectors, especially manufacturing both in terms of employment and the value added share.

Overall these results suggest that there was considerable heterogeneity in economic development. The trends of structural change are quite similar across countries, but we observe some divergent developments, especially for the manufacturing sector. The similarity in broad trends of economic development is also compatible with important heterogeneity at the country level. Further analysis for the EU Member States shows that common trends in structural change are able to explain a large part of the development of employment and value-added shares over time, but also that idiosyncratic and contrasting elements are important in determining the development of sectoral shares across countries.

The same patterns of structural change emerge from a more detailed look at structural adjustments in the EU-12[51] economies during the transformation from a planned economy to a market economy, and then during the process of integration into the Single Market (see Box 2.3). The broad trend of a decrease in production activities, especially manufacturing and agriculture, and an increase in services sectors was quite uniform across these countries. However, at the level of individual countries important differences can be observed.

2.5. INTERNATIONAL TRADE AND SPECIALISATION AS DRIVERS OF DIFFERENCES IN THE ECONOMIC STRUCTURE

What explains these differences in economic structure across countries? The differences for the manufacturing sector are the most interesting, showing a polarisation process with an increasing disparity across Member States. One important factor is international trade. Openness and international specialisation patterns clearly have an impact on observed structural change. Connolly and Yi (2008) claim that up to 30% of South Korea's catch-up between 1962 and 1995 can be traced to its openness. Matsuyama (2009) and Yi and Zhang (2010) show that differences in the structure of economies can be related to differences in international trade, specialisation, and differences in economic development, which is partly path-dependent.

Two important drivers of specialisation and structural change are innovation, i.e. the creation of new varieties of products, and the selection of new products through the process of market competition or changes in demand that affect the economic weight of products and may even lead to the replacement of products. The replacement mechanism is very important as it captures the key mechanism behind Schumpeter's vision of economic development driven by the process of "creative destruction". This perspective of qualitative change is closely related to a view of economic development as a process of structural change, where resources are continuously reallocated from activities with low productivity to activities with higher productivity.

This view has been emphasised in a series of contributions by Hidalgo et al. (2007), Hidalgo and Hausmann (2009) and Felipe et al. (2012) – see also Reinstaller et al. (2012) – which linked the process of economic development of a country to the idea of changes in the space of its exported products. In such a perspective, the overall complexity and sophistication of a country's productive structure is the key indicator to explain its economic development.

Different abilities to accumulate capabilities to produce new improved products can explain differences in their performance. This literature provides a novel way to study the differences in structural change across countries.[52]

[51] Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia.

[52] Some recent contributions argue that the hump-shaped pattern of development observed for the shares in value added of the manufacturing sector over time can only be explained by taking an open economy perspective and in the context of

Table 2.4. Dynamics and heterogeneity of structural change in the EU-27, 1995–2011

	Employment shares					
	Share 2011	Change 1995–2005	Change 2005–2011	Inequality 2011	Change 1995–2005	Change 2005–2011
Agriculture	5.8	–2.6	-0.6	39.6	2.9	1.1
Mining and Utilities	1.3	–0.5	0.0	31.8	–2.1	–0.2
Manufacturing	15.3	–3.2	–1.9	16.6	4.0	1.4
Construction	7.1	0.8	–0.7	9.6	2.2	–5.0
Distribution	26.6	1.1	0.5	7.5	–0.3	1.5
Personal Services	6.1	0.5	0.3	18.3	–0.9	1.1
Business Service	14.6	3.0	1.7	18.9	–1.8	–1.4
Non-market Services	23.1	1.0	0.7	10.1	–1.5	–0.6
	Value added shares					
	Share 2011	Change 1995-2005	Change 2005-2011	Inequality 2011	Change 1995-2005	Change 2005-2011
Agriculture	2.7	–2.2	–0.1	30.3	–1.5	0.9
Mining and Utilities	3.7	–0.5	0.5	26	2.4	1.7
Manufacturing	16.8	–3.0	–0.8	18.2	5.2	1.7
Construction	5.6	0.6	–0.9	14.4	2.8	1.1
Distribution	23.3	0.9	–1.1	8.9	2.0	–1.1
Personal Services	4.3	0.4	0.4	20	–0.1	8.1
Business Service	25.3	3.3	1.3	11.7	–0.3	–1.4
Non-market Services	18.3	0.6	0.6	10.3	1.2	0.5

Source: WIFO calculations, Eurostat, National Accounts.
Note: unweighted averages; inequality is measured using the Gini Index across countries.

Table 2.5. Heterogeneity of structural change in the EU-15, 1975–2005

	Employment share		Value added share	
	Inequality 2005	Change in inequality 1975-2005	Inequality 2005	Change in inequality 1975-2005
Agriculture	38.5	1.8	29.4	–0.6
Mining and Utilities	32.0	9.2	24.3	1.0
Manufacturing	15.2	7.6	16.5	7.8
Construction	14.6	7.0	13.3	5.4
Distribution Services	6.0	1.7	10.0	3.9
Personal Services	17.2	–2.3	11.9	–3.1
Business Services	20.3	–2.4	13.1	–2.7
Non-Market Services	10.7	–5.8	9.8	–3.5

Source: WIFO calculations, EU KLEMS

Box 2.3. Structural change in the EU-12 during transformation and integration into the Common Market

In general, the Member States which joined the EU in 2004 and 2007 had oversized and inefficient industrial sectors. At the start of the transformation process, the high degree of industrialisation was a drawback. It implied, among other problems, the underdevelopment of important services sectors. Due to comparative disadvantage, industry in all the former communist countries suffered disproportionately from the 'transformational' recession in the early 1990s. The relative decline of industry went hand in hand with a rapid expansion of services sectors. By 2011, only the Czech Republic and Romania had a manufacturing sector with a share in GDP of more than 20% – about the same as in two of the more industrialised older Member States: Germany and Ireland. In Hungary, Poland, Romania, and the Baltic states, manufacturing industry managed to retain at least part of its previous position, thanks largely to active restructuring and privatisation efforts, fostered in particular by FDI inflows. At the beginning of the 2010s, the shares of manufacturing to GDP in the majority of EU-12 Member States were higher than in EU-15 economies. However, this is in line with many developing economies.

The changes in employment shares in the EU-12 countries were even more dramatic during the last two decades. Employment declined more than output and millions of jobs were lost during the transition from central planning to market economies. Nevertheless, the manufacturing sector remains an important job provider, with the highest employment shares in the manufacturing industry recorded in the Czech Republic, Slovakia and Slovenia. With the exception of Latvia, Cyprus and Malta, manufacturing accounts for more than 15% of total employment in all EU-12 Member States. Similarly high shares of manufacturing employment are recorded for only a few EU-15 countries: Portugal, Italy, Austria, Germany and Finland.

Structural change has been more pronounced in Bulgaria, Romania, Latvia and Lithuania than in the Czech Republic, Hungary, Estonia or Poland. Furthermore, the 'earlier' transition period 1995-2000 was more profound than the integration period immediately before EU accession (2000-2005). The most recent period, 2005-2011 is characterised in several countries by more restructuring than before EU accession (for instance in the Czech Republic, Slovakia and Slovenia). This period was also affected by the recent economic crisis which hit manufacturing, construction and tradable services much harder than other economic sectors. Among the EU-15, Sweden, Austria and Germany experienced only small adjustments, whereas structural adjustments were more pronounced in Ireland and Finland.

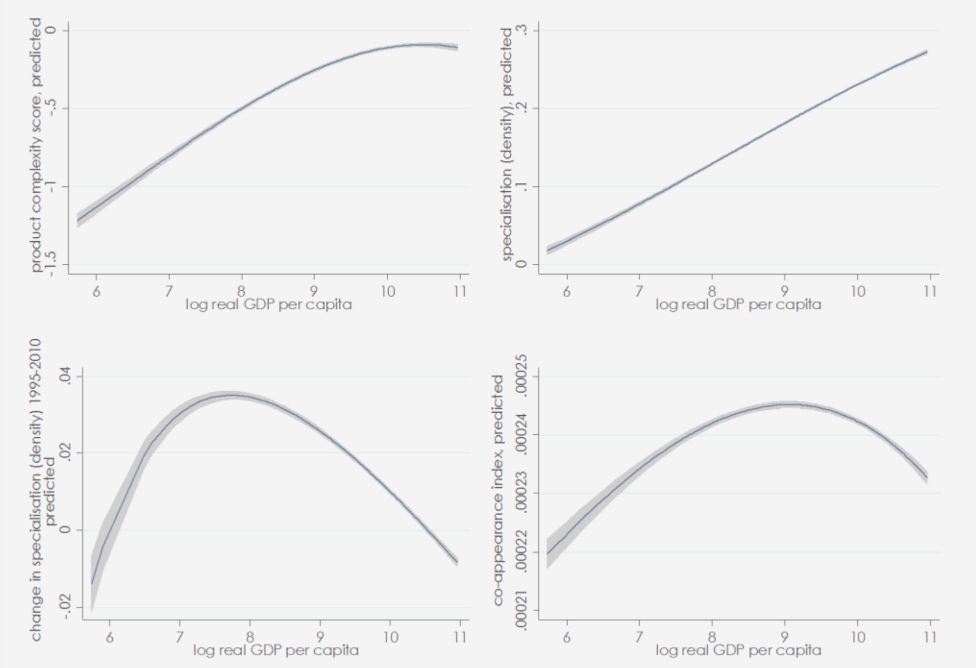
Despite varying country-specific restructuring patterns, several stylised facts common to most countries can be observed for the EU-12: the output shares of agriculture and manufacturing have declined whereas those of real estate, renting and business activities, information and communication, financial and insurance services, as well as public administration have increased. However, it must be said that the patterns of structural change were quite different across individual countries. It is especially interesting that a number of new distinct features of structural adjustment emerged during the relatively short crisis period between 2008 and 2011. Apart from a certain revival of manufacturing (Hungary, Romania and the Baltic states) it was construction and trade which suffered most from declining value-added shares during the crisis in a number of EU-12 countries. Structural adjustments were less pronounced in the Czech Republic during this period (as in a number of EU-15 Member States, such as Austria, France, Germany, Belgium, Italy and Sweden). In Poland – the only EU Member State which did not experience a decline in GDP during the crisis period – a certain return to a 'traditional' structural pattern occurred as a number of 'productive' sectors (energy, construction and trade) managed to increase their shares in GDP while the shares of information, communication services and especially financial services showed some declines.

The processes of variety creation and creative destruction can be made visible by the appearance and disappearance of exported products or product classes. Exporting new products changes the composition of the product basket of countries. Therefore the structural change in one country may affect the economic structure in other countries. The analysis of changes in the composition of export baskets of countries using trade data at the four-digit product level for 232 countries covering the years 1995 to 2010 (cf. Gaulier and Zignago 2010) allows the study of structural change and what is termed "creative destruction". We use the product space indicators proposed by (Hidalgo et al. 2007; Hidalgo and Hausmann 2009) that capture trade specialisation, product complexity, and appearance and disappearance of traded products across countries.

Figure 2.7 provides a summary of these indicators by relating them to per capita income levels of the countries. The upper panels (product complexity and trade specialisation) show values for 2010; the lower panels (change of trade specialisation and co-appearance and disappearance of products) show differences between 1995 and 2010.

The product complexity score (PCS) is shown in the upper left panel. This indicator can be interpreted as capturing latent information on both the depth (capability to produce exclusive products due to high levels of accumulated knowledge) and the breadth of the knowledge base (capability to make many products with different knowledge bases) needed to be active in a specific product class (cf. Reinstaller et al. 2012).[53] It is constructed using information on how many countries produce a specific product and on how diversified these countries are. The plot in the figure shows that more developed countries produce more sophisticated products which require higher capabilities and suggests that economic development goes along with a perpetual structural change in the export basket towards more complex products.

Figure 2.7. Average product complexity, density and co-appearance across income levels. Predicted values on the basi of fitted fractional polynomials, 2010



Source: WIFO calculations; BACI dataset (Gaulier and Zignago 2010);

The upper right panel shows the product neighbourhood density[54]. This indicator is a proxy for the trade specialisation of countries. It exploits the fact that similar products are related to each other by drawing on common knowledge bases and similar factors of production. It is therefore also a measure for the factor substitutability across products. Higher scores imply a higher specialisation. In order to plot this indicator it has been averaged over products in the product basket of a country. The plot shows that countries at higher levels of economic development tend to become more specialised in their exports. The products they export are more closely related to each other in terms of similar factor input requirements.

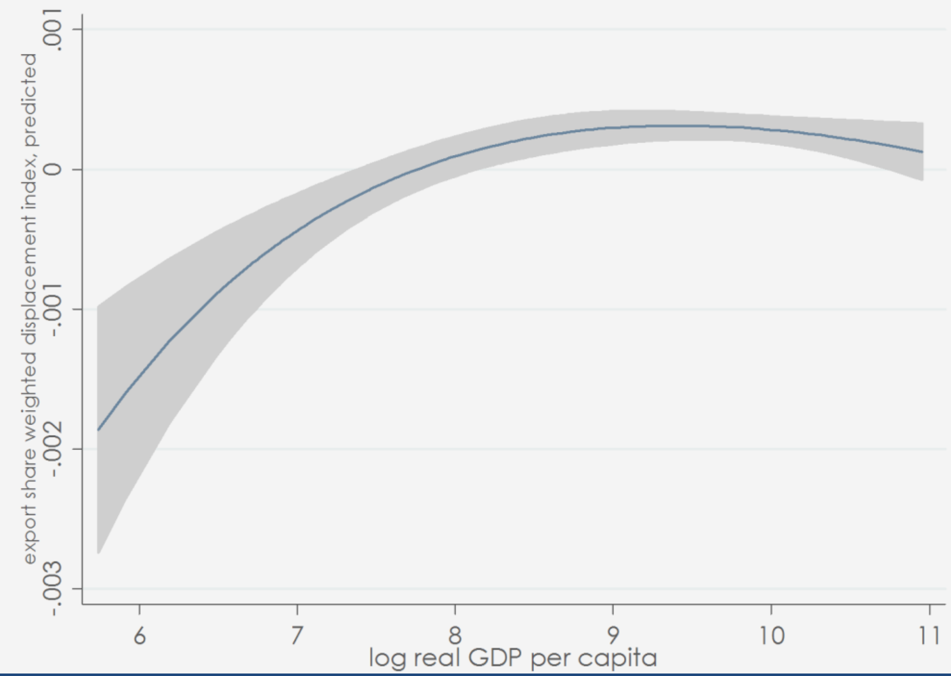
The lower left panel of Figure 2.7 shows the change of the neighbourhood density between 1995 and 2010. It is plotted against GDP per capita levels in 2010. The figure suggests that trade specialisation seems to be a fast process at lower levels of economic development, while it starts to slow down at a GDP per capita corresponding to about USD 3000 (or e^8), in a hump-shaped relationship.

The lower right panel plots the co-appearance index of the products countries export. This measure captures the presence of ‘temporal clustering’, where products appear in the export basket across countries at the same time. A higher value indicates a temporal clustering and shows whether countries start exporting these products simultaneously. The plot shows that the co-appearance index follows an inverted U-shape over levels of per capita income, with a predicted maximum at an income level corresponding to about USD 8000 per capita (=e^9). While a more thorough examination of the relationship between the co-appearance index and the change in neighbourhood density (specialisation) is necessary, a first glance at the results suggests that the co-appearance of products is closely related to the dynamics of related specialisation. Increases in specialisation appear to go along with bursts in the export activity of products.

53 The empirical range of the product complexity scores lies between –4 and 2. These figures correspond to standard deviations from the mean product complexity score normalised to zero. Hence an indicator value of 2 indicates that the complexity score of a product or product class is two standard deviations away from the mean. A product with a complexity score of zero indicates that – relative to the entire sample – it has just average complexity.

54 At the product level, the indicator takes on values between 0 and 1, where 0 indicates no relation and 1 a perfect relation of a product to the productive structures of a country the specialisation pattern of a country.

Figure 2.8. Specialisation of productive structures and changes over the 1995–2010 period across income levels predicted values on the basis of fitted fractional polynomials



Source: WIFO calculations; BACI dataset (Gaulier and Zignago 2010)

Figure 2.8 displays the export share weighted displacement index. This index measures the number of disappearances of some product classes within a specified time window after a country has started exporting another product.[55] It captures the creative destruction induced in a productive system when a country starts making a specific product. Negative values indicate that a country exports mostly products which across all countries tend to be displaced by other products. Positive values indicate that products which tend to displace other products have a higher weight in the export basket of a country. Such products can be considered to be more innovative, high-end products. Beyond a threshold income level close to USD 3,000 per capita, displacing products start to dominate the export basket of countries. This figure gives a clear indication that the characteristics of traded products change in countries with levels of income per capita in the range between USD 3,000 and USD 8,000.

As Figure 2.9 shows, the export baskets of the EU-27 consist by and large of products with positive displacement scores. This indicates that most of the exports of the Member States are products from the upper end of the quality ladder. The data also shows that inside this group of products with positive displacement scores, some Member States have a higher export share in products with above-average complexity scores whereas others have a higher share of products with average or below-average complexity scores.[56] The product complexity score can be taken as a measure that captures the difficulty of imitating exported products. For Member States with average or below-average complexity scores, this evidence implies that they produce up-market products that are easier to imitate. As a consequence, they are also subject to more intense price competition from lower-income countries than Member States producing innovative products that rely on a more complex knowledge base and therefore are also more difficult to imitate.

Further results show that across manufacturing sectors, product classes with negative and positive displacement indices co-exist. In the chemical industry for instance, the share of the two product categories is almost equal. By contrast, in the machinery and equipment industry the share of displacing products, i.e. products with a positive displacement index, outweighs the number of products that tend to be displaced, whereas the opposite situation exists in the textile and apparel industries. Sectors thus undergo a permanent restructuring process which is driven by changes at the level of products or product classes. These results show that more sophisticated products both in terms of complexity and displacement scores are more frequent in medium-high and high-tech industries. Therefore, in the more advanced economies, sectors

[55] The variable takes on values between -1 and 1. See Klimek et al. (2012) for details on the indicator.

[56] Unreported results show that the export basket of catching-up countries such as Brazil is dominated by products with negative displacement scores and a relatively high share of products with below-average complexity scores inside this product class.

producing more sophisticated products drive out other sectors. However, it is important to stress from a policy perspective the considerable path dependence in the development paths of the productive structures of economies (e.g. Reinstaller et al. 2012). This implies that the diversification into economic structures characterised by innovative products which are difficult to imitate is harder to achieve by countries lacking specific knowledge bases and specialisation patterns than by countries that have these capabilities. Thus an important limit to the change in the export basket of countries is the path dependency of industrial structure.

The path dependency of industrial structure also suggests that it might be easier to lose some products and competences in the process of international competition than to build up different capabilities which allow the differentiation of the product space of a country. This dynamic process of reconfiguring capabilities, competencies and the national product space is part of the interaction between manufacturing share and international competiveness.

While it is true that for most countries agricultural and manufactured goods are the most important tradables, the discussion should not be reduced to the size of the manufacturing share alone. The composition of the manufacturing share itself, whether manufacturing consists of sophisticated and complex products with unique features or mainly of products which compete with goods from many countries, is very important as this determines the long-run position of countries.

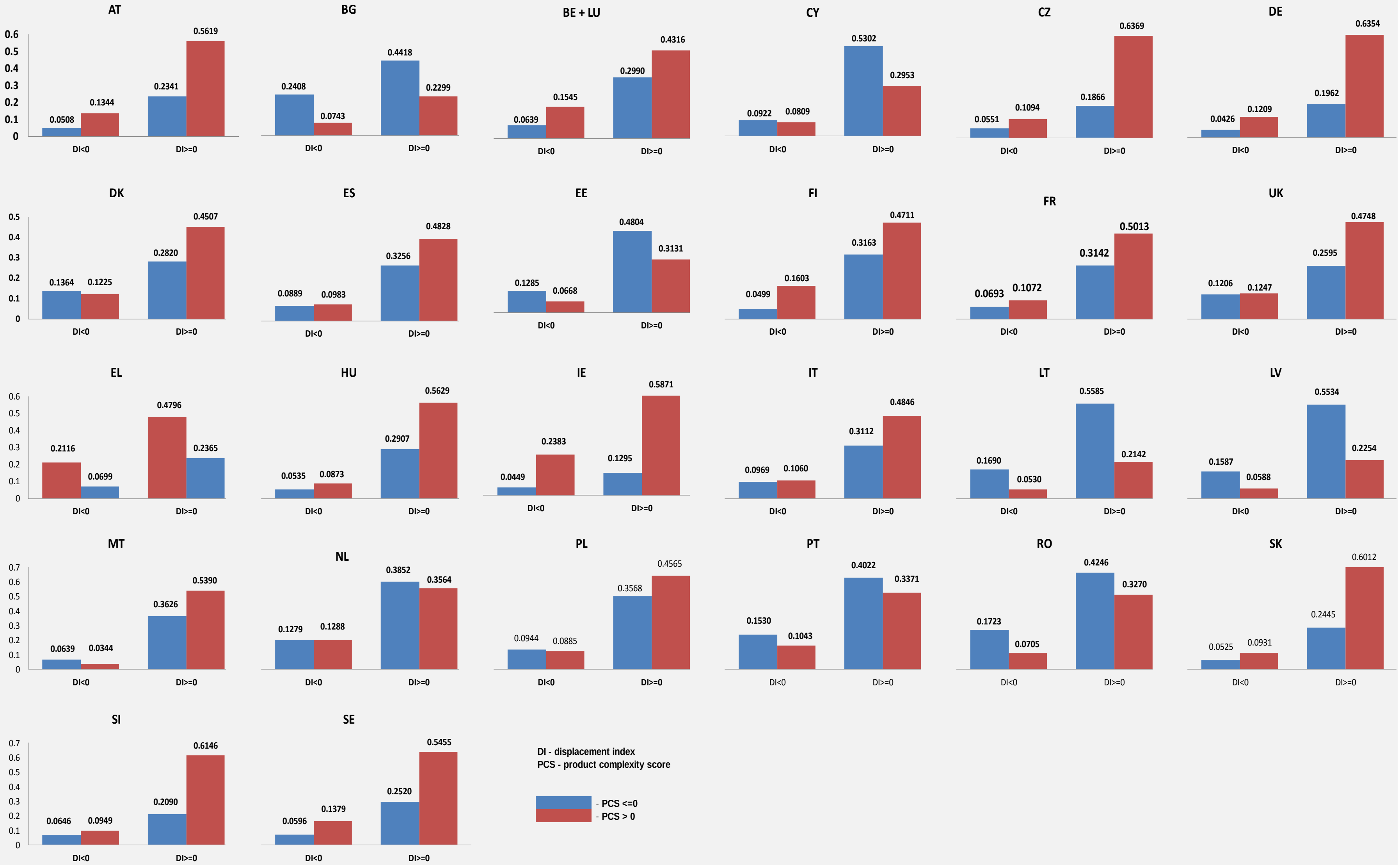
2.5.1. The role of institutions in structural change

The product space literature suggests that capabilities are crucial in explaining differences in structural change and economic development. On the other hand, economic development is closely linked to the institutional quality of countries. For example, Knack and Keefer (1995) and Dollar and Kraay (2001) argue that rule of law is an important driver of economic growth.

The literature on institutions and economic development suggests that many institutional indicators are highly correlated with economic development (e.g. Langbein and Knack 2010). A few studies have provided evidence of causality running from institutions to economic performance (Acemoglu et al. 2001, Rodrick et al. 2004). Reinstaller et al. (2012) confirm that product space indicators capturing the complexity of the export basket are closely correlated with institutional quality and high knowledge intensity. However, in this literature the relationship between structural change and institutional quality is not made very explicit, as it is not possible to measure structural change in an unambiguous way. The problem is that structural change can be growth-enhancing and growth-reducing. In the presence of international trade the reallocation of resources (e.g. labour and capital) can lean towards high-productivity sectors or in the opposite direction. Latin America has been cited as an example of a larger region which in the past experienced growth-reducing structural change. In the 1960s and 1970s in particular, economic policy driven by macroeconomic populism and protectionist import-substitution policies provided the basis for this outcome (e.g. McMillan and Rodrick 2011). This suggests that two different types of institutions and policies are central to fostering growth-enhancing structural change: institutions and policies to promote the efficient reallocation of resources across sectors and institutions, and policies to encourage the development of capabilities which allow enterprises to innovate.

The literature on market frictions in structural change emphasises that aggregate outcomes not only depend on rationalisation and reorganisation processes within firms and industries, but also on the reallocation of resources across sectors. Restuccia and Rogerson (2013) survey the evidence and show that structural change can be limited by the existence of regulations and other frictions that inhibit the reallocation of resources across sectors and firms. This can be costly in a static sense, as the resources are not used in the most efficient way. However, even more importantly, the dynamic impact may affect the adoption of new technology and further development of capabilities. McMillan and Rodrick (2011) provide evidence that countries with more flexible labour markets experience growth-enhancing structural change. Many factors can be identified, such as certain types of taxes, labour market regulation, size-dependent policies or trade barriers, in addition to regulations and myriad costs of doing business in the formal sector. Bartelsman et al. (2013) provide an overall analysis that compares the United States to seven European economies for the period 1992 to 2001 and find that idiosyncratic distortions play an important role in the allocation of resources across establishments. Their results suggest that output could be increased by up to 15% in some countries if the allocation of resources was improved. However, it is very difficult to identify the sources of the misallocation. One of the biggest impediments to the reallocation of resources is financial frictions. Financial markets are an important selection mechanism for entrepreneurial projects and a well-developed financial system is therefore important to fostering entrepreneurial activity, structural change and economic growth (Aghion et al. 2007, Buera et al. 2011). Microeconomic evidence suggests that credit market imperfections are important sources of differences in productivity across countries. An inefficient financial sector can significantly impede

Figure 2.9. Composition of the export basket in terms of product complexity and displacement indices: shares in total exports, EU-27



Source: WIFO calculations; BACI dataset (Gaulier and Zignago 2010) the creation of new businesses and the growth of enterprises. In particular, sectors with a larger scale (e.g. manufacturing) and industries that have high costs of product development (e.g. biotechnology) are disproportionally affected by financial frictions. However, financial repression that directs finance towards certain sectors is not a force which supports growth-enhancing structural change (Johansson and Wang 2011). Institutional aspects such as government effectiveness, low corruption and the efficiency of the legal system are important to competitiveness in terms of foreign direct investment (Alfaro et al. 2008). Thus, institutional quality is likely to affect specialisation patterns.

Here the capabilities that affect specialisation and structural change, which are associated with the knowledge base of countries, are of greater importance. The national innovation system perspective also provides a useful view on these issues as systemic failures are significant in explaining the innovative performance of firms and countries. The national system of innovation is defined as a 'network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies' (Freeman 1987). Systemic failures such as the lack of interaction between the actors in the innovation system, mismatches between basic research in universities and applied research in industry, malfunctioning technology transfer institutions, and deficiencies in the absorptive capacity of enterprises may all contribute to poor innovation performance. Powell and Grodal (2005) show that innovation networks have a positive impact on innovation activity, but network failures can cause barriers to innovation. Other evidence suggests that differences in the patterns of technology diffusion may account for a sizable part of the divergence in incomes between rich and poor countries (e.g. Comin and Mestieri Ferrer 2013).

Differences in the time scales of the adoption of new technologies and the penetrations rates once new technologies are adopted are important in determining differences in economic structure. Here the lesson of the literature on systems of innovation clearly indicates that successful technology support policy must consider arguments of systemic and institutional failures. Growth traps and catch-up failures are most often related to failures to select the right set of institutions. For example, Acemoglu et al. (2006) emphasise the different need for policy institutions (educational systems, firm dynamics, innovation policies) in countries that are close to or far from the world technological frontier. Catching-up does not depend on a particular institutional configuration, but on the interlocking complementarities within the institutional arrangements of the national innovation system, an aspect that von Tunzelmann (2004) calls network alignment. Structural change is thus dependent on growth-enhancing policies and institutions that allow the efficient allocation of resources within economies. Policies and institutions that hinder such reallocation processes are a prime source of inefficiency and economic backwardness.

The recent crisis in Europe has shown that short-term cyclical developments can lead to mispricing of assets and a misallocation of economic resources, for example with respect to the expansion of the construction sector in the lead up to current crisis. However, the evidence shows that the changes in the manufacturing share are mainly related to the broad trends of structural change mediated by international specialisation documented earlier. For example, there is nothing in the analysis of the inequality of employment and value added shares, in Table 2.4 and Table 2.5 that suggests that the divergence between European countries increased substantially during the crisis period (the drop in 2009 was symmetric across countries and the manufacturing share normalised for most countries in 2010 and 2011). Nevertheless, it is known that some sectors such as manufacturing and construction are very responsive to demand downturns. The production of capital goods and consumer durables are central industries in manufacturing that are sensitive to changes in the economic climate. Investment falls during recessions as does business R&D (e.g. Aghion and Banerjee 2005, Hölzl et al. 2011). Thus fiscal policy measures which aim at demand management should also consider the structure of the economy and the pro-cyclical behaviour of business R&D and innovation activities over the business cycle. Supporting business R&D and innovation during times of economic crisis can support the ability of countries to achieve economic growth in the long run and support economic restructuring. Policies that aim at reducing the openness of countries to international trade, in contrast, are likely to be counterproductive. The experience with financial repression and protection from international competition is more often negative than positive.

2.6. SUMMARY AND POLICY IMPLICATIONS

There are clearly identifiable broad patterns of structural change that are quite homogenous across countries and associated with the level of economic development. The agriculture share is declining with the process of economic development. The manufacturing share is declining, both in terms of its employment share and its value added share at a certain point of economic development, while the shares of services in employment and output are increasing over time. These patterns can be broadly explained in terms of the impact of technical change and productivity improvements together with changing patterns of demand due to higher income (the 'Engels curve').

New technologies and new skills change productivities, while demand patterns change with changing income. The decline in the economic weight of agriculture is associated with the increasing mechanisation of agriculture which still leads to a rise in labour and total factor productivity even in the richest countries of the world. The increase in productivity leads to lower prices and to a lower factor demand (e.g. labour) if productivity developments outstrip the growth in demand for sectoral products. The same mechanism characterises manufactured output, with the important difference that the products (and the product characteristics) in manufacturing are changing much faster than products in agriculture. A hundred years ago there was no computer industry and the output of the electronics industry was very different.

However, if we look at shorter time periods, such as the 15 years considered in the sectoral growth decompositions, it can be seen that most growth comes from processes of economic growth within industries. It is a well-known stylised fact that aggregate productivity improvements are mostly related to within-sector (and even within-firm) productivity improvements. Reallocation between sectors and between industries becomes more important the longer the time period of the analysis.

These patterns are almost the inevitable outcome of the basic mechanisms underlying structural change. Similar patterns are not only found using historical data for European countries or cross-sectional data for a large number of countries; these patterns are also very similar for US states and EU members. Nevertheless, it is equally important to realise that there is some heterogeneity in the structure of economies across countries. The working of structural change is also mediated through international trade, institutions, and international and domestic competition.

On-going reallocations in economic weight across different sectors should not be assessed only in terms of reallocation of sector shares towards more productive sectors. That would completely neglect the linkages between sectors that are essential in generating productivity improvement. Structural shifts towards education-intensive activities (business services and especially non-market services) do not necessarily impact on growth potential in a negative way, even if they apparently reduce aggregate productivity. The education sector generates skilled labour inputs for manufacturing and R&D.

International competitiveness is *inter alia* about trade balances at the aggregate level; but "creative destruction" at the product level is likely to be a major driver of developments at the aggregate level. Thus, international trade is an important determinant of the development of sectoral shares in countries. The successful catch-up stories of Germany in 19th century and Japan and South Korea in the 20th century cannot be explained without taking into account international trade, comparative advantage in tradables and specific competencies and capabilities in the production of new and high-value added products. Here it is important to acknowledge that structural change shaping the economic development of countries is highly path-dependent and cumulative. Any change is rooted in present knowledge bases and constrained by existing specialisation patterns. Complementary capabilities need to be built up. Therefore policies to support structural change should always start by taking into account the existing production structures of countries and regions, as well as the knowledge base of supporting institutions. Appropriate policies to foster structural change may therefore also be country-specific and region-specific, and depend on existing specialisation patterns. Skills and technology are essential for achieving growth-enhancing structural change. Structural change is generally associated with the emergence of new products and industries and the disappearance of other products and occupations at the micro-economic level which have a macroeconomic impact.

Producing more complex product classes and upgrading existing products requires technological competencies, skilled labour and administrative capabilities at the business and government levels. It should therefore not come as a surprise that the share of services (non-government services such as education and business services) starts to rise once countries achieve income levels where the nature of international competition changes from a purely cost-driven to a more resource-intensive quality competition. For the most successful exporting countries it is crucial to develop new products that are not produced by many other countries. Upgrading possibilities are not distributed evenly: they seem to be concentrated in high technology sectors and complex products. Given the path-dependent development of economic structures and comparative advantage (as indicated by the product space literature), countries seeking to shift their industrial production up the technology ladder are likely to also need to increase and improve non-government services, such as education and business services.

The fact that upgrading structures is a cumulative process makes it difficult to develop new specialisation patterns out of the blue. This presents a problem for countries where industrial restructuring is necessary. The centrality of institutions and policies in the process of structural change leads to a view that the general quality of institutions is important to structural change. Policies that foster structural adjustments should therefore be conceived in a broad way and cover such different areas as education, research, technology and innovation policies, while also focusing on the general quality of governance.

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ANNEX 2.1
DEFINITION OF PRODUCT SPACE INDICATORS

Product space indicators

Hidalgo et al. (2007) define the product space as a bi-partite network linking countries to products. To construct this network, they define a proximity measure, $\varphi_{i,j}$, between two products i and j as the pairwise conditional probability P of a country exporting one good given that it exports another. This measure is defined as follows:

$\varphi_{i,j} = \min\{P(RCA_i|RCA_j), P(RCA_j|RCA_i)\}$, (proximity)

where RCA_i means that a country has a revealed comparative advantage (RCA) for product i and is therefore a significant exporter of that product. The RCA is taken in order to ensure that marginal exports do not introduce noise into the data. The minimum is taken to avoid that if a country would be a sole exporter of a good the conditional probability would take on the value 1. By taking the minimum of the reciprocal relationship this problem is avoided. Proximity is therefore a measure that links any product to any other product traded in the world. In terms of a network, the proximity can be conceived as the edges of the network with the products being its nodes.

In order to assess the likelihood that a product becomes a significant export in a country Hidalgo et al. (2007) define a measure called "density". We refer to this indicator as "**neighbourhood density**" to distinguish it from the statistical notion of density. It measures the average proximity of a product to a country's current productive structure. For products for which the country is not a yet a significant producer this measure therefore indicates how embedded the product would be and by implication to what extent complementary capabilities are already available in a country. It therefore captures the likelihood that a country develops a comparative advantage in any product. The neighbourhood density ω_j^k is calculated as follows:

$\omega_j^k = \sum_i x_i \varphi_{i,j} / \sum_i \varphi_{i,j}$, (neighbourhood density)

where x_i is unity if product *i* has an RCA>1 in country *k*. The neighbourhood density takes on the value 1 if a country produces all *i* products to which product *j* is connected in the product space. The neighbourhood density is therefore normalised between 0 and 1 and takes on the maximum when a product is connected to all other products in the product mix of a country.

The product complexity scores (PCS) have been calculated using the method of reflections advanced by Hidalgo - Hausmann (2009). It exploits information on the diversification of a country and the ubiquity of the products (i.e. in how countries have an RCA>1 for a given product). $M_{c,p}$ is the matrix linking product to countries and has an entry of 1 if country *c* has an RCA for product *p*. Then the matrix can be summed up row wise over products *p* one obtains a measure for the diversification of a country *c*.

$$k_{c,0} = \sum_p M_{c,p} \cdots \text{diversification} \quad (1)$$

If, on the other hand, the matrix is summed up column wise one obtains a measure for the ubiquity of comparative advantage in the trade of a specific product *p*, i.e. this measure tells us how many countries *c* have a comparative advantage in trading this product.

$$k_{p,0} = \sum_c M_{c,p} \cdots \text{ubiquity} \quad (2)$$

By combining these two indicators it is possible to calculate through recursive substitution how *common products are that are exported by a specific country*,

$$\rightarrow k_{c,n} = \frac{1}{k_{c,0}} \sum_p M_{c,p}\, k_{p,n-1} \ldots \text{for } n \geq 1, \quad (3)$$

and h*ow diversified the countries are that produce a specific product*

$$\rightarrow k_{p,n} = \frac{1}{k_{p,0}} \sum_c M_{c,p}\, k_{c,n-1} \ldots \text{for } n \geq 1. \quad (4)$$

If formula (3) goes through an additional iteration the indicator now tells us how diversified countries are that export similar products as those exported by country *c*. An additional iteration for formula (4) tells us then how ubiquitous products are that are exported by product *p*'s exporters. Each additional iteration *n* adds information on the neighbour of a country or product that is *n* steps away from country *c* or product *p*. Higher iterations than those presented in the table are increasingly difficult to interpret. The indicator $k_{p,n}$ standardised relative to all products at iteration n gives the **product complexity score PCS**.

It is possible to calculate the simultaneous or slightly lagged appearance and disappearance of products using product space metrics. In this way a dynamic view is introduced in the product space analysis. We follow the method proposed by Klimek et al. (2012). To calculate the co-appearance and displacement indices define appearance and disappearance events as follows:

- Appearance: $A(i)_{c,t} = 1 \cdots$ if $v_{c,t-1} \leq 50000USD$ and $v_{c,t} > 50000USD$; $A(i)_{c,t} = 0 \cdots$ otherwise.
- Disappearance: $D(i)_{c,t} = 1 \cdots$ if $v_{c,t-1} > 50000USD$ and $v_{c,t} \leq 50000USD$; $D(i)_{c,t} = 0 \cdots$ otherwise,

where *t* defines a specific point in time and *c* a specific country, $v_{c,t-1}$ is the value of exports a country has in any product class *i*. The product index *i,j* runs from 1 to *n*, where n corresponds to the number of product classes in the analysis. Hence, the empirical number of co-appearances between any pair of product classes *i* and *j* is given by

$$PA_{i,j} = \sum_t \sum_c A(i)_{c,t} A(j)_{c,t} \quad \text{for each } i,j = 1..n \ \ (1),$$

whereas the empirical number of displacements over period ℓ after the appearance of a product class *i* is given by

$$PAD_{i,j}^{(\ell)} = \sum_t \sum_c \sum_{t'=t+1}^{t+\ell} A(i)_{c,t} D(j)_{c,t'} \quad \text{for each } i,j = 1..n \qquad (2).$$

The period ℓ was set to 3 such that all displacements of a product class *j* three years after the appearance of product class *i* have been taken into account.

The **co-appearance index AI** follows then from equation (1) if on the one hand we control for the fact that products with a high number of appearance are likely to have also a higher number of co-appearances, and if on the other hand the resulting factor is normalised to lie in the interval$[0,1]$.

$$AI_i = \frac{1}{\mathcal{N}} \sum_j \frac{PA_{i,j}}{\max[PA_i, PA_j]} \quad \text{for each } j = 1..n \ \ (3),$$

where $PA_{i,j} = \sum_t \sum_c A(i,j)_{c,t}$ is the number of appearances of each product class *i* and *j* across countries *c* and over all observation periods *t*, and $\mathcal{N}$ is the normalisation factor rescaling the sum to the established range.

The **displacement index DI** is instead defined as

$$DI_i = \frac{1}{\mathcal{N}} \sum_j \left[PAD_{i,j}^{(\ell)} - PAD_{j,i}^{(\ell)}\right] \ \mathit{for\ each}\ j = 1..n \qquad (4).$$

Clearly, if the sum in equation (4) is negative, then product class i is on average displaced more often by appearances of the other product classes j during the period ℓ. A positive indicator value instead means that *i* displaces on average more often any other product class *j* than *j* replaces *i* after its appearance. $\mathcal{N}$ is again the normalisation factor rescaling the sum to the established range.

In order to analyse the displacement across NACE sectors we have aggregated the displacement scores $PAD_{i,j}^{(\ell)}$ as follows:

$$PADS_{k,l}^{(\ell)} = \frac{1}{\mathcal{N}} \sum_{i \epsilon S_l} \omega_i \sum_{j \epsilon S_k} \omega_j PAD_{i,j}^{(\ell)} \ \mathit{for\ each}\ j = 1..n \qquad (5),$$

where weights *ω* represent the share in total export value of sectors *k* and *l* of products *i* and *j* in Sector *S*. The weights therefore give higher importance to product class displacements that have a higher value in total exports of a NACE sector than those that have a lower value. For all calculations period ℓ has been set to 3, i.e. we include all disappearance events three years after the appearance of a product in the counts.

Chapter 3.

REDUCING PRODUCTIVITY AND EFFICIENCY GAPS: THE ROLE OF KNOWLEDGE ASSETS, ABSORPTIVE CAPACITY AND INSTITUTIONS

From the mid-1990s productivity growth in the EU slowed down compared to the US, which in contrast was experiencing rapid productivity acceleration (O'Mahony and van Ark, 2003). As a result, the US-EU productivity gap widened. While the post-1995 productivity slowdown was felt across all EU countries, productivity trends have differed and economic disparities have amplified since the economic and financial crisis, which hit countries with different intensities (Mas, 2010). Understanding the reasons underlying productivity differentials has become a priority for policy makers so that useful policies to promote and restore long-lasting economic growth in Europe, beyond the traditional models of catch-up and convergence, can be implemented.

Productivity, a key source of economic growth and competitiveness, is defined as the amount of output that can be produced per unit of input. The term productivity, however, is used to describe two related concepts: labour productivity and total factor productivity (TFP). Labour productivity, which refers to the amount produced per each unit of labour, can be improved through either a greater use of capital relative to labour (capital deepening), or through an increase in TFP growth. TFP measures the part of an output increase not accounted for by increases in the quantity and quality of inputs. TFP movements are mainly due to technical efficiency increases, which imply catching up to the existing technology frontier, or due to technological improvements as the frontier shifts outwards over time.

Prior to the financial and economic crisis which started during 2007-2008, the debate on the European labour productivity slowdown pointed to ICT capital accumulation as a major reason for the under-performance of EU labour productivity. This largely reflected the significantly slower adoption of ICT technologies in the EU compared to the US, in particular in services sectors. Moreover, industry-based studies revealed that the US productivity advantage was concentrated in specific services sectors, mainly trade, finance and business services (Timmer et al. 2010). In these ICT-intensive using sectors, the large ICT investment flows during the second half of the 1990s together with complementary investments in organizational capital led to a rapid TFP growth during the first half of the 2000s (Van Ark et al, 2008; Brynjolfsson and Saunders 2010).

The initial hypothesis was that Europe was merely lagging behind the US in the adoption of ICT technologies, and therefore, it would take some time for its benefits to materialise. Now, it has become apparent that high levels of investment alone do not produce faster economic growth and better productivity performance. Several years after the 'ICT revolution', the EU is not only still lagging behind the US, but the productivity growth gap has recently widened.

Empirical findings show that in the EU there was insufficient investment in the skills and organizational changes necessary to reap the benefits of ICT technologies (Brynjolfsson and Hitt 2000; O'Mahony and Vecchi 2005). Lower investments in intangible assets broadly conceived (R&D, human capital, etc.) are likely to explain a portion of the US-EU productivity gap as these factors affect countries' absorptive capacity, i.e. their ability to take advantage of the technology developed elsewhere (international technology transfers).

Most of the leading technologies available worldwide are developed by a few frontier countries which dominate the entire global market. Technological laggards can benefit by imitating such technologies through international trade. However, in order to assimilate and exploit the foreign knowledge in the production of their own goods, it is indispensable for laggard countries to develop a certain degree of absorptive capacity, i.e. to reach a minimum threshold of technological competence. Absorptive capacity is considered essential to close the gap with the technology leaders and spur economic growth (Griffith et al. 2004).

Another factor that has recently been identified as a cause of the lower TFP performance in the EU, is the more rigid regulatory framework compared to that in the US (Nicodème and Sauner-Leroy 2004, Bourlés et al. 2012). For example, it has been shown that low levels of competition and strict employment laws prevent the necessary optimal adjustments to factor allocation in order to take full advantage of new technologies (Conway et al. 2006; Bassanini et al. 2009; Arnold et al. 2011).

An issue largely unexplored, and to which this study wishes to contribute, is whether the regulatory environment determines the efficiency with which resources are used in production (technical efficiency). This has become a major issue in recent years as the ability to exploit existing resources emerges as one of the most important sources of productivity gains in the most mature economies (van Ark et al., 2012).

Although the recent downturn has shifted the focus on the functioning of markets as, a possible mechanism driving productivity differentials across areas of the world, understanding the channels through which the regulatory environment determines TFP growth, remains a challenge.

The main contribution of this chapter is to provide a comprehensive analysis of the determinants of productivity growth, focusing on the role played by the restrictions in the product, labour and financial markets as well as, the role of intangible assets (e.g. ICT, R&D) and absorptive capacity (e.g. skills). The use of Stochastic Frontier Analysis, is used to investigate the main factors affecting changes in technical efficiency for a large sample of countries and industries in the EU, an issue largely unexplored in the literature to date.

Specifically, this chapter addresses the following questions:

- What are the recent trends in productivity growth in the EU and the US? Which areas of the economy are driving the most recent growth patterns? What is the relative role of the various factors inputs?
- Do the institutional framework and laws governing the functioning of the factor and product markets shape the EU's ability to benefit from technology originated in the frontier countries?
- Does the EU regulatory setting influence the level of production efficiency, i.e. the ability of firms/industries to use factor inputs in the most technically feasible way? What are the main institutional factors that explain the efficiency gap with the US? To what extent do these factors interact with the use of ICT and with the technology characteristics of EU industries?

Section 3.1 of this chapter highlights the main productivity and growth trends in the EU in comparison with other major world economies for the period from 1995 to 2012. A decomposition of labour productivity growth into its main components, and a detailed up-to-date account of sectoral productivity developments are provided. Section 3.2 reports econometric evidence on the factors affecting international diffusion of R&D focusing on the institutional determinants of a country's absorptive capacity. Section 3.3 quantifies the extent to which ICT and institutional factors have had an impact on the efficient use of resources. Assessing both the economic and institutional drivers of technical efficiency is helpful to understand the sources of the productivity gap and to design policies that might reduce it. Section 3.4 integrates the analysis by presenting evidence on firm behaviour at the outset of the crisis, focusing on firms' strategic decisions regarding investments in tangible and knowledge assets and their impact on productivity. Section 3.5 concludes the analysis and outlines the policy implications.

3.1. Growth accounting and the effect of the crisis at country and sector level

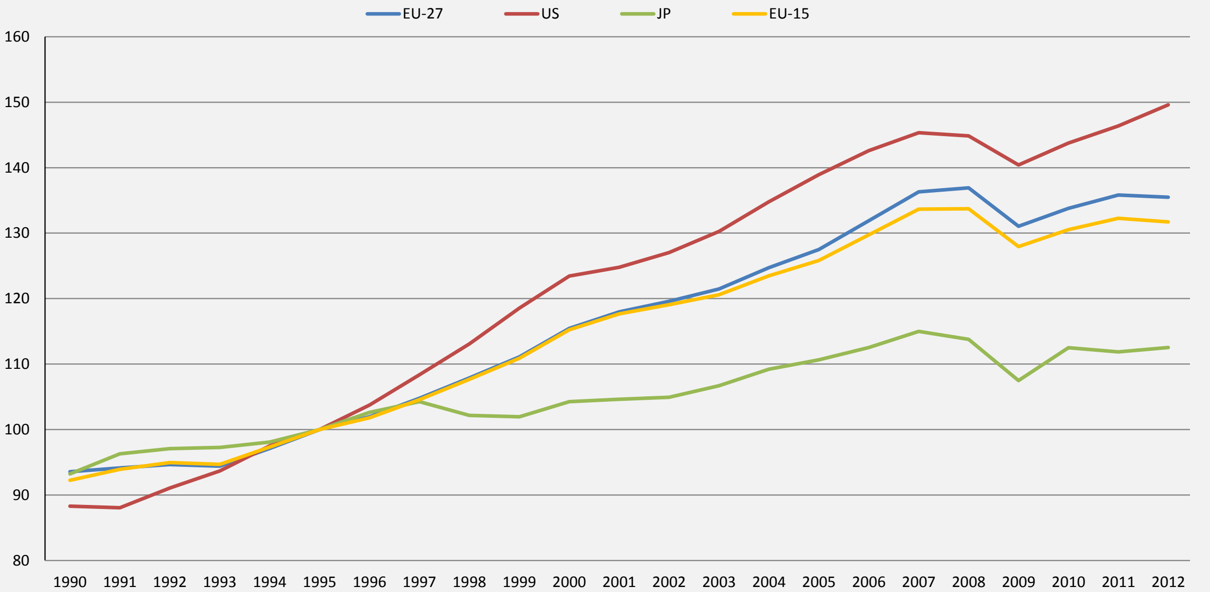
3.1.1. Economic performance of the EU and other major economies: overview of aggregate output and productivity trends

This section presents an overview of recent output and productivity trends in the EU, highlighting the main convergence and divergence patterns from a comparative perspective. From the mid-1990s the US economy has grown at a higher rate than the EU and Japan (see Figure 3.1). During the period 1995-2004, the average GDP[57] growth rate in the US was 3.3%, around 0.85 percentage points higher than that experienced by the EU-27. This trend reversed briefly during the period 2004-2007, as the EU-27 started to grow faster than the US (3% versus 2.5%). This performance was partly driven by the newest Member States, as GDP growth in the EU-27 was higher than the EU-15. Japan performed considerably worse than Europe during the period 1995-2007, achieving only moderate GDP growth rates (between 1 % and 1.5%).

At the outset of the crisis, in 2008, output growth slowed down across all areas, and in 2009 output levels fell globally. By 2010, however growth had resumed across the US, EU and Japan. The US exhibited the strongest recovery. Performance in the EU improved during 2010 and 2011; however, the sovereign debt crisis caused a fall in GDP growth in 2012. Japan's output level has remained largely flat since 2010.

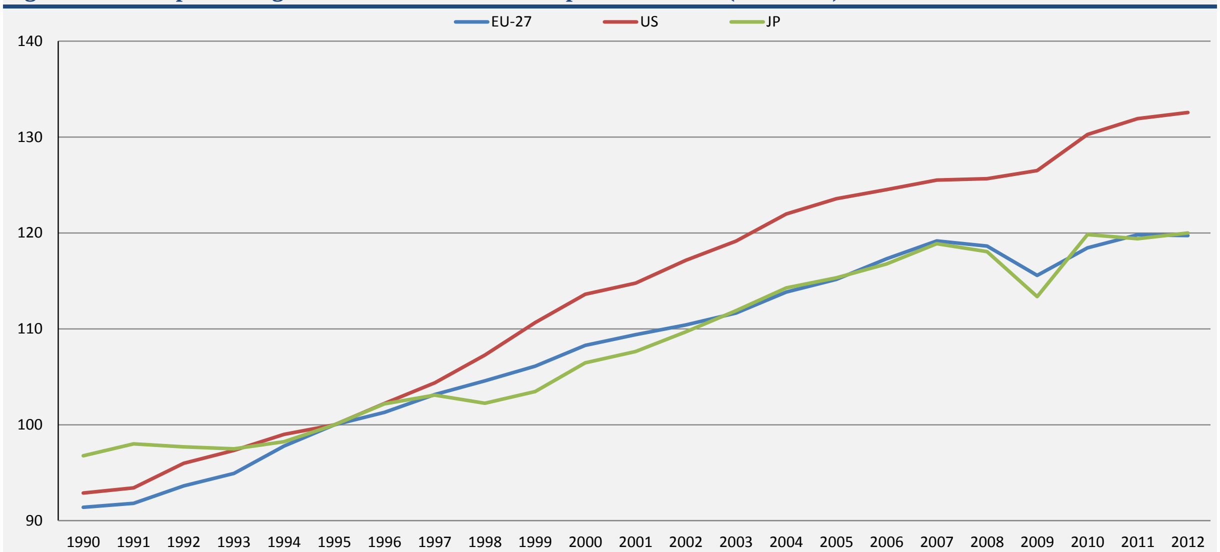
[57] The source for the Gross Domestic Product data is the Total Economy database, The Conference Board, January 2013 release.

Figure 3.1. GDP growth in the EU, US and Japan. 1990-2012 (1995=100)



Source : The Conference Board Database and own calculations.

Figure 3.2. GDP per hour growth in the EU, US and Japan. 1990-2012 (1995=100)

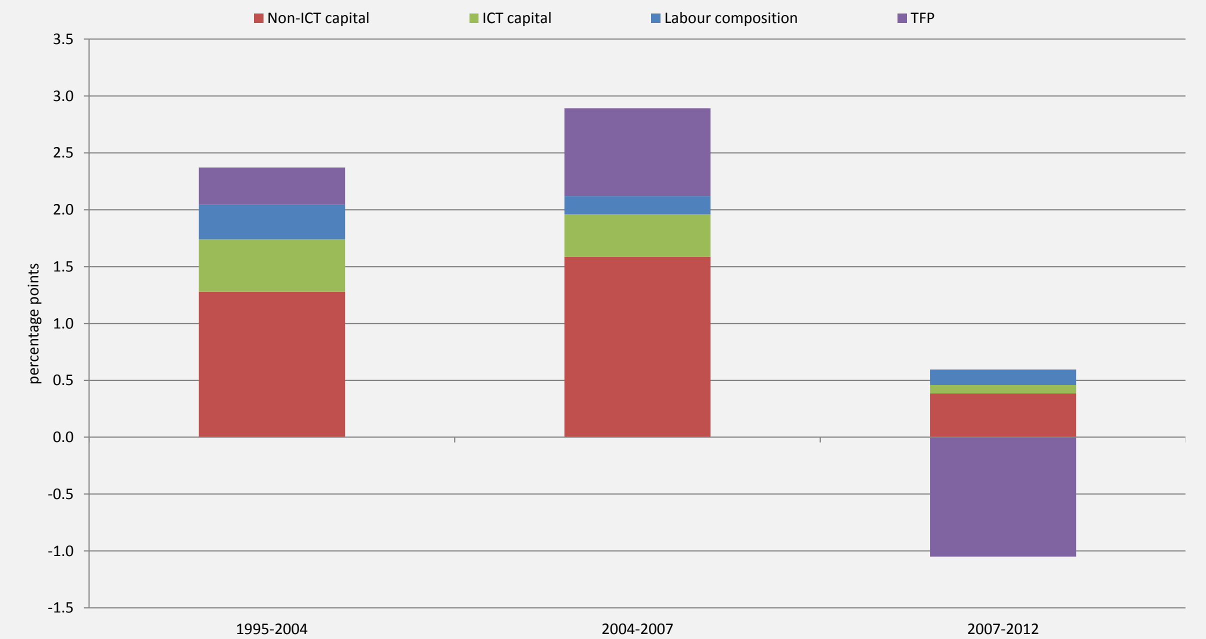


Source: The Conference Board Total Economy Database and own calculations.

Figure 3.2 illustrates trends in productivity, measured as GDP per hour, in the EU, US and Japan. From the mid-1990s to the early 2000s productivity accelerated in the US but not in Europe or Japan. In a period characterised by the widespread diffusion of Information and Communication Technologies (ICT), the US productivity lead was amplified thanks to its greater ability to invest and benefit from the new technology. While EU productivity showed signs of catching up towards US levels during 2004-2007 (see Figure 3.1), the onset of the crisis has worsened the EU position. Although slower than in the pre-crisis period, the US labour productivity growth rate fluctuated around 1% per annum, even at the height of the global downturn. In contrast, in the EU and in Japan, labour productivity levels fell in the aftermath of the crisis, only to recover from 2010. As a result, the gap in labour productivity between the US and the EU widened again. Between 2007 and 2012, the US labour productivity growth was approximately 2 percentage points higher than the EU and 3 percentage points higher than Japan.

From 2010 onwards Japan experienced a strong productivity recovery, outperforming the EU and the US. This contrasts with the slowdown in output growth shown in Figure 3.1. This finding is a consequence of the large reduction in the total number of hours worked, which testifies the flexibility of the Japanese wage system and its labour hoarding tradition (Darby et al. 2001). In the case of

Figure 3.3. Growth accounting in the EU: Decomposition of labour productivity growth, 1995-2012



Source: EUKLEMS and own calculations.

the EU, which is characterised by a large degree of heterogeneity in the institutional and policy environment, labour market responses were largely country-specific. While some countries were able to adjust to worsening demand conditions via a reduction in hours worked (e.g. UK, Germany, France, Netherlands) others carried out major labour shedding, mostly concentrated in low-skill sectors, resulting into an overall increase in productivity levels (e.g. Spain and Ireland).

3.1.2. Growth accounting analysis: Sources of productivity growth at aggregate level

The objective of this section is to explore the role of inputs to production and Total Factor Productivity (TFP) in explaining aggregate labour productivity developments, measured by GDP per hour. The inputs considered are capital assets, distinguished into ICT and non-ICT assets, and labour composition, which represents the contribution of skilled labour. The TFP component, which is derived using the neoclassical growth accounting methodology, quantifies the part of the output growth not accounted for by growth in the quantity and quality of inputs; TFP captures the influence of unmeasured factors on productivity, such as efficiency improvements, technological change and spillovers. The different factors contributing to labour productivity growth are shown in Figure 3.3 for the EU and Figure 3.4 for the US.

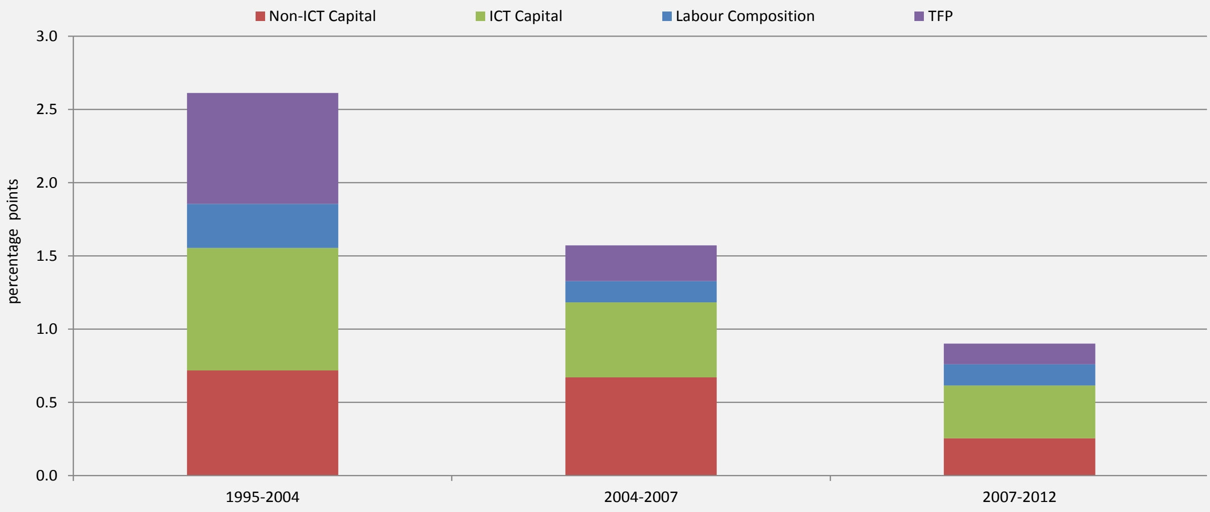
During the period 1995-2004, the most important contributor to labour productivity in the EU[58] was the accumulation of capital assets. TFP gains in the EU were significant during this period but growth rates were considerably lower than in the US. In the US, the main factor driving labour productivity growth during the period 1995-2004 was ICT capital. The growth contribution of ICT was substantially slower in the EU.

The EU experienced significant TFP acceleration during the subsequent period, 2004-2007. Non-ICT capital accumulation and TFP were the main factors contributing to labour productivity growth and to the catching up process towards the US, shown in the main output trends. During the same period, the US experienced a productivity slowdown, mainly caused by a decrease in the speed of ICT capital accumulation and a lower contribution of TFP growth.

After 2007, the effect of the crisis was particularly strong in Europe and negatively affected the contribution of all factors of production, with the sole exception of labour composition. The latter finding is consistent with prior evidence of labour quality growth in many European countries. For example, Kang et al. (2012) find that the average skill level of the workforce, which mainly reflects qualifications achieved through the general education system, rose during the recession years. TFP growth was mostly

58 The EU includes the following eight countries: AT, BE, DE, ES, FR, IT, NL, UK.

Figure 3.4. Growth accounting in the US: Decomposition of labour productivity growth, 1995-2012



Source: EUKLEMS and own calculations.

affected by the financial crisis as its contribution turned negative. The contribution of capital, although still positive, declined substantially compared to the pre-crisis period, reflecting the consequences of tightening credit conditions for European firms.

Goodridge et al. (2013) observed that in the UK, while capital investment decreased considerably with the recession, investments in intangible assets increased, particularly investments in R&D and software. This, together with a higher proportion of skilled workers, increases future growth potential, facilitating recovery.

In the US, the crisis also affected the contribution of TFP and non-ICT capital, although neither turned negative. The contribution of ICT capital decreased slightly compared to the 2004-2007 period, while labour composition increased slightly. This testifies that, as in the UK, US firms prioritised the employment of highly skilled workers.

The analysis of growth trends at the aggregate level is consistent with the hypothesis that the US productivity lead in the late 1990s and early 2000s resulted from a first mover advantage in ICT. Large TFP gains at the time of rapid ICT investment suggests that ICT may have had an impact on productivity beyond that of ICT-capital deepening (O'Mahony and van Ark 2003); this has been attributed, for instance, to the existence of spillovers related to knowledge assets and to large investments in organizational capital (Bryonjolffson and Saunders 2010). The EU experience reveals that TFP movements may have followed the US productivity developments, albeit with a time-lag. Basu et al. (2004) argue that the `missing' TFP growth in the United Kingdom, compared to the US, in the second half of the 1990 is likely to have been caused by a delay in undertaking investments that would complement the adoption of the new technology.

In the EU, substantial declines in TFP have been recorded since 2007. TFP appears to have behaved in a highly pro-cyclical way and existing contributions suggest that this reflects a decline in the overall efficiency of the production process. However, these results should be treated cautiously as it is too soon to draw conclusions based on the most recent TFP movements (OECD, 2012).

3.1.3. Productivity developments in the EU and the United States: a sectoral perspective

A more detailed explanation of the nature of the EU-US productivity gap is provided by looking at the contribution of each sector in the economy. Labour productivity growth trends are examined for specific industries (Figure 3.5. and Figure 3.6.). While the analysis of these sectoral productivity trends are informative, offering an interesting snapshot of pockets of growth, the relative industry contribution to the overall EU-US productivity gap will be determined by the size of each sector and by the differences in industrial structure.

Due to limited data availability[59], the focus here is on a group of eight EU countries[60] (Austria, Belgium, Spain, France, Germany, Italy, Netherlands and the UK). Industry productivity data are drawn from the latest release of the EUKLEMS database (O'Mahony and Timmer 2009) and follow the NACE Rev. 2 classification of economic activities (see Annex 3.1).

[59] EUKLEMS most recent updates, covering up to year 2010 are only available for a limited number of European countries.

[60] These economies represented in 2012 approximately the 80% of EU output.

During the period 1995-2004, the sectors experiencing the highest growth rates in the US include the ICT-producing sector electrical and optical equipment, with an average growth of almost 21%, followed by coke and refined petroleum products[61], with a rate of 15%. Then come information and communication activities[62] and wholesale and retail activities, which experienced productivity growth rates of around 4%.

In the EU, the best performing sectors during the same period included coke and refined petroleum, with a rate of labour productivity growth rate of 8%, finance and insurance activities, and electricity, gas and water supply, both with rates of around 6%. Next were chemicals and chemical products, with a rate of 5%. During that period in the EU the lowest labour productivity growth rates were observed in retail trade, professional, scientific, technical, administrative and support services; community, social and personal services; and arts, entertainment, recreation and other service activities.

Between 1995 and 2004, the European failure to match the US acceleration in output and productivity has largely been attributed to developments in market services (Timmer et al. 2010). The analysis in this section reveals that the sector which most contributed to amplify the US productivity advantage was in fact wholesale and retail distribution, due to its strong productivity performance and its relatively large share in the economy. Other services sectors with sizeable contributions include the professional, scientific, technical, administrative and support services, and finance and insurance activities. These findings are consistent with previous evidence (EC 2008). The electrical and optical equipment sector also made a key contribution with its outstanding growth performance.

Throughout the period 2004-2007, two factors jointly contributed to the reduction of the EU-US productivity gap: the acceleration of productivity in most EU manufacturing industries relative to the productivity performance in US manufacturing, and a robust performance of many EU services sectors.

The highest productivity growth rates in the EU manufacturing sector[63] were achieved in chemicals and chemical products, with a rate of 13%; in contrast, the US electrical and optical equipment sector continued to show impressive growth while in the EU growth remained modest.

In services, labour productivity slowed significantly between 2004 and 2007 in the US wholesale and retail sector compared to the exceptional performance observed in the earlier period. On the other hand, the EU performance in the same sector improved substantially, reaching a 3% productivity growth, nearly doubling the growth rate achieved in previous periods. The information and communication activities sector experienced robust labour productivity growth in both the US and the EU; in the latter area, this meant a considerable improvement as labour productivity had previously followed a deteriorating trend. In most EU services, labour productivity improved, particularly in the professional, scientific, technical activities, and community, social and personal services. This is in contrast to the poor performance of both sectors in the period 1995-2004. Overall the evidence shows that those sectors which contributed to narrowing the EU productivity gap relative to the US between 2004 and 2007, were those responsible for the stagnant EU productivity in the previous decade.

During the financial crisis (2007-2010), labour productivity stalled in the EU, while it continued to improve in the US. The majority of manufacturing sectors in the EU-8 experienced a fall in productivity levels, probably reflecting a higher exposure to global demand fluctuations compared to the services sectors. Manufacturing productivity as a whole decreased by more than 1% annually, with chemicals, decreasing by more than 4% annually. Productivity in the construction sector also deteriorated considerably as well as in some services activities, such as wholesale and information and communications. Those sectors that showed the most resilience to the weakening economic conditions in the EU-8 were financial and insurance activities growing by 6% annually, professional, scientific, technical activities and retail trade growing by around 2% per annum.

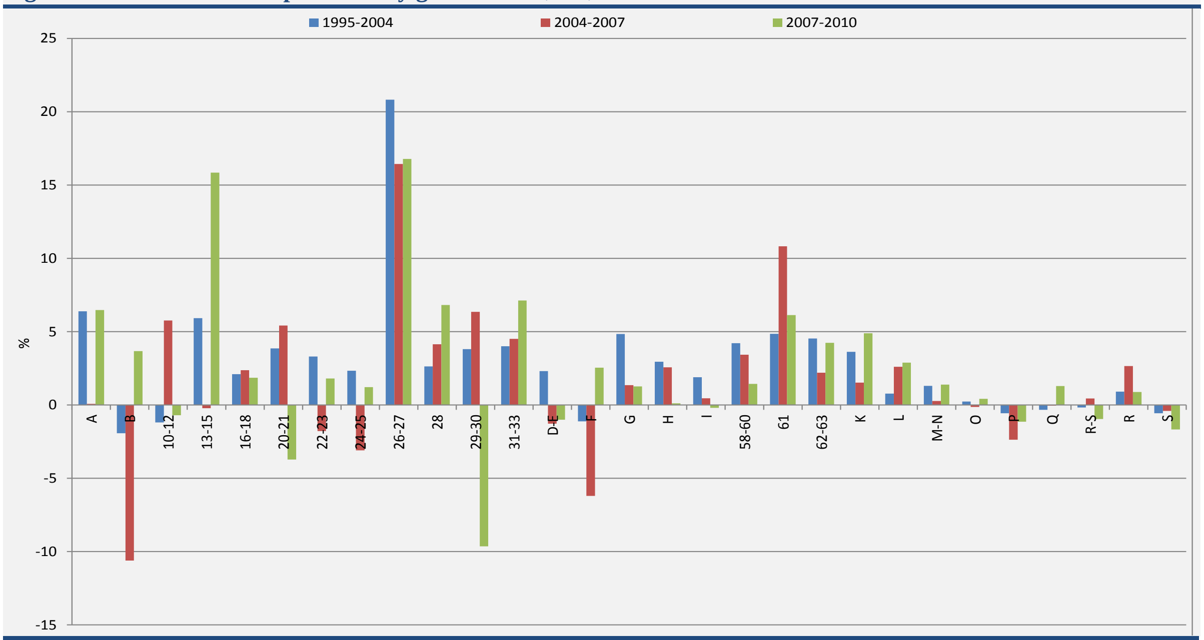
In the US, manufacturing productivity grew by over 4% annually during 2007-2010. One of the few sectors that experienced a worsening in productivity levels was chemicals. The majority of services activities though experienced robust growth, in particular telecommunications, finance and insurance and IT and information services. Productivity growth in the electrical and optical equipment sector did not show signs of slowing down.

61 Care needs to be taken in interpreting these results as measurement issues in this sector may be important.

62 The Information and Communication sector (J code in Nace Rev. 2) comprises the following activities: publishing, audiovisual and broadcasting activities; telecommunications; IT and information services activities.

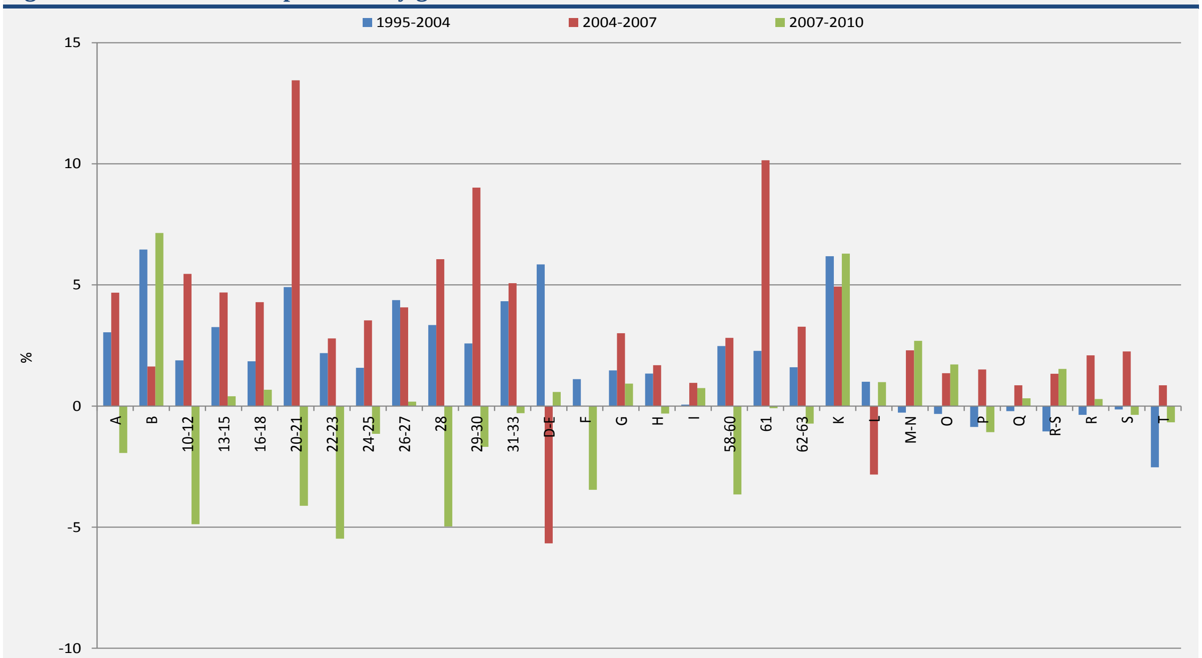
63 The coke and refined petroleum products sector (code 19 in Nace Rev.1) is excluded from this picture.

Figure 3.5. Sectoral labour productivity growth rates, US, 1995-2010



Source: EUKLEMS and own calculations.

Figure 3.6. Sectoral labour productivity growth rates, EU-8, 1995-2010



Source: EUKLEMS and own calculations.

Other interesting lessons can be drawn from the analysis of post-crisis industry trends. In summary, the sectors which contributed to further increase the US productivity advantage are electrical and optical equipment and the majority of manufacturing sectors, as well as construction, and telecommunications (which had shown an outstanding performance in the EU prior to the crisis). Those sectors which helped the EU to narrow the gap in the most recent period include financial activities and business services, accommodation and food, some public services and other services activities. Many of the ICT-using services sectors that had improved their labour productivity in the pre-crisis years continued to perform well; the exception was wholesale and retail, greatly affected by weak consumer demand.

A further extension of the industry level analysis based on growth accounting allows the identification of those factors that played a major contribution in determining productivity growth performance in selected industries. The results, discussed in detail in the background study, reveal that up to 2007 TFP was the main driver of productivity growth in the EU and US manufacturing. In the EU, TFP was also the main source of declining productivity trends after the crisis, next to physical capital contributions. In services the picture is more heterogeneous. In wholesale and retail, the contribution of TFP in Europe is delayed compared to the US, and it particularly affects productivity in the latest years before the financial crisis. In information and communication services, the contribution of TFP was particularly large since the mid-1990s in both countries. Despite a declining productivity performance since the crisis, this sector continues to fare considerably well.

3.2. THE ROLE OF KNOWLEDGE TRANSFER, ABSORPTIVE CAPACITY AND INSTITUTIONS FOR PRODUCTIVITY GROWTH

One way to better understand possible causes of the productivity gap is to consider the impact of investments in intangible assets such as R&D. The importance of investing in innovation activity has long been recognised in the theoretical and empirical literature (Romer 1990, Aghion and Howitt 1992, Park 2008, Nishioka and Ripoll 2012). What is perhaps less often acknowledged is that resources for such innovations tend to be highly concentrated in a small number of advanced OECD countries[64], which have the required skills and institutions in place to invest heavily in R&D. This implies that for countries whose firms are not at the technological frontier, the diffusion of technology from the frontier is likely to be an important source of productivity growth, through both imitation and follow-on innovation and adaptation (Evenson and Westphal, 1995). Knowledge transfers can occur via different channels, such as FDI, joint ventures, reverse engineering, and collaborations. A survey of the biggest EU R&D investing companies shows that knowledge transfer is more important among companies than between companies and the public sector. Knowledge transfer is especially relevant for companies in high R&D intensity sectors[65]. In this section the focus is on the diffusion of technology via intermediate goods trade an approach consistent with existing theoretical models (e.g. Grossman and Helpman 1991). The first objective of the analysis is to assess how knowledge transfers affect productivity growth; secondly, the role of absorptive capacities and barriers to diffusion is taken into account, as these can make an important difference to the extent to which countries benefit from innovations carried out elsewhere.

The methodology used to study the impact of foreign R&D spillovers follows closely the contribution by Nishioka and Ripoll (2012), which requires data on R&D stocks by country and industry and input-output tables capturing inter-industry and inter-country linkages. This is carried out using data on R&D expenditure from the OECD ANBERD database[66], from which a R&D stock for ten manufacturing industries and 20 countries is calculated using the perpetual inventory method. Information on intermediate flows required for the calculation of the R&D stock of intermediates is taken from the recently compiled World-Input-Output-Database (WIOD), which reports data on socio-economic accounts, international input-output tables and bilateral trade data across 35 industries and 41 countries over the period 1995-2009 (see Dietzenbacher et al. 2013)[67].

Though R&D stocks could only be calculated for a limited number of countries and industries, two interesting stylised facts emerge: firstly, over 80% of the R&D stock is concentrated in a small number of industries (electrical and optical equipment, transport equipment and chemicals and chemical products and in particular the pharmaceutical sector which plays a key role among highly innovative industries); secondly, the US and Japan dominate R&D stocks in the sample of countries considered, with respectively 40% and 28% of the total, followed by Germany (11%), France (8%) and the UK (7%). This indicates that these five countries account for 80% of the overall R&D stock, consistent with Eaton and Kortum (1999).

Using these R&D stocks and the information on inter-industry and inter-country linkages makes it possible to calculate the variables capturing the 'direct and indirect R&D content' of intermediate input flows: First, the R&D stocks divided by gross output provides a vector containing the direct R&D requirements by sector and country. This vector is then multiplied with the global Leontief inverse, derived from the WIOD and the global inter-industry, transaction matrix. The latter only includes the

[64] The share of R&D financed by enterprises in advanced countries was 98% in the 1980s and 94% in the 1990s (UNIDO, 2002). Even within developed countries however R&D is concentrated, with Eaton and Kortum (1999) noting that in the late 1980s, 80 percent of OECD research scientists and engineers were employed in five countries (US, UK, Germany, Japan and France).

[65] See: www.jrc.eswww.jrc.es: Tübke, A.; Hervás, F. and Zimmermann, J.: "The 2012 EU Survey on R&D Investment Business Trends", European Commission, Joint Research Centre, EUR 25424 EN, pp.21.

[66] It is important to stress that the BERD data are territory based. Alternatively, attention might be paid to this issue at the company level (e.g. Cincera and Veugelers, 2010).

[67] Some of the associated data have been updated to 2011.

foreign inter-industry flows therefore capturing the role of international R&D spillovers.[68]

As expected, those countries and industries which dominate R&D expenditures also tend to have the highest shares in the direct and indirect use of R&D[69]. Relatively large shares are also found for construction, suggesting that there are strong linkages between manufacturing and this sector. With respect to countries, large increases in the indirect use of R&D can be found for the US, Japan and the rest of the world between 1995 and 2010. China has also experienced a large increase in both direct and indirect R&D usage over time. This increase is solely due to increased flows of R&D intensive intermediates into China over this period (China is excluded from the list of R&D source countries given the limited industry data).

The assessment of the role of absorptive capacity and barriers to diffusion requires the inclusion of additional variables. Absorptive capacity is measured using information from the 2013 release of Barro and Lee's dataset on the average years of secondary schooling in the population over 15 years of age (*Syr*)[70]. As additional indicator of absorptive capacity, the analysis includes the level of R&D taken in logs (Cohen and Levinthal 1989). Data on R&D are extracted from the OECD ANBERD dataset. The role of absorption barriers is assessed by using several OECD indicators. A first set describes regulation in the labour market and includes: an indicator on strictness of regulation of employees on regular contracts (*EPR*), an indicator for strictness of regulations for temporary forms of employment (*EPT*), and an indicator of strictness of regulation and specific requirements for collective dismissal (*EPC*). These variables are on a scale of 0 to 6, with 0 having the least and 6 the most restrictions. To be consistent with the hypotheses of Parente and Prescott (1994, 1999) R&D spillovers are expected to be weaker in countries with higher values for these indices. To examine whether R&D spillovers are affected by the power of labour unions in limiting the take-up of potentially labour-saving technology, further information on trade union density from the OECD is included (*Union*). A further indicator employed is the OECD indicator of product market regulation (*PMR*). The indicator captures the stringency of product market regulatory policy, with higher values being associated with policies that are more restrictive to competition[71]. A further variable that is included is an indicator of the strength of Intellectual Property Rights (*IPR*). IPRs are a policy tool to encourage innovative activities. By preventing the copying and imitation of a patent, IPRs may reduce technology diffusion. However, since information on patents is made public, stronger IPRs may encourage technology diffusion (Breitwieser and Foster 2012). The index of IPRs used is developed by Ginarte and Park (1997) and updated by Park (2008). This index uses information on the coverage of patents, membership in international treaties, enforcement mechanisms, and restrictions on patent rights and duration, with higher numbers indicating stronger protection[72].

Finally, information from the Heritage Foundation's Index of Economic Freedom is used for additional variables. In particular, the sub-indices on investment freedom (*invest*) and financial freedom (*finance*) are included, where higher numbers imply more restrictions[73].

3.2.1. Empirical model and estimation

To study the impact of foreign R&D content of intermediates on labour productivity the following production function is used:

$$\Delta \ln y_{iht} = \Delta \ln F_{F,iht} + \beta_1 \Delta \ln k_{iht} + \beta_2 \ln y_{ih1995} + \alpha_i + \delta_h + \pi_t + \varepsilon_{iht}$$

(3.1)

The growth rate of labour productivity Δlny is dependent on the growth rate of foreign R&D spillovers ΔlnF_F, the growth rate of the capital-labour ratio Δlnk and the initial lagged value of output per worker to allow for conditional convergence. Further industry i, country h and time t fixed effects are included, while ε is an error term. The inclusion of fixed effects controls for unobserved heterogeneity across the respective dimensions. Results are reported

68 Technical details are provided in the background study to this chapter.

69 It should be stressed here that these results are confined to those countries and industries for which reliable R&D data are available. As R&D is concentrated in a few industries and countries, the computation of direct and indirect R&D stocks provide good proxies for international R&D spillovers that can be used in empirical econometric analysis. However, no more detailed inference on source and use country and industries can be made without having better knowledge of R&D stocks across all countries and industries.

70 See http://www.barrolee.com/. These data have been used as a measure of absorptive capacity in similar studies (see for example Falvey et al. 2007).

71 This indicator ranges on a scale from 0 to 6. The data is available at the country-level only and for three years (i.e. 1998, 2003, 2008). Missing years are imputed using linear interpolation. For further details see Wölfl et al. (2009).

72 The index takes on a value between zero and five.

73 The raw data are on a scale of zero to 100, with 100 implying no restrictions. To be consistent with the other measures of absorption barriers this variable is redefined to be equal to $100 - freedom\, variable$. For further details on the construction of these indicators see the background study.

in Table3.1. The negative and significant coefficient on initial output per worker confirms the presence of conditional convergence.

The coefficient on the capital-labour ratio is positive and significant in all specifications, indicating that greater capital intensities are associated with higher labour productivity growth. With respect to the main variable of interest, the coefficient estimates indicate that a 1% increase in the growth of foreign R&D content of intermediates is associated with a higher growth rate of labour productivity of between 0.15% and 0.19%. Thus, these results suggest that the R&D stock of intermediates is positively associated with output per worker.

The second question to address is whether the relationship between the foreign R&D stock of intermediates and labour productivity is affected by the indicators of absorptive capacity and absorption barriers described above. The econometric strategy involves estimating a model of the following form:

$$\begin{aligned}\Delta\ln y_{iht} = {} & \gamma_1 \Delta \ln F_{F,iht} 1(Z_{iht} \leq \lambda) \\ & + \gamma_2 \Delta \ln F_{F,iht}\, 1(Z_{iht} > \lambda) \\ & + \beta_1 \Delta\ln k_{iht} + \beta_2 \ln y_{ih1995} \\ & + \beta_3 Z_{iht} + \alpha_i + \delta_h + \pi_t \\ & + \varepsilon_{iht}\end{aligned}$$

(3.2)

where Z is the indicator of absorptive capacity or absorption barriers and 1 is the indicator function taking the value one if the term in brackets is true. The model differs from a standard linear model in that the elasticity of labour productivity with respect to foreign R&D (i.e. γ) is allowed to differ depending upon whether absorptive capacity is above or below some threshold value (λ). In particular, the elasticity of labour productivity is given by γ_1 if absorptive capacity is below (or equal to) the threshold and is given by γ_2 if absorptive capacity is above the threshold. The actual threshold value is calculated endogenously following Hansen (1996, 1999 and 2000) with significance of the thresholds determined by bootstrapping (see Annex 3.2.C). When estimating this model the threshold variable, Z, is included linearly. The set of threshold variables capturing absorptive capacity and absorption barriers also includes the initial values of labour productivity ($\ln y_{1995}$). This allows for the examination of whether an indicator of relative backwardness impacts upon the relationship between foreign R&D and labour productivity. While being further behind the technological frontier usually means that there is more scope for technological catch-up it could also imply that a country or sector does not have the ability to make use and benefit from advanced technology (see Falvey et al. 2007). As such, the impact of backwardness measures on the relationship between foreign R&D and labour productivity growth is ambiguous from a theoretical point of view.

Results from estimating a single threshold are presented in Table 3.2. where each column presents the threshold estimates for the variable indicated in the header line as motivated in the text above. Coefficients on initial output per worker and the growth of the capital-labour ratio are consistent with the results in Table 3.1. In terms of the threshold results, a variety of outcomes appears. The *backwardness* measure shows that the lower the labour productivity the larger the spillover effects.[74] The coefficient in the low regime (0.264) is more than twice the coefficient in the high regime (0.105) – though both are significant – indicating that foreign R&D spillovers appear to be significantly stronger in countries and industries that are further away from the frontier.

The indicators of *absorptive capacity* (i.e. average years of secondary schooling, *Syr,* and ln*R&D*), produce consistent results. The coefficients indicate that foreign R&D spillovers are larger in countries with a higher number of average years of secondary schooling and in countries and industries which are more R&D intensive. While the difference in coefficients (0.11 versus 0.27) in the case of *Syr* is significantly different, the differences in the case of lnR&D (0.15 versus 0.17) are not significant, i.e. the linear model is preferred.

When labour market indicators are used as a threshold variable, results vary across the different indicators. When using indicators of the strength of regulation on regular contracts and collective dismissal, spillover effects are larger in the low regime (i.e. in countries with less regulations). The coefficient estimates imply that a 1% increase in the growth of the foreign R&D stock has a 0.13%

74 Alternatively one might use interaction terms between R&D and absorptive capacities and barriers. However, the use of the threshold model rather than interaction terms has a number of advantages. Firstly, using threshold models doesn't impose a monotonic change in the effect of the explanatory variable as the threshold or interaction term increases (i.e. the impact of the explanatory variable on the dependent variable can switch signs and change size at different points on the distribution of the threshold variable). Secondly, the coefficients are easier to interpret. The impact of the explanatory variable on the dependent variable is given by a fixed parameter for all observations within a particular regime. With interaction terms it is more difficult to identify the overall impact of a change in the explanatory variable, with researchers often resorting to graphing the relationship for different values of the threshold/interaction variable. Thirdly, when the threshold/interaction variables are bound as in our case (e.g. between zero and six) the threshold model is less open to misinterpretation (e.g. extrapolating beyond the range of the threshold/interaction variable).

increase in labour productivity growth for countries with a value of the EPR below the threshold and a -0.001% decrease for countries above the threshold. A similar change increases labour productivity growth by 0.21% for countries with EPC below the threshold, and by just 0.04% for countries above the threshold. The strength of regulation on temporary contracts produces the opposite result. In particular, while a 1% increase in the growth of the foreign R&D stock is associated with an increase in labour productivity of 0.24% for countries with EPT above the threshold, the change for countries below the threshold is just 0.03%. Finally, when using union density as threshold variable results show that foreign R&D spillovers are larger in the low union density regime. A 1% increase in the growth of foreign R&D is associated with a 0.19% increase in labour productivity growth in the low regime, and a 0.03% increase in the high regime.

In terms of the remaining indicators, one finds that, in the cases of PMR, $Invest$ and $Finance$, the relationship between foreign R&D growth and labour productivity growth is stronger in the high regime, that is, in the regime with more stringent product market, investment and financial regulation. In the case of PMR the coefficient in the low regime is negative and significant. For $Invest$ the difference in the coefficients on the foreign R&D variable between the two regimes is relatively small – though still significantly so (0.149 versus 0.172), while for $Finance$ the differences are much larger (0.08 versus 0.237). Though this might be an unexpected result, it should be noted that these indicators could also reflect institutional quality in a broader sense. As countries with higher institutional quality might attract more R&D intensive firms or have tighter cooperation in R&D activities, etc. these results would be in line with the literature stating that the quality of institutions matters.

Summarising, the results confirm those from the simple model reported in Table 3.1. whereby the foreign R&D content of intermediates is positively associated with labour productivity growth. However, the size of these spillovers depends on absorptive capacities and barriers; countries and industries further behind the technological frontier enjoy stronger foreign R&D spillovers, in line with Falvey et al. (2007). The results also support Falvey et al (2007) as well as Crespo-Cuaresma et al (2008) in finding that foreign R&D spillovers are stronger in countries with greater absorptive capacity (as measured by average years of secondary schooling and R&D spending). In terms of absorption barriers, the results are mixed. With the exception of regulations on temporary workers, stronger labour market regulation and greater union density are associated with lower foreign R&D spillovers, consistently with Crespo-Cuaresma et al. (2008) and Parente and Prescott (1994, 1999 and 2003). Concerning the other absorption barriers related to product market, financial and investment regulation there is no evidence that lower anti-competitive barriers encourage foreign R&D spillovers. Indeed, the reverse appears to hold though these indicators might reflect the overall institutional quality, which is conducive to growth. Finally, one finds that stronger levels of IPR protection can limit the extent of foreign R&D spillovers, possibly by limiting the ability to replicate and borrow technology from abroad.

Table 3.1. Foreign R&D and labour productivity growth

	(1) $\Delta \ln y$	(2) $\Delta \ln y$	(3) $\Delta \ln y$
$\ln y_{1995}$	-0.0104***	-0.0106***	-0.0142***
	(0.000741)	(0.000797)	(0.00289)
$\Delta \ln k$	0.482***	0.422***	0.465***
	(0.0278)	(0.0301)	(0.0334)
$\Delta \ln F_F$	0.190***	0.176***	0.150***
	(0.0180)	(0.0192)	(0.0202)
Time F.E.	No	Yes	Yes
Country F.E.	No	No	Yes
Industry F.E.	No	No	Yes
Observations	15,850	15,850	15,850
R-squared	0.372	0.419	0.455
F-stat	289.2***	338.2***	87.04***

*Notes: ***, **, * significant at 1, 5 and 10%. Robust standard errors in parentheses.*

Table 3.2. Single threshold results

Threshold variable	(1) $\ln y_{1995}$	(2) Syr	(3) ln R&D	(4) EPR	(5) EPT	(6) EPC	(7) Union	(8) PMR	(9) IPR	(10) Invest	(11) Finance
$\ln y_{1995}$	-0.011***	-0.014***	-0.014***	-0.00488	-0.00430	-0.00452	-0.00488	-0.00428	-0.013***	-0.0143***	-0.0142***
	(0.00226)	(0.00225)	(0.00226)	(0.00305)	(0.00304)	(0.00325)	(0.00300)	(0.00292)	(0.00234)	(0.00226)	(0.00224)
$\Delta\ln k$	0.457***	0.465***	0.465***	0.629***	0.632***	0.664***	0.631***	0.621***	0.467***	0.465***	0.454***
	(0.00587)	(0.00586)	(0.00587)	(0.0104)	(0.0104)	(0.0115)	(0.00993)	(0.00999)	(0.00611)	(0.00589)	(0.00588)
$\Delta\ln F_F^{LOW}$	0.264***	0.111***	0.149***	0.126***	0.0307***	0.208***	0.191***	-0.0291**	0.211***	0.139***	0.0807***
	(0.0107)	(0.00766)	(0.00631)	(0.0110)	(0.00999)	(0.0239)	(0.0129)	(0.0121)	(0.00759)	(0.00732)	(0.00792)
$\Delta\ln F_F^{HIGH}$	0.105***	0.212***	0.174***	-0.000967	0.241***	0.0357***	0.0339***	0.156***	-0.057***	0.172***	0.237***
	(0.00705)	(0.00952)	(0.0226)	(0.0145)	(0.0182)	(0.0104)	(0.00963)	(0.0108)	(0.0127)	(0.0103)	(0.00904)
Z		0.00358	9.47e-05	-0.00574	-0.026***	-0.072***	0.000722	-0.00141	-0.00102	-0.00041***	0.000384***
		(0.00754)	(0.000390)	(0.0131)	(0.00347)	(0.0111)	(0.000475)	(0.00830)	(0.00376)	(0.000133)	(0.000126)
Threshold	1.566	3.958	12.270	2.470	3.444	1.959	16.498	1.737	4.180	49.506	32.222
Percentile	21	66	50	64	79	13	18	47	70	90	46
P-value	0.000***	0.000***	0.297	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.008***	0.000***
Observations	15,850	15,850	15,850	9,559	9,559	8,061	10,372	9,742	14,200	15,850	15,850
R-squared	0.461	0.458	0.455	0.448	0.453	0.471	0.461	0.479	0.468	0.455	0.462
F-stat	158.4***	154.6***	153.0***	98.60***	100.5***	93.59***	120.8***	119.9***	151.5***	153.3***	157.7***

*Notes: ***, **, * significant at 1, 5 and 10%. Robust standard errors in parentheses. All models include unreported time, industry and country fixed effects*

3.3. EFFICIENCY ANALYSIS AT THE INDUSTRY LEVEL

This section provides an analysis of the determinants of technical efficiency in Europe, the US and Japan, using stochastic frontier analysis (SFA). Technical efficiency in this study refers to the ability of a firm/industry to achieve the maximum output using the set of available resources. The growth accounting and the regression analysis framework used in the previous sections are based on the assumption that all resources, i.e. capital and labour inputs, are fully utilised and therefore it cannot account for changes in productivity originating from efficiency improvements. Technical efficiency analysis relaxes this assumption and assumes that only the top performing industry is able to use resources in the most efficient way. The other industries will lie below the frontier and the distance to the frontier output defines the efficiency gap. Identifying which industry/country is at the frontier and how efficiency levels have changed over time is important to direct policies towards the correct tool to promote performance. In fact, the best performing industry in terms of productivity might not be the most efficient one, and higher productivity could be achieved by improving the allocation and usage of the available resources. On the other hand, a highly efficient industry might not be the most productive because of, for example, low investments in strategic assets such as ICT and R&D capital; in this case, policies should be directed towards promotion of investments.

The most intuitive way of understanding frontier analysis is to assume that the actual output produced can be lower than the maximum output, given the level of available resources. By defining actual output in industry *i* at time *t* as YA_{it} and the maximum output as YF_{it}, technical efficiency can be expressed as:

$$TE_{it} = YA_{it}/YF_{it} \quad (3.3)$$

Efficiency levels in each industry range between 0 and 1, with higher scores indicating higher efficiency. The derivation of technical efficiency levels requires the estimation of a production function where output, measured by value added, is produced with a combination of inputs. The most basic model includes the total number of hours worked (*H*) and total capital (*K*) as factor inputs. Below, a more extended specification will also be considered that accounts for different types of capital (ICT and non-ICT capital) and intangible assets (labour quality and R&D capital).

The analysis is carried out using industry-level data, extracted from the EUKLEMS database. The total sample includes 16 countries. Of these, 14 are European (AT, BE, CZ, DE, DK, ES, FI, FR, HU, IE, IT NL, SE and UK); the other two being Japan and the US. For each country, data are available for 21 industries, including manufacturing and services[75]. The analysis is conducted between 1995 and 2007 outlining industry performance in the pre-financial crisis period. The exclusion of the downturn is motivated not only by data availability, but also by the consideration that technical efficiency relates to the structure of the industry, and this is less likely to be affected by cyclical factors or exogenous shocks.

Results from the estimation of a frontier production function, expressed in log-levels, are presented in Table 3.3[76]. The first column (1) displays estimates for total capital services, while column (2) distinguishes between ICT and non-ICT capital services. Results are robust across the two specifications and, with the exception of ICT capital, all coefficient estimates are positive and statistically significant. They are consistent with prior knowledge of factor shares. Human capital, measured by the labour quality variable, has a positive, albeit small, effect on productivity. In column (2), the impact of ICT is positive with an elasticity of 0.04%, which is consistent with the existing evidence (Kretschsmer 2012). However, the coefficient is not statistically significant at conventional levels. It is possible that the model specification needs to account for additional complementary assets (Diedrick et al. 2003). In fact, when R&D is included, the significance of the ICT variable improves as in column (4). Another possible explanation is that the impact of ICT is highly heterogeneous across countries and industries, and its effect is likely to be higher in the most ICT intensive users. More importantly, further developments of this analysis will show that ICT exerts an indirect effect on productivity, via the reduction of technical inefficiencies.

Results in Table 3.3. columns (3) and (4), confirm the importance of R&D in increasing productivity, consistently with the reference literature, where this value generally ranges between 0.04 and 0.18 (Griliches and Mairesse 1984; Kumbhakar et al. 2010; Bloom et al. 2013).

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75 Industries included in the analysis are: Food and Beverages, Textile and Leather, Wood & Cork, Pulp, Paper and Printing, Coke, refined petroleum and nuclear fuel, Chemicals, Rubber and Plastic, Other non-metallic minerals, Basic metals, fabricated metal products, Machinery NEC should this be n.e.c., Electrical Equipment, Transport Equipment, Manufacturing NEC should this be n.e.c.,, Transport and Storage, Post and Telecommunication, Business Services, Electricity, Gas and Water, Construction, Wholesale and Retail, Financial Intermediation, Other Community and Social Services. This classification is based on NACE Rev. 1 and differs from the one used in the Section 3.1.3.

76 The estimation of the production function in the panel dimension requires the introduction of fixed effects to control for cross-sectional time-invariant heterogeneity. Along with country- and industry-specific intercepts, the specification also includes a set of time dummies to control for unknown or unobserved factors that are likely to affect all industries at different points in time.

Table 3.3. Estimation of stochastic frontier production function
Dependent variable: Value added

	(1)	(2)	(3)	(4)
Total number of hours worked	0.790***	0.755***	0.632***	0.612***
	(0.031)	(0.031)	(0.036)	(0.037)
Tangible assets				
Total capital	0.351***		0.446***	
	(0.024)		(0.028)	
Non-ICT capital		0.394***		0.445***
		(0.024)		(0.029)
ICT capital		0.019		0.026
		(0.017)		(0.020)
Intangible assets				
Labour quality	0.011***	0.010***	0.008***	0.007***
	(0.002)	(0.002)	(0.002)	(0.002)
R&D capital			0.061***	0.061***
			(0.008)	(0.008)
Constant	1.418***	1.154***	1.246***	1.248***
	(0.168)	(0.171)	(0.189)	(0.189)
Gamma	0.401	0.343	0.394	0.433
Likelihood ratio test	11.025	5.176	7.434	9.663
(P-value)	(0.000)	(0.011)	(0.000)	(0.000)
Wald test (P-value)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
Observations	4532	4519	3650	3488

*Notes: ***, **, * significant at 1, 5 and 10%. Gamma is the proportion of the total error variance due to inefficiencies. The Likelihood ratio test is a test of the null hypothesis that there are no technical inefficiencies in production.*
Source: EUKLEMS and OECD ANBERD.

The inclusion of R&D does not significantly affect the coefficient estimates for labour quality, and generates only a marginal increase in the effect of total capital – see column (3) and non-ICT capital in column (4)[77]. This is a consequence of the complementary relationship between R&D and capital assets[78].

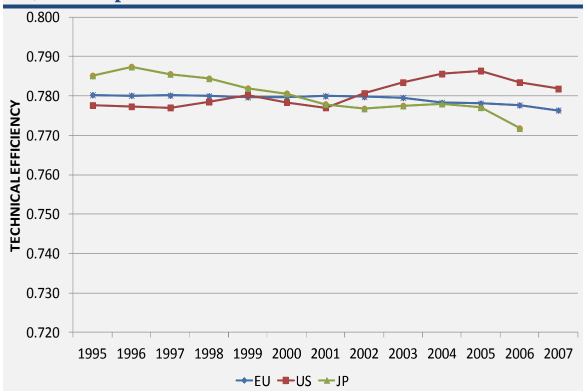
The SFA modelling framework allows the derivation of technical efficiency (TE) for each industry/time period. Estimates of technical efficiency can be derived from any of the specifications presented in Table 3.3. , hence a choice needs to be made to carry out the analysis. The last row of the table shows that the number of observations drops substantially when including R&D, as information on this asset is missing for several service industries in various countries. Given that the main objective of this

[77] Diagnostic statistics are presented at the bottom of Table 3.3. The Gamma parameter measures how important inefficiencies are in each model. A value of 1 indicates that all deviations from the frontier are due to inefficiency, while a value of 0 implies that there are no inefficiencies; in the latter case, SFA does not provide any additional information compared to OLS. In this study, the Gamma parameter is approximately equal to 0.4 meaning that inefficiencies are important and explain 40% of the total residual variation. The presence of inefficiencies is also assessed via the Likelihood Ratio test, which confirms that this component is statistically significant. The Wald test is a test of the null hypothesis that all coefficients are jointly equal to zero. The null is rejected in all specifications.

[78] The impact of the total number of hours worked is significantly lower in regressions 3 and 4, compared to the first two columns of Table 3.3. This is related to the fact that a large proportion of R&D costs is composed of the wages of employees involved in R&D activities. This 'double counting' is a well-known phenomenon in productivity studies (Schankerman1981, Guellec and van Pottelsberghe 2004).

section is to analyse efficiency trends across the full spectrum of manufacturing and services, the specification in column (2) is used to derive technical efficiency scores[79].

Figure 3.7. Average technical efficiency (TE) in the EU US, and Japan

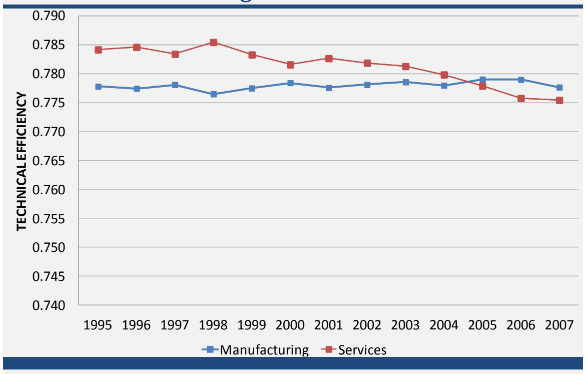


Source: EUKLEMS Database and authors' computations.

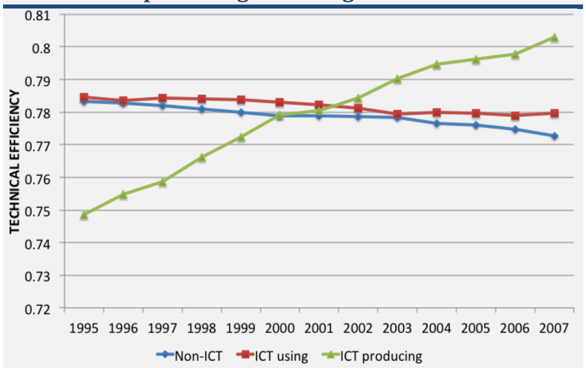
Figure 3.7. presents average efficiency scores for the EU, the US and Japan. Although actual efficiency levels do not differ greatly across economies, their variation over time shows some interesting patterns. In the mid-1990s, the US had lower efficiency levels than Japan and Europe, but then TE increased rapidly placing the US at the frontier since 2002. Existing evidence dates the resurgence of US productivity to 1995, around seven years before the aggregate increase in efficiency. This difference can be explained by the presence of lags in the full implementation of the new technology and the reorganisation of production, emphasised in the General Purpose Technology (GPT) literature (Hornstein and Krusell 1996, Aghion 2002). While the existing evidence mainly refers to the direct impact of ICT on productivity, here the analysis provides new results supporting the GPT nature of new digital technologies. From 2002 to 2005 the efficiency gap between the US and the other two economies widened. However, from 2005 efficiency levels fell in the US, while the EU trend remains virtually unchanged. Japan was the frontier country in 1995 but its efficiency declined from 1996, and since 2000 its efficiency has been below the European average. These patterns are not dissimilar from trends in TFP levels discussed in Jorgenson and Nomura (2007). Similarly to the US, in Japan changes in efficiency follow changes in productivity with a lag of about five years.

A look at average TE in selected groups of industries provides insights on the ones performing better. Panel A of Figure 3.8. presents mean efficiency trends in manufacturing and services. This shows that services have experienced a declining efficiency performance over time, while in manufacturing efficiency has remained fairly stable over the period. Figure 3.8. Panel B and Figure 3.9. Panel A show that efficiency

Figure 3.8. Technical efficiency
Panel A. Manufacturing and services



Panel B. ICT producing and using industries



Source: EUKLEMS Database and authors' computations.

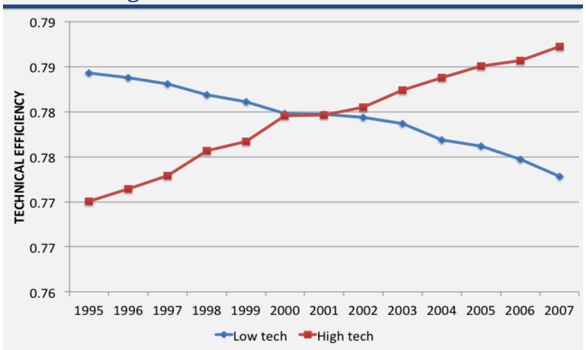
has been increasing over time in the most innovative sectors, namely ICT producing and high-tech industries. This suggests that increases in productivity went hand-in-hand with increases in efficiency until 2007. The efficiency in the ICT-producing sector increased by 5%, from 0.75 in 1995 to 0.80 in 2007, while improvements were more moderate in high-tech industries (approximately 2%).

Panel B of Figure 3.9. focuses on services, distinguishing between knowledge-intensive and non-knowledge intensive industries. While the overall performance of the tertiary sector has been declining over time, this figure reveals that the average picture is influenced by the dynamics of low knowledge-intensive services, as they are characterised by a steady decrease in TE. On the other hand, the most knowledge intensive industries, after a dip in efficiency in 2000, performed relatively well, with increasing efficiency throughout the period.

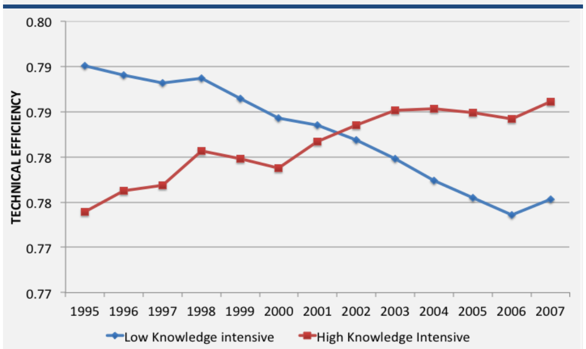
[79] The correlation of TE scores arising from the four specifications is very high, ranging between 0.97 and 0.99. Hence, the exclusion of R&D does not affect the estimation of TE.

Figure 3.9. Technical efficiency in high-tech and low-tech industries

Panel A. High-tech and low-tech



Panel B. Knowledge and non-knowledge intensive services



Source: EUKLEMS Database and authors' computations.

3.3.1. Reducing efficiency gaps: discussion of the main determinants

Understanding why industries vary in the extent to which they use resources effectively, and what policies might be more suitable to foster efficiency performance, requires the extension of frontier analysis to account for the factors that might cause industries to fall below the frontier and therefore widen efficiency gaps. This study focuses on the role played by ICT capital and the business environment where industries operate. The assessment of the impact of these factors on technical efficiency is obtained by the empirical estimation of the following relationship:

$$TE\ GAP_{it} = a_0 + \sum a_j Indicator_{ct} + \theta K\_ICT_{it} + \gamma time_{it} + \varepsilon_{it} \quad (3.4)$$

γ is a simple time trend that captures how an efficiency gap is determined by exogenous technological changes[80] and ε_{it} is the error term. The inclusion of a large number of indicators naturally causes co-linearity problems, hence the researcher needs to deal with the trade-off between efficiency of the estimator (which is reduced in the presence of collinearity) and omitted variable bias. To address this issue, the estimation will sequentially include different indicators, checking for the presence of ICT and the degree of competitiveness in all specifications[81]. The decision to include these two factors is driven by the existing evidence that suggests the presence of complementarities between, for example, product market regulation and employment protection legislations (Griffith et al. 2007, Fiori et al. 2012)[82]. The analysis uses a wide range of indicators that have been rescaled so that all vary between 0 and 1, with larger values indicating more stringent regulation.

Table 3.4. to Table 3.6 present the sign of the impact for each of the factors affecting technical efficiency, and the related statistical significance. Table 3.4. presents a summary of the results based on a specification that includes ICT and a set of indicators capturing the degree of market competitiveness. The latter includes the Upstream Regulation Index (RI), which assesses the impact of anti-competitive legislation in the tertiary sector on the performance of downstream sectors that use services as a production input (Conway et al. 2006); Enforcing Contract Time (ECT), which is based on the number of days to enforce a contract in each country (World Bank 2012); and two alternative measures of competitiveness, the Herfindal index and the degree of industry fragmentation[83]. The coefficient for ICT is negative and statistically significant in all specifications, indicating that this asset plays a very important role in lowering inefficiencies in the use of resources. Although ICT did not have a significant effect in the estimation of the production function, it plays an important role in reducing efficiency gaps, which will also affect productivity but in an indirect way. This result is particularly interesting when compared with the existing industry-level evidence, which usually fails to find significant effects of ICT on TFP growth (Stiroh 2002, Basu et al. 2004, Acharya and Basu 2010). This implies that distinguishing between TFP and TE can provide important insights on the role of ICT. Up to now, this issue has been unexplored by the economic literature.

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80 The estimation of the efficiency gap is carried out simultaneously with the estimation of the productivity frontier, using Maximum Likelihood methods. This one-step procedure guarantees consistency in the coefficient estimates.

81 The authors also tried to include intangible assets (R&D and labour quality) as determinants of both productivity and efficiency. However, these estimates were highly unstable, hence such factors were only included in the specification of the production function (see Table 3.3).

82 The impact of the latter factor is always accounted for with the use of the upstream Product Market Regulation index (RI), unless otherwise specified.

83 The Herfindal index and the indicator of industry fragmentation are derived using information from the Amadeus database, made available via EUKLEMS.

Consistently with the existing evidence on the link between the lack of competition and productivity (Buccirossi et al. 2012, Conway et al. 2006), Table 3.4. indicates that higher values of upstream regulation significantly increase the efficiency gap. In other words, administrative restrictions on competition in the services market have widespread negative effects on production efficiency, well beyond the tertiary sector. This effect is robust to the use of alternative variables that describe the degree of competitiveness of the market, such as the Enforcing Contract Time (ECT), the Herfindal index and industry fragmentation. Note that the sign of the latter is negative as higher values indicate higher fragmentation, which is associated with more competition. Hence, results in Table 3.4. provide strong support for the hypothesis that a more competitive business environment reduces the efficiency gap.

workers can have opposite effects on performance. For example, Damiani et al. (2013) document that deregulation of temporary contracts negatively influences TFP growth in European industries. These findings suggest that excessive flexibility in the use of temporary workers leads firms to use this category of workers to buffer cyclical demand movements (Gordon 2011), rather than attempting to find the most efficient way to combine factor inputs[84]. The introduction of minimum wage legislation also constrains the efficient use of labour input by increasing the efficiency gap, through reducing competitiveness in the labour market, a claim that is frequently used by those scholars who opose the introduction of the minimum wage (Currie and Fallick 1996)[85].

The final set of indicators accounts for the effect of financial market regulation, property right protection and regulation of FDI on the efficiency gap. Financial market regulation is measured using three indicators: the financial reform index, constructed by combining liberalisation scores on seven different areas of the financial market (Abiad et al. 2008); the financial freedom index, as defined in Section 3.2; and the ratio of product market capitalisation over GDP (Beck et al. 2009). The indicator of property rights regulation is defined in Section 3.2. The FDI regulation index summarises information on four forms of legal intervention (equity restrictions, screening and approval requirements, restrictions on foreign key personnel and other operational restrictions; see Kalinova et al. 2010). Results including these indicators are presented in Table 3.6. Both the financial reform and the financial freedom indicators

Table 3.4. Reducing the efficiency gap: the role of product market competition

	(1)	(2)	(3)	(4)
ICT capital	-0.623***	-0.636***	-0.693***	-0.004
Upstream regulation (RI)	3.081***	3.111***		
Enforcing contract time		0.639***		
Herfindal			0.747**	
Industry fragmentation				-1.097***
Wald test (P-value)	<0.001	<0.001	<0.001	<0.001
Observations	3648	3648	2454	2256

*Note: ***, **, * significant at 1, 5 and 10%. All specifications include a time trend. A negative sign implies that the variable decreases the efficiency gap.*

Table 3.5. reports results based on a specification that includes indicators of employment protection legislation. Three of these (EPR, EPT, EPC) are described in Section 3.2. The EPL burden indicator is an industry level variable based on the notion that EPL, although it applies uniformly to all industries within a country, is more binding in those industries that rely on lay-offs than in industries characterised by a higher degree of voluntary turnover (Bassanini et al. 2009). NMW stands for National Minimum Wage and it is only available for those countries where NMW is prescribed by law (Visser 2011). Considering the role of NMW is interesting in the light of the political and economic debate concerning its effect on employment outcomes (Card and Krueger 1995, Neumark and Washer 2008). Results in Table 3.4. show that more stringent EPL for regular workers and collective dismissals significantly increases the efficiency gap. On the other hand, regulation on temporary workers has the opposite effect, indicating that stronger protection on this kind of contracts decreases inefficiencies. This finding is not unexpected as existing evidence shows that the legal discipline on regular and temporary

[84] This result is also consistent with those in section 3.3 of this chapter, where countries with higher employment protection for temporary workers enjoyed higher spillovers from foreign R&D stocks.

[85] In the basic textbook model of labour demand an increase in the minimum wage reduces the employment in the covered sectors of those workers whose wage rates would otherwise fall below the minimum” (Currie and Fallick 1996; p. 405).

Table 3.5. Reducing the efficiency gap: the role of employment protection legislation

	(1)	(2)	(3)
ICT capital	-0.574***	-0.559***	-0.557***
Upstream regulation (RI)	4.304***	2.926***	3.141***
EPL burden indicator	0.142***		
EPL regular		4.351***	3.513***
EPL temporary		-2.173***	-3.007***
EPL collective dismissal			2.716**
NMW			1.372***
Wald test (P-value)	<0.001	<0.001	<0.001
Observations	3146	3648	3021

*Note: ***, **, * significant at 1, 5 and 10%. All specifications include a time trend.*

consistently show that lower levels of regulation in this market increase the efficiency gap. Conversely,

access to alternative sources of finance, like the bond market, significantly improves TE performance. This follows the main results of the literature, where a positive relationship between financial development and growth is usually found (Rajan and Zingales 1998, Maskus et al. 2012), but where it is also suggested that excessive financial liberalisation may be detrimental for performance when it discourages savings or triggers financial instability (Ang 2011, Ang and Madsen 2012). The recent financial crisis has shown that excessive freedom in the financial market can have catastrophic consequences.

Results also show that increasing protection of intellectual property reduces the efficiency gap, although the effect is not statistically significant. This suggests that property rights regulations might not be relevant for efficiency improvements. The measure of openness to external markets, summarised by the FDI regulation index, shows that stricter FDI rules decrease the efficiency gap. Although this goes against the extensive literature on the positive relation between trade openness and growth, there are several reasons that might explain this result in the sample used in this study. Firstly, the countries considered have very low levels of regulations, hence trade openness is not a major issue (note that the coefficient is only significant at the 10% significance level). Additionally, next to the literature which emphasises the importance of trade openness for growth, there are also contributions that support the positive role of protectionist measures. For example, estimates in Yanikkaya (2003) predict a positive and significant relationship between trade barriers and growth. Although these results are driven by developing countries, they nevertheless imply that the relationship between trade and growth is quite complex. Moreover, the present analysis deals with the specific issue of technical efficiency and it is possible that the impact of FDI openness on growth differs from the effect of this factor on technical efficiency. Additionally, product market and labour market regulations might prevent or delay the necessary adjustments in the combination of inputs, which would allow countries to fully benefit from globalisation. Hence, it is possible that increasing international openness may lead to higher levels of

Table 3.6. Reducing the efficiency gap: financial regulation, intellectual property rights protection, openness

	(1)	(2)	(3)	(4)
ICT capital	-0.626***	-0.545***	-0.496***	-0.502***
Upstream Regulation (RI)	3.057***	2.441***	2.204***	2.255***
Financial Reform Index	-1.451	-1.849**		
Private Bond Mkt Cap/GDP		-0.307***	-0.317***	-0.288***
Financial Freedom			-2.650***	-2.776***
IPR				-0.080
Regulation of FDI				-1.303*
Wald test (P-value)	<0.001	<0.001	<0.001	<0.001
Observations	3648	3648	3648	3648

*Note: ***, **, * significant at 1, 5 and 10%. All specifications include a time trend.*

production efficiency only over a relatively long time horizon. Further investigation of this issue goes beyond the scope of the present analysis but suggests an interesting development for future research.

3.4. EU PRODUCTIVITY PERFORMANCE AT THE FIRM LEVEL: EVIDENCE FROM EU-EFIGE SURVEY ON MANUFACTURING FIRMS

This section complements the industry level analysis with evidence based on a newly available firm level dataset (EU-EFIGE) which collects information on 14,759 manufacturing firms across seven EU countries (Austria, France, Germany, Hungary, Italy, Spain and the UK)[86], over the period 2007-2009. The analysis focuses on how the financial crisis has affected performance and innovation strategies at the micro level. The focus is on productivity (TFP) rather than efficiency, as data constraints prevent the use of Stochastic Frontier methods.

The financial crisis of 2008-2009 was a watershed for the European Union as it widened growth disparities among the Member States.

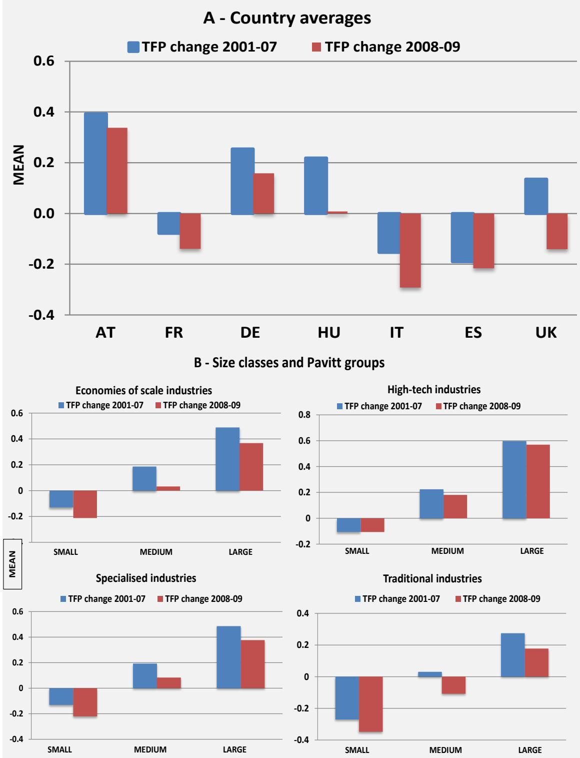
Figure 3.10. (Panel A) describes TFP changes between 2008 and 2009 compared to the average annual rate of growth in the pre-crisis period (2001-2007). The average rate of TFP growth was negative in the early 2000s, i.e. before the crisis, in France, Italy and Spain. With the downturn, productivity performance worsened in all countries, but remained positive in Austria, Germany and Hungary. The UK is the country where the deceleration in TFP was most dramatic between the two sub-periods, falling from a positive rate of 16.5% to -15%. In absolute values, Italian firms registered the worst rates of TFP change in the downturn (-29%). There are some important regularities in productivity dynamics in firm-level performance. On average, those firms performing better in terms of TFP growth before the downturn, as measured by the average rate of change between 2001 and 2007, also presented higher rates of productivity growth during the period 2008-2009.

Panel B in Figure 3.10. provides a breakdown of TFP performance, distinguishing among size classes and industry categories. Confidentiality issues prevent the use of detailed industry information, hence the analysis will follow the Pavitt (1984) taxonomy to control for major industry characteristics.

Small-sized companies (fewer than 50 employees) were diffusely characterised by negative productivity dynamics. Large companies (over 249 employees) outperformed other types of firms in all productions[87].

After a period of moderately positive rates of TFP growth, medium-sized firms (50-249 employees) faced a severe drop during the crisis. A relevant exception is in the science-based firms whose productivity growth was positive although slightly reduced during the crisis with respect to the early 2000s. The collapse of the market in 2008-2009 severely hit traditional industries, which experienced

Figure 3.10. TFP growth 2001-07 and 2008-09 (by country, size class and Pavitt)



Note: S=small firms. M=medium firms. L=large firm,
Source: EFIGE dataset.

a fall in TFP levels of almost 30%, especially because of small firms' performance.

Firm-level productivity is pro-cyclical as, in the short term, it reflects shocks to demand conditions. Therefore, to better understand cross-country differentials in TFP dynamics, it is necessary to look at how the 2008-2009 crisis affected the performance of EU firms in terms of turnover fall. In Europe, sales declined in 72% of the companies in 2009 compared

[86] The number of firms varies across countries, with approximately 3,000 firms in France, Germany, Italy and Spain, 2067 firms in the UK, 443 in Austria and 488 in Hungary. The sample was originally designed to be representative of the manufacturing sector and, to this aim, was stratified along three dimensions: industries (11 NACE-CLIO industry codes), regions (at the NUTS-1 level of aggregation) and size class (10-19; 20-49; 50-250; more than 250 employees). The dataset does not provide information on firms exiting the market due to the crisis.

[87] Small firms (less than 50 employees) make up 73% of the overall sample, medium firms (between 50 and 249 employees) account for 20% and large firms (more than 249 employees) accounts for 7% of the sample. This implies that large firms are over-represented, due to their relevance in aggregate competitiveness dynamics (Altomonte and Aquilante 2012; p. 5).

Table 3.7. Percentage of firms experiencing a turnover reduction in 2009 compared to 2008 (by size class)

	AT	FR	DE	HU	IT	ES	UK	Total
Small firms	60.3	69.6	61.6	75.4	74.3	82.2	66.7	71.5
Medium firms	72.2	73.4	68.9	82.2	80.0	80.8	64.7	72.9
Large firms	67.4	73.8	56.9	68.9	80.0	84.3	65.7	69.7
Total	63.7	70.7	63.1	76.4	75.4	82.1	66.1	71.7

Source: EFIGE dataset.

Table 3.8. Percentage of firms experiencing a turnover reduction in 2009 compared to 2008 (by Pavitt groups)

	AT	FR	DE	HU	IT	ES	UK	Total
Economies of scale	66.7	71.9	64.5	77.4	75.3	87.4	68.4	73.0
High-tech	65.2	49.2	48.0	73.3	54.5	69.8	49.5	53.9
Specialised	74.2	72.2	71.9	76.4	77.5	83.9	68.1	74.8
Traditional	61.4	71.9	59.7	75.7	76.5	80.8	65.1	71.9

Source: EFIGE dataset.

to the pre-crisis values. This share is considerably higher for Spain (82%), Hungary and Italy (around 75%). In Germany, the percentage of the sample facing a turnover fall is 63%. As Table 3.7. shows, the financial turmoil caused a real downturn that was very pervasive involving all types of firms.

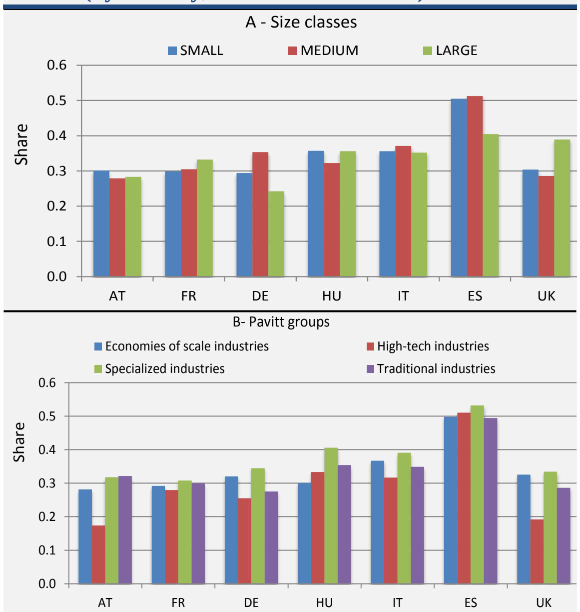
The industry breakdown provided by Table 3.8. illustrates that specialized suppliers were hit by the crisis as 75% of companies experienced a decrease in sales. From this perspective, the crisis looks more severe in Spain, Italy, and Hungary where the proportion of firms facing a turnover reduction was above the EU average. Scale-intensive firms were also considerably affected by the crisis, particularly in Spain where almost 90% of the total sample reduced sales. On the other hand, the fall of turnover was less pervasive among high-tech firms.

Rates of investment fluctuate remarkably along the business cycle, reflecting firms' expectations of future sales and profitability. In the recent downturn, the fall in investment was exacerbated by the credit crunch. Along with the intensity of the business cycle, cross-country differentials in firms' capital formation reflect disparities in the structure of the domestic financial systems. In Europe, 43% of firms reduced planned investment in equipment between 2008 and 2009 (ICT and non-ICT assets). This proportion rises with firm size, from 42% for small firms to 47.6% of large firms (Table 3.9). The greater sensitivity of investment in large companies probably depends on a wider exposure to the international market, and therefore to the collapse of foreign demand.

However, there are big differences among countries, as large firms performed relatively better in Germany, Austria and, to a lesser extent, in the UK.

The decrease in investment was quite diffuse throughout the economy in France and Spain, where between 55% and 60% of the sample reduced their

Figure 3.11. Firms reducing product/process innovation in 2009 (by country, size class and Pavitt)



Source: EFIGE dataset.

commitments. Conversely, the effect of the credit crunch and the demand fall appears less severe in Austria, Germany and Italy, where only 30-35% of manufacturing firms cut investment plans. The analysis of investment dynamics following the Pavitt groupings provides additional insights (Table 3.10). Although the overall average is similar for traditional, specialised suppliers and scale intensive industries, there is large heterogeneity across countries. Supplier-dominated (traditional) firms performed relatively better in Germany, Italy and Austria, but struggled in France. Among high-tech firms, Austria is the country with the smallest decrease in investments, followed by Germany, the UK and Italy. Spain and France show a parallel performance in specialised providers and scale- intensive firms.

Innovation performance of EU firms is examined using a large spectrum of indicators. The most comprehensive measure at hand from the EU-EFIGE dataset is the percentage of companies introducing a process or/and product innovation between 2007 and 2009 (Table 3.11.).

In Europe, 65% of companies were engaged in such activities. The breakdown is 61% for small firms, 73% for the medium-sized firms and 79% for the largest ones. Austria leads in terms of the proportion of firms involved in innovation, followed by Spain and Italy. It is well known that this kind of qualitative indicator is more suited to describe the innovative capacity in less technologically advanced production, which explains why Germany is at the bottom of the ranking. Germany recovers in the ranking when looking at proxies for formal innovation such as the proportion of R&D-performing firms, R&D intensity over sales and patenting.

On average, one out of two EU firms declares that it carries out R&D projects. Again, Austria shows the largest proportion of innovators, closely followed by Germany and Italy. Engagement in formal research is rather low in Spain and in Hungary[88].

The financial crisis and the consequent downturn caused a drop in firm demand and severely clouded expectations of future sales. These issues, combined with tighter credit conditions, led one third of EU firms to postpone their programmes for product or/and process innovation (Figure 3.11 Panel A). The share of firms reducing their engagement in innovation activities reaches 50% among Spanish SMEs. A larger heterogeneity emerges when looking at how firms changed their innovation programmes because of the deepening crisis across industry groupings (Figure 3.11, Panel B). Half of the Spanish firms postponed product/process innovation; this proportion is similar among Pavitt categories. Apart from Spain, innovation activities of high-tech companies were less affected by the turmoil.

Table 3.9. Percentage of firms reducing investment in 2009 compared to 2008 (by size class)

	AT	FR	DE	HU	IT	ES	UK	Total
Small firms	32.3	55.1	26.8	46.4	35.8	52.0	39.5	42.0
Medium firms	45.5	54.9	36.0	41.5	36.0	55.5	43.2	44.2
Large firms	40.6	62.6	31.5	60.5	50.4	58.6	43.0	47.6
Total	35.8	55.7	29.8	46.6	36.7	52.9	40.6	42.9

Source: EFIGE dataset.

Table 3.10. Percentage of firms reducing investment in 2009 compared to 2008 (by Pavitt groups)

	AT	FR	DE	HU	IT	ES	UK	Total
Economies of scale	37.8	52.8	29.1	46.6	38.2	56.7	40.8	43.0
High-tech	21.1	43.7	22.7	41.7	29.4	42.4	24.7	31.3
Specialised	41.7	55.0	37.4	39.3	40.2	57.8	40.9	44.9
Traditional	37.2	58.8	26.7	50.6	35.6	51.1	41.9	43.2

Source: EFIGE dataset.

Table 3.11. Firm innovation performance in 2007-2009: summary of results (% of total)

	AT	FR	DE	HU	IT	ES	UK	Total
Product/process innovation	75.9	56.3	64.6	55.7	67.5	69.6	67.3	64.9
Reduction product/process innovation (in 2009)	29.4	30.2	30.4	34.8	35.8	50.1	30.3	35.4
Doing R&D	55.5	50.7	54.6	26.8	55.0	46.0	53.2	51.2
R&D intensity on turnover	6.5	6.2	7.8	5.7	7.3	7.1	6.9	7.0
Patent an innovation	19.4	11.7	15.8	4.3	14.2	11.2	14.0	13.2

Source: EFIGE dataset.

3.4.1. Analysis of the productivity effect of the crisis: econometric evidence

This section investigates how the financial crisis affected firms' productivity performance by developing an empirical model where the rate of growth of TFP between 2008 and 2009 ($\Delta lnTFP_{i,2008-2009}$) is explained by a large set of company characteristics, all defined as dummy

[88] For a comparison of the EU with non-EU R&D performance see Moncada-Paternò-Castello et al. (2010). This study shows that the US has a stronger sectoral specialisation in the R&D intensive (especially ICT related) sectors, compared to the EU. Furthermore, the population of R&D investing firms within these sectors is relatively larger.

variables[89]. The analysis is based on the following specification:

$$\Delta \ln TFP_{i,2008-09} = \alpha_1 \ln TFP_{i,2008} + \alpha_2\, CRISIS_i + \alpha_3\, INTANG_i + \alpha_4\, OPENESS_i + \alpha_5\, LABOUR_i + \alpha_6\, FINANCE_i + \alpha_7\, OTHER_i + size_i + pavitt_i + country_i + \varepsilon_i$$

(3.5)

To allow for the dynamic profile of productivity performance, the level of TFP in 2008 is included among the regressors. A negative coefficient on this variable would indicate the presence of a catch-up effect, whereby lower productivity firms fill the gap with the best performing ones. The first set of dummy variables (*CRISIS* in eq. 3.5*)* seeks to check for the effect of the financial crisis on TFP. This set includes information on the reduction of turnover, investment and innovations. These are all expected to negatively impact on TFP growth. A second set of dummies (*INTANG*) captures firms' decisions in relation to invest in intangible assets and provides information on whether the firm has conducted R&D investments over the period[90], employed a higher proportion of educated workers compared to the national average (human capital) or implemented some relevant organisational changes. Extensive evidence at the micro economic level shows that intangible factors concur to build the knowledge stock of the company, enhancing its productivity performance and, more generally, the degree of competitiveness (Hall et al. 2009, O'Mahony and Vecchi 2009).

Another set of controls looks for firms' engagement in the international market (*OPENESS*). These include firms' decision to import material or service intermediate inputs in 2008 or before, and the decision to carry out FDI. An additional dummy variable for companies belonging to foreign groups is also considered to assess whether there is a positive relationship between firms' participation in international networks and productivity growth. The existing literature generally supports the evidence that international firms are more productive than those less prone to undertake foreign activities (Wagner 2012). However, little is known about the performance of these firms during particularly critical economic conditions.

The model also accounts for the role of institutional settings on firms' productivity, consistently with the analysis in previous sections of the chapter. The information on the EFIGE data set makes it possible to check how companies adjusted their activities as a result of the changes in labour market regulations throughout the 2000s (*LABOUR* variable in the econometric model 3.5). The impact of such reforms is captured by a dummy variable which identifies companies resorting to temporary and part-time contracts. Existing evidence shows that a high share of temporary workers is negatively associated with productivity growth, due to the low experience and low endowments of firm-specific human capital of such employees (Daveri and Parisi 2010).

Due to the financial nature of the downturn, it is also important to check whether worsening conditions in the credit market affected firms' performance (variable '*FINANCE'* in the econometric model 3.5). This is captured by the inclusion of a dummy variable that takes value of 1 if the firm required credit during the crisis but did not obtain it. There is considerable evidence that EU SMEs were severely hampered in accessing credit but the issue of whether this translated into lower rates of productivity growth is less explored (Houlton et al. 2012). Firms' decisions to invest in intangible assets and to compete on international markets are related to their managerial abilities (Castellani and Giovannetti 2010). The analysis accounts for this issue by including a family management variable (a dummy equals 1 if the share of managers of the controlling family is higher than the national mean) and a quality certification dummy, which equals 1 if the firm has received some quality equivalent certification. Managerial practices explain large variation in firm productivity growth, negatively affecting aggregate productivity growth (Bloom and Van Reenen 2007, 2010).

Other control variables include the age of the firm, country, size and industry (Pavitt) dummies. The productivity impact of firms' age is captured by a dummy variable taking the unit value if the firm is less than six year old. This controls for possible differences in performance between young and relatively old firms. The former have higher growth potential, but they are not necessarily as productive (or efficient) as the incumbents. During the 1990s, highly innovative start-ups were found to make an important contribution to aggregate productivity growth in the US, whilst their role in the EU was less clear (Bassanini and Scarpetta 2002).

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89 The cross-sectional regression model is estimated by OLS, using heteroskedasticity robust standard errors.

90 R&D-performing firms is the preferred measure of innovation effort among those available as its effect is more robust across specifications.

Table 3.12. Determinants of TFP growth 2008-2009: OLS regression (by total sample, size classes and Pavitt groups) Dependent variable: TFP change 2008-2009

	(1) Total sample	(2) Small firms	(3) Medium firms	(4) Large firms	(5) Scale intensive	(6) High-tech	(7) Specialized	(8) Traditional
Log TFP 2008	0.881***	0.880***	0.903***	0.843***	0.898***	0.900***	0.886***	0.868***
	(0.010)	(0.012)	(0.017)	(0.043)	(0.017)	(0.054)	(0.019)	(0.016)
Crisis effect								
Turnover reduction	-0.063***	-0.065***	-0.048***	-0.079***	-0.063***	-0.074***	-0.055***	-0.063***
	(0.005)	(0.005)	(0.010)	(0.021)	(0.010)	(0.021)	(0.011)	(0.006)
Investment reduction	-0.019***	-0.013**	-0.034***	-0.025	-0.019**	-0.013	-0.032***	-0.013**
	(0.004)	(0.005)	(0.009)	(0.019)	(0.009)	(0.026)	(0.011)	(0.006)
Innovation reduction	-0.006	-0.008	-0.003	0.018	-0.018**	0.030	0.008	-0.007
	(0.004)	(0.005)	(0.008)	(0.018)	(0.009)	(0.023)	(0.010)	(0.006)
Intangibles								
R&D-doing firm	0.011**	0.011**	0.009	0.014	0.031***	-0.010	-0.004	0.005
	(0.005)	(0.005)	(0.009)	(0.021)	(0.010)	(0.024)	(0.010)	(0.006)
Human capital	0.008*	0.011**	-0.006	0.010	0.006	-0.034	-0.002	0.015**
	(0.005)	(0.006)	(0.010)	(0.025)	(0.010)	(0.021)	(0.010)	(0.007)
Organizational change	0.003	-0.002	0.003	0.019	0.003	-0.016	-0.007	0.007
	(0.004)	(0.006)	(0.009)	(0.017)	(0.009)	(0.026)	(0.009)	(0.006)
Controls								
Openness								
Importer of materials	0.005	0.009	-0.009	0.005	0.003	0.030	0.010	0.002
	(0.004)	(0.005)	(0.009)	(0.020)	(0.010)	(0.023)	(0.010)	(0.006)
Importer of services	0.013**	0.011	0.013	0.020	0.017	0.047**	-0.001	0.012
	(0.005)	(0.007)	(0.009)	(0.019)	(0.011)	(0.023)	(0.010)	(0.007)
FDI active	0.012	0.009	0.019	0.010	0.056**	0.006	0.003	-0.013
	(0.011)	(0.031)	(0.015)	(0.019)	(0.024)	(0.033)	(0.019)	(0.018)
FDI passive (foreign group)	0.022***	0.032**	0.012	0.045**	0.017	0.037	0.014	0.029*
	(0.008)	(0.016)	(0.011)	(0.020)	(0.014)	(0.033)	(0.015)	(0.016)
Labour input								
Flexible contracts	-0.003	0.002	-0.036**	0.018	0.006	0.001	-0.037***	0.002
	(0.006)	(0.007)	(0.017)	(0.028)	(0.014)	(0.034)	(0.012)	(0.008)
Financial input								
Rationed credit	-0.017	-0.027*	0.026	0.011	0.010	-0.028	-0.041	-0.020
	(0.012)	(0.014)	(0.018)	(0.051)	(0.023)	(0.045)	(0.032)	(0.015)
Other firm characteristics								
Family management	-0.013***	-0.012**	-0.023	0.052	-0.004	-0.007	-0.031**	-0.013**
	(0.005)	(0.005)	(0.020)	(0.040)	(0.011)	(0.030)	(0.014)	(0.006)
Quality certification	0.009**	0.009*	0.007	0.007	-0.005	0.032	0.032***	0.009
	(0.004)	(0.005)	(0.009)	(0.021)	(0.009)	(0.028)	(0.010)	(0.006)
Young (less than 6 yrs)	-0.001	0.008	-0.026***	-0.032	-0.008	-0.057**	0.014	0.000
	(0.004)	(0.005)	(0.009)	(0.025)	(0.009)	(0.027)	(0.009)	(0.006)
Constant	0.081***	-0.005	0.083**	0.150***	0.055*	0.123	0.126***	0.046*
	(0.021)	(0.043)	(0.036)	(0.047)	(0.031)	(0.082)	(0.031)	(0.025)
Size dummies	Yes	No	No	No	Yes	Yes	Yes	Yes
Pavitt dummies	Yes	Yes	Yes	Yes	No	No	No	No
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,077	4,852	1,641	584	1,844	273	1,349	3,611
R-squared	0.878	0.844	0.882	0.867	0.883	0.900	0.872	0.865

*Notes: Robust Standard errors in parentheses. ***, **, * significant at 1,5 and 10%.*

Regression results are presented in Table 3.12. Estimates are provided for the overall sample, and then split according to size classes and Pavitt groups. Overall, results corroborate most of the trends highlighted in the earlier sections. The positive coefficient on the level of TFP in 2008 suggests that there has been no productivity catch-up among companies during the crisis. This feature is common across size classes and industry groups. This implies that, within any single country, those firms which were most productive at the outset of the downturn accommodated better the negative shock, with above-average outperformance in terms of TFP growth during 2008-2009.

Firms which experienced a turnover and an investment reduction underperformed compared to those less affected by the crisis. The significance of both variables indicates that the downturn impacted distinctly on these two dimensions of firm performance and this, in turn, negatively affected TFP growth. The effect of turnover reduction was relatively more severe among large and high-tech firms, while the decline in investment particularly affected productivity growth in medium firms and specialised producers. On average, firms endowed with intangible assets performed better, especially when these factors were the outcome of research activities or resulted from the employment of highly educated workers. Results in Table 3.12 indicate that intangible assets are important drivers of productivity growth, particularly for small firms and those specialised in scale-intensive production. The fact that intangible inputs were not associated with better productivity performance in more technologically advanced productions, such as science-based industries, may be due to the low variation among these firms in R&D engagement and human capital endowment. Interestingly, companies that had undertaken organisational changes before the crisis did not display a different productivity performance from the rest of the sample during the downturn.

This may reflect the long time necessary before these changes affect productivity (Rincon et al. 2012). International firms were more productive with respect to those active solely in the domestic market, in particular those affiliated to a foreign group. This feature is common to both small and large firms. Conversely, the industry breakdown does not offer insights on the role of this variable among Pavitt categories, apart from the weakly significant effect found for traditional firms. Among high-tech firms, productivity grew faster in those importing service intermediate inputs; scale intensive firms that had previously carried out some production tasks abroad also experienced higher productivity growth (FDI active). In accordance with the literature on the regulation governing the labour market, firms relying upon flexible contracts experienced lower productivity growth. However, this effect is confined to medium-sized firms and specialised suppliers. Results also provide evidence on the negative impact of worsening credit conditions on productivity for small firms (Houlton et al. 2012). Concerning other firm characteristics, results show that family management is another condition which hampered the productivity growth of smaller firms, traditional companies and specialised suppliers. Apart from this last group of firms, going through quality certification does not signal better managerial practices and, as a consequence, faster productivity growth. Looking at the age profile, productivity did not grow at a differential speed among young firms; rather, young medium-sized and high-tech firms underperformed compared to more mature firms. Probably, young companies were not sufficiently structured to tackle the collapse of the market between 2008 and 2009, or were not able to fully exploit their growth potential due to the worsening in demand conditions.

3.5. SUMMARY AND POLICY IMPLICATIONS

This chapter has described the main features of recent EU aggregate and industry productivity performance from an international perspective, and has provided empirical evidences on the key forces behind the productivity growth differentials with respect to the US. Identifying these factors is crucial for designing policies able to reduce the gap and to restore sustained growth in Europe. In the late 1990s, characterised by the emergence of ICT technologies, market services were the main culprit of the EU productivity disadvantage. In the years leading to the financial crisis, however, the EU experienced strong ICT-related labour productivity growth in these sectors, mirroring earlier developments in the US, and boosting convergence towards US productivity levels. Since the crisis, however, the EU-US productivity gap has widened again.

The responses to the downturn have been heterogeneous across the different sectors in the EU. Overall, service sectors appear to have been relatively less affected by the global economic crisis compared to manufacturing. Some key sectors, such as business services, have helped in narrowing the productivity gap with the US in recent years. A plausible explanation is that these sectors are usually more sheltered from international competition than manufacturing sectors, and therefore, less exposed to global economic shocks. It is also possible that these sectors have continued to reap the benefits of strong tangible and intangible investments undertaken over the past decade.

This positive outlook for labour productivity expansion in some EU services sectors, however, contrasts with a poor TFP performance. This finding suggests that the EU continues to experience lower levels of efficiency, with which inputs are used in the production process, than the US. These results call for a more in-depth analysis of factors affecting TFP since, this is one of the main engines for increasing income levels in the long run.

The econometric analysis has considered two main channels through which it is possible to raise the productivity growth potential and close the gap with technology leaders. First, consideration has been given to the role of absorptive capacity and knowledge-base (intangible) assets – i.e. R&D and human capital – in activating, and benefiting from, international technology transfers. This mechanism has been found in the literature to be highly conducive to productivity growth through spillovers. However, its growth-enhancing effect is heterogeneous and it requires the ability to accommodate the inflow of new technological knowledge by re-allocating factors or, for instance, expanding new product lines. The set of rules that regulate the functioning of internal markets is important in process of checking for the productivity effects of technology transfers. This analysis has not found convincing evidence that more restrictive regulations on the labour, product and financial markets significantly hamper the capacity of a country to reap the benefits of knowledge developed elsewhere.

The second channel is the role of production efficiency as a possible driving force behind the widening productivity gaps between the EU and the US. The analysis has shown that productive efficiency is significantly higher in countries with less restrictive product market regulations or employment protection laws. However, when there are few restrictions on the use of temporary contracts and in financial markets, the efficiency gaps with respect to the frontier are likely to increase, as these might encourage firms to adopt cost-cutting strategies rather than the most efficient methods of production. Investment in ICT assets, on the other hand, is one of the crucial factors that help in reducing the distance from the most efficient country and/or industry.

Broadly consistent evidence also emerges from the analysis of firm-level performance at the outset of the financial crisis. The analysis undertaken for seven EU economies provides strong micro foundations to the observed widening productivity differentials at a more aggregate level. This study shows that the most productive firms, prior to the crisis, which experienced faster TFP growth afterwards. This finding confirms that, even within the EU, the recent downturn seems to have reinforced the trend of diverging productivity patterns which emerged in the earlier period.

Overall, the analysis carried out in this chapter provides insights into which policies may be more effective in raising productivity performance within the EU and closing the gap with the US. A common finding throughout the chapter is that intangible assets (R&D, human capital, organizational change) are important sources of TFP growth and sustained long-run competitiveness. From this perspective, initiatives aimed at stimulating such investments may be particularly useful.

Albeit EU countries represent an important share of R&D at a worldwide level, they are less specialized in high-tech sectors compared to the US. The different structural specialisation of the EU countries explains why they have fewer young firms among its leading innovators and their young firms are less innovative than in the US (Cincera and Veugelers 2010). Also, in Europe the proportion of R&D-doing firms is considerably lower than the US. These factors can explain the discussed research gap (Moncada-Paternò-Castello et al. 2010).

Ample evidence can be found in the literature, for example, about the effectiveness of tax incentives to raise research effort. This policy instrument does not distort market incentives because; it reduces the cost of R&D without influencing firms' choices regarding specific projects (David et al. 2000)[91]. In the OECD area, public policies to directly sustain R&D have also been implemented through a combination of measures favouring a large spectrum of knowledge-intensive sectors (ICT, pharmaceuticals, bio-technologies, etc.). In this way, these countries have sought to shift their industrial structures towards high-tech productions and increase thus their international competitiveness.

Specific policy initiatives may also be put in place to increase a firm's endowment of qualified workers, for instance facilitating hiring of highly qualified workers (such as professional managers) or to sustain workforce training to enhance the endowment of firm-specific human capital. Other sound policies could be directed towards raising investment in inputs such as ICT, which can assist in the reorganisation of production. Specific ICT applications, such as enterprise software systems, have been related to increasing productivity at the firm level in the existing literature (Engelstatter 2009). These measures would also be viable for smaller firms which do not always have the necessary resources to embark on formal R&D activities and need alternative ways of increasing their competitiveness (EC 2012 and 2013). It should be borne in mind that ICT may spur productivity performance by increasing efficiency in production tasks and this effect may occur with some lags. These measures may therefore be accompanied by other policies targeted to facilitating factors. Policies aimed at improving the functioning of product and factor markets may be

[91] A possible drawback is that it influences the composition of research project favouring those with a higher profitability in the short run.

particularly effective. Reducing the strictness of product market regulations, largely concentrated in key service-providing industries, is likely to be conducive to higher levels of efficiency across the whole economy, by allowing input re-allocation, outsourcing of marginal tasks, and the adoption of the best production and managerial practices. Changes in the regulatory setting of the labour market should also be tailored to restore an optimal mix of regular and temporary workers, bearing in mind that an excessive liberalisation of temporary workers' contracts may hinder productivity and efficiency performance.

Given the role of financial input on productivity performance, it appears useful to promote policies designed to increase firms' access to external funding, such as bank credit and private bonds. These measures should be conceived and applied within an appropriate regulatory framework which will safeguard the stability and facilitate the reduction of productivity and efficiency gaps.

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ANNEX 3.1
ABBREVIATIONS

ECR	Enforcing Contract Time
EPC	Employment Protection Legislation for collective dismissals.
EPL	Overall Employment Protection Legislation
EPR	Employment Protection Legislation for regular contracts
EPT	Employment Protection Legislation for temporary contracts
EU-15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom.
EU-27	Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Lithuania, Luxembourg, Latvia, Malta, Netherlands, Poland, Portugal, Romania, Spain, Sweden, Slovenia, Slovakia, UK.
EU-8	Austria, Belgium, France, Netherlands, Spain, Germany, Italy, UK.
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GPT	General Purpose Technology
ICT	Information and Communications Technologies
IPR	Intellectual Property Rights
JP	Japan
LC	Labour Composition
LP	Labour Productivity
NACE	National Classicisation of Economic Activities
NMW	National Minimum Wage
NUTS	The Nomenclature of Territorial Units for Statistics
OECD	Organisation for Economic Cooperation and Development
OLS	Ordinary Least Squares
PMR	Product Market Regulation
R&D	Research and Development
RI	Regulation Impact
SFA	Stochastic Frontier Analysis
SME	Small and Medium-sized Enterprise
TE	Technical Efficiency
TFP	Total Factor Productivity
US	United States

Nace Rev. 2, Classification and Description of Economic Activities

NACE Rev. 2	NACE Description
TOT	TOTAL INDUSTRIES
A	AGRICULTURE, FORESTRY AND FISHING
B	MINING AND QUARRYING
C	TOTAL MANUFACTURING
10-12	Food products, beverages and tobacco
13-15	Textiles, wearing apparel, leather and related prodcuts
16-18	Wood and paper products; printing and reproduction of recorded media
19	Coke and refined petroleum products
20-21	Chemicals and chemical products
22-23	Rubber and plastics products, and other non-metallic mineral products
24-25	Basic metals and fabricated metal products, except machinery and equipment
26-27	Electrical and optical equipment
28	Machinery and equipment n.e.c.
29-30	Transport equipment
31-33	Other manufacturing; repair and installation of machinery and equipment
D-E	ELECTRICITY, GAS AND WATER SUPPLY
F	CONSTRUCTION
G	WHOLESALE AND RETAIL TRADE; REPAIR OF MOTOR VEHICLES AND MOTORCYCLES
45	Wholesale and retail trade and repair of motor vehicles and motorcycles
46	Wholesale trade, except of motor vehicles and motorcycles
47	Retail trade, except of motor vehicles and motorcycles
H	TRANSPORTATION AND STORAGE
49-52	Transport and storage
53	Postal and courier activities
I	ACCOMMODATION AND FOOD SERVICE ACTIVITIES
J	INFORMATION AND COMMUNICATION
58-60	Publishing, audiovisual and broadcasting activities
61	Telecommunications
62-63	IT and other information services
K	FINANCIAL AND INSURANCE ACTIVITIES
L	REAL ESTATE ACTIVITIES
M-N	PROFESSIONAL, SCIENTIFIC, TECHNICAL, ADMINISTRATIVE AND SUPPORT SERVICE ACTIVITIES
O-U	COMMUNITY SOCIAL AND PERSONAL SERVICES
O	Public administration and defence; compulsory social security
P	Education
Q	Health and social work
R-S	ARTS, ENTERTAINMENT, RECREATION AND OTHER SERVICE ACTIVITIES
R	Arts, entertainment and recreation
S	Other service activities
T	Activities of households as employers

ANNEX 3.2 METHODOLOGIES

3.2.A. METHODOLOGY TO AGGREGATE PRODUCTIVITY DATA

The Conference Board Total Economy Database (TED) and the EUKLEMS database contain a wide range of economic performance measures on a country-by-country basis. This information is however of limited use if one wants to establish meaningful comparisons of growth and productivity trends between the whole of the EU and other world economies. In this study, the methodology set out in Timmer et al, 2007 is followed to construct EU aggregate (e.g. the EU-27 or EU-15) measures of output, input and productivity.

This methodology is based in the use of a Törnqvist quantity index, which is a discrete time approximation to a Divisia index. A Divisia index defined as a continuous-time weighted sum of the growth rates of various components, where the weights are the component's shares in total value; in the Törnqvist index, the growth rates are defined as the difference in the natural logarithm of consecutive observations of the components, and the weights are equal to the mean of the factor shares of the components in the corresponding pair of time periods (e.g. years).

Aggregation over countries

The derivation of an aggregate measure of labour productivity for the EU-27 is outlined in practical terms here. First of all, annual growth rates of labour productivity for each of the EU-27 countries are computed for the time period under consideration (as the differences in the natural logarithms). Secondly, the annual shares of each country in EU nominal output are calculated using PPP-converted values, which adjust for purchasing power parities price differentials across countries [92] (Inklaar and Timmer, 2008).

The calculation of nominal output shares for each of the EU countries is given by the following expression:

$$V_{c,j,t} = \frac{\left[\frac{PY_{c,j,t}}{PPP_{c,j,t}}\right]}{PY_{EU,j,t}}$$

where V denotes PPP-adjusted nominal output; PY denotes nominal output; c denotes country, j denotes industry, and t denotes year.

The overall labour productivity for the EU-27 is then calculated as a weighted average of country productivity growth rates, as set out below:

$$\Delta lnLP_{EU,j,t} = \sum_{c}^{n} \bar{V}_{c,j,t}\, \Delta LnLP_{c,j,t}$$

where $\bar{V}_{c,j,t}$ denotes the two-year average shares of each country in total nominal output. Once the annual growth rates for the EU country grouping are obtained, it is feasible to construct an aggregate index of labour productivity in relation to a base year (for example, assuming that labour productivity is equal to 100 in year 1995).

Aggregation over industries

A similar procedure to the one outlined above can be applied to calculate aggregate performance for a specific group of industries. For instance, to measure productivity growth in the high-technology manufacturing sector of a particular country. Moreover, if productivity in the high-technology manufacturing sector of the EU as a whole

[92] Purchasing Power Parities (PPP), which are available for economy level and for detailed industries, are usually given for a benchmark year. Here the PPPs are given for 1997 (See Inklaar and Timmer, 2008).

wants to be computed, a double aggregation procedure has to be followed. First an aggregation is performed over countries, and then, over industries, following recommendations in Timmer et al (2007).

$$\Delta lnLP_{EU,t} = \sum_{j}^{n} \bar{V}_{EU,j,t}\, \Delta LnLPY_{EU,j,t}$$

3.2.B. GROWTH ACCOUNTING METHODOLOGY

The growth accounting methodology (Jorgenson and Griliches, 1967; Jorgenson et al, 1987) has been widely used to assess the contribution of the different factors of production to aggregate economic growth. According to this methodology, which is rooted in neoclassical theory, the part of output growth that is not accounted by the growth in inputs, usually capital and labour can be attributed to TFP, a proxy measure for technological progress. Assuming a Cobb-Douglas production function, output Y (i.e. value added) is a function of capital (K) , labour (L), and technology (A) in the following terms:

$$Y = AL^{\alpha}K^{\beta}$$

Assuming that factor markets are competitive, full input utilisation and constant returns to scale, the growth of output can be expressed as the cost-share weighted growth of inputs and technological change (A), using the translog functional form common in such analyses:

$$\alpha + \beta = 1$$

$$\Delta\, \mathrm{LN}\, y_t = \bar{\alpha}\Delta l_t + \bar{\beta}\Delta k_t + \Delta A_t$$

where $\bar{\alpha}$ and $\bar{\beta}$ are the two-period average share of labour and capital input in nominal output.

With the use of this empirical approach it is possible to identify and quantify the role of labour and capital in aggregate growth. More recent contributions extended the framework to allow for the separate analysis of ICT assets (computers, software and communications) and non-ICT capital assets (machinery, transport equipment, residential buildings, infrastructure), as well as for changes in workforce composition, in terms of labour characteristics such as educational attainment, age or gender (Jorgenson et al, 2005). Growth in output can be decomposed into the following elements:

$$\Delta y_t = \bar{\alpha}\Delta l_t + \bar{\beta}_{ict}\Delta ictk_t + \bar{\beta}_{nict}\Delta nictk_t + \Delta TFP_t$$

where the contribution of each factor input is given by the product of its share in total costs and its growth rate;

$\bar{\beta}_{ict}$ is the two-period average share of ICT assets in total capital compensation; and $\bar{\beta}_{nict}$ is the two-period average share of non-ICT assets in total capital compensation.

The growth in labour input can be split into growth of hours worked and changes in labour composition. Labour composition in EUKLEMS is derived by dividing labour into types and multiplying growth in each type by wage bill shares.

$$\Delta l_t = \Delta h + \Delta LC$$

To analyse productivity it is useful to divide output and inputs by the number of hours. The following expression can be derived for labour productivity growth:

$$\Delta\left(\frac{y}{l}\right) = \bar{\beta}_{ict}\Delta(\frac{ictk}{l}) + \bar{\beta}_{nict}\Delta(\frac{nictk}{l}) + \bar{\alpha}\Delta(\frac{LC}{l}) + \Delta TFP$$

Based on the above formulae, the EUKLEMS and The Conference Board Total Economy Database provide a full decomposition of output and labour productivity growth into the contributions of the various factor inputs and TFP growth.

3.2.C. THRESHOLD REGRESSIONS

Threshold models have in recent times received a great deal of attention as a means of modelling parameter heterogeneity and non-linearities. In a series of papers Hansen (1996, 1999 and 2000) develops a technique that allows the sample data to jointly determine both the regression coefficients and the threshold value for OLS and (non-dynamic) fixed effects panel models.

The threshold model for a single threshold can be written as:

$$y_i = \alpha_0 + \delta_1 x_i 1(q_i \leq \lambda_1) + \delta_2 x_i 1(q_i > \lambda_1) + \varepsilon_i$$

where 1 is the indicator function and q_i is the threshold variable. Here the observations are divided into two regimes depending on whether the threshold variable is smaller or larger than λ_1. The two regimes are distinguished by different regression slopes, δ_1 and δ_2. Chan (1993) and Hansen (1999) recommend estimation of λ_1 by least squares. This involves finding the value of λ_1 that minimises the concentrated sum of squared errors. In practice this involves searching over distinct values of q_i for the value of λ_1 at which the sum of squared errors is smallest, which is then our estimate of the threshold. Once we have an estimate for the threshold it is straightforward to estimate the model. Hansen (2000) extends this method to the case of non-dynamic fixed-effects panel models.

Having found a threshold it is important to determine whether it is statistically significant or not, that is, to test the null hypothesis; $H_0: \delta_1 = \delta_2$. Given that the threshold λ_1 is not identified under the null, this test has a non-standard distribution and critical values cannot be read off standard distribution tables. Hansen (1996) suggests bootstrapping to simulate the asymptotic distribution of the likelihood ratio test allowing one to obtain a p-value for this test. Firstly, one estimates the model under the null (i.e. linearity) and alternative (i.e. threshold occurring at λ_1). This allows one to construct the actual value of the likelihood ratio test (F_1):

$$F_1 = \frac{S_0 - S_1(\lambda_1)}{\Sigma^2}$$

$$\text{where,} \qquad \Sigma^2 = \frac{1}{N(T-1)} S_1(\lambda_1)$$

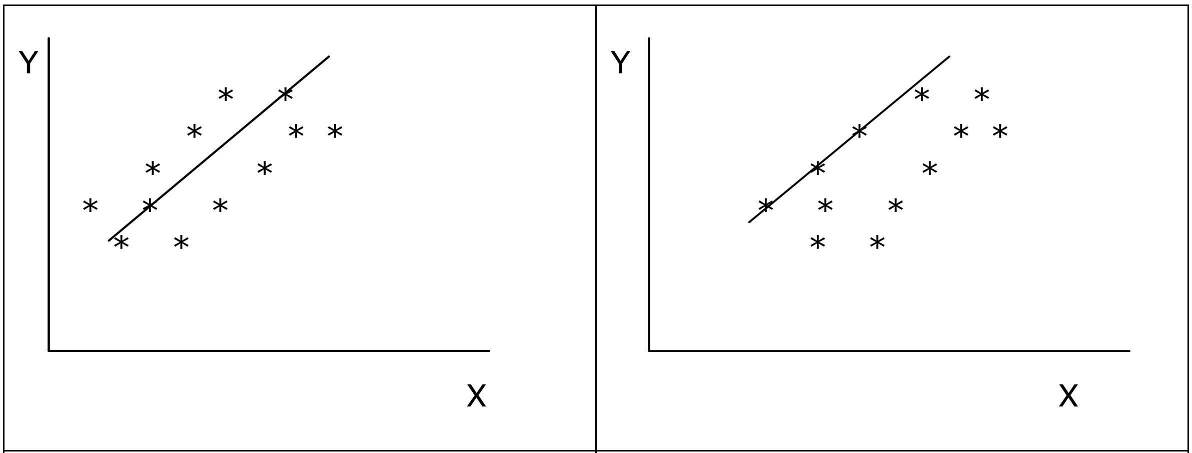
Here S_0 and S_1 are the residual sum of squares from the linear and threshold models respectively. Using a parametric bootstrap (see Cameron and Trivedi, 2005) the model is then estimated under the null and alternative and the likelihood ratio F_1 is calculated. This process is repeated a large number of times. The bootstrap estimate of the p-value for F_1 under the null is given by the percentage of draws for which the simulated statistic F_1 exceeds the actual one.

The approach is also easily extended to consider more than one threshold. While it is straightforward to search for multiple thresholds, it can be computationally time-consuming. Bai (1997) has shown, however, that sequential estimation is consistent, thus avoiding this computation problem. In the case of a two-threshold model, this involves fixing the first threshold and searching for a second threshold. The estimate of the second threshold is then asymptotically efficient, but not the first threshold because it was estimated from a sum of squared errors function that was contaminated by the presence of a neglected regime. Bai (1997) suggests estimating a refined estimator for the first threshold, which involved re-estimating the first threshold, assuming that the second threshold is fixed. The test of significance of the second threshold proceeds along the same lines as described above, with the null and alternative hypotheses being of a one and two threshold model respectively.

3.2.D. STOCHASTIC FRONTIER ANALYSIS (SFA)

Frontier Analysis, initially developed in Farrell (1957) and successively extended by Aigner et al. (1977), Kumbhakar and Lovell (2000) and Greene (2005) among others, aims to identify the production frontier, i.e. the maximum level of output that can be achieved by using the available inputs. Compared to regression analysis, the estimation of the frontier production function implies fitting a regression line over the units (industries in our case) that produce the most output. The difference between the two techniques can be easily seen in the following figure, where Y indicates output and X denotes a generic input:

Countries/industries at the frontier are those that are making the most efficient use of their resources. Those below the frontier have some level of inefficiency, which can be directly estimated by the distance between each industry and the frontier industry



A: Regression analysis | B: Frontier analysis

.

It is possible to distinguish between two frontier methods, Deterministic Frontier (DEA) and Stochastic Frontier (SFA). DEA (Farrell 1957, Charnes, Cooper and Rhodes 1978) provides a non-parametric approach for estimating production technologies and measuring inefficiencies in production. It relies on the assumption that all deviations from the frontier are caused by technical inefficiency, without making allowanced for measurement errors and/or random components. This implies that not only the method is very sensitive to the presence of outliers, but also lacks the necessary diagnostic to help the user determine whether or not the chosen model is appropriate, which variables are significant and which are not. These shortcomings are overcome by using the SFA.

Here the identification of the frontier technology is based on the econometric estimation of a production function, usually a Cobb-Douglas or a semi-translog function. Differently from standard regression analysis, frontier analysis allows for the presence of a composite error term, which includes a random component and an inefficiency term. The random component allows for the presence of measurement errors and other effects not captured by the model. The inefficiency term measures technical inefficiencies, i.e. the distance of each country/industry from the frontier. This ranges between 0 and 1, with higher values identifying more efficient units. Technical efficiency scores derived for each unit/industry can then be analysed across different dimensions to pinpoint areas characterised by low/high inefficiencies.

The performance of an industry depends not only on the inputs used in the production process but also on other external or environmental factors that can affect the efficient use of resources. These are usually factors that are outside the control of an industry, even though it is possible that some factors play a dual role, i.e. they affect both frontier output and inefficiency (Kneller and Stevens 2006). The SFA framework can easily account for this by modelling the mean level of the inefficiency term as a function of these additional factors. Production frontier and determinants of inefficiency are estimated simultaneously by maximum likelihood (ML) (Battese and Coelli 1995).

3.2.E. PAVITT TAXONOMY (1984)

Using industry-specific characteristics of innovative UK firms Pavitt (1984) identifies some major technological trajectories in manufacturing, on the basis of which it is possible to identify some specific patterns of sectoral innovation. The Pavitt (1984) taxonomy maps industries according to the source of innovation activities made by the firms (internal vs external), the nature of innovation (informal vs formal, or learning vs R&D), firm size (small, medium, or large), appropriability of innovation (low vs high returns to innovation), method of protection (secrecy vs patents) etc. Industries or firms can be grouped into the following categories:

Scale-intensive: They are large firms exploiting increasing returns to scale and learning-by-doing associated with the size of the reference market, or of their own plant. The source of innovation may be both external and internal. In the former case, these firms acquire production technologies from specialised suppliers. In the latter case, in-house R&D activities are performed to develop new types of products; in this case, patenting is effective to protect innovation. The main economic activities of such firms are basic metals or the production of durable goods.

Science based: They are mainly large firms using internal sources of knowledge to produce innovations (R&D). Their knowledge base is complex and relies upon scientific advances. Sometimes, innovations are developed between private firms and universities and other research institutes. Patents are the major, but not exclusive, tools to protect innovations. Small firms may be very competitive in certain technologically advanced niches. The main economic activities of such firms are pharmaceuticals, electronics, etc.

Specialised suppliers: They are small- and medium-sized firms manufacturing sophisticated equipment and/or precision machinery. They strongly rely upon internal sources of innovation (engineering and design capabilities are pivotal), developing new products by continuously interacting with their customers, i.e. downstream firms using in their production the equipment developed by this category. The nature of innovation of this type of firms is therefore informal and based on learning.

Supplier dominated: They are traditional firms, representing the least technologically advanced branch of the manufacturing sector. Their main source of innovation is external and consists in introducing cost-saving process innovations, or implementing advanced technologies, equipment and materials, developed in other sectors. The only internal source of innovation is the learning associated with the usage of acquired inputs. Given the low level of appropriability of internal innovation, patenting is not very developed. The main economic activities of such firms are food, textile, footwear, etc.

Chapter 4.

A 'MANUFACTURING IMPERATIVE' IN THE EU: THE ROLE OF INDUSTRIAL POLICY

The economic crisis changed the perceptions of the role of the manufacturing sector in the economy. Manufacturing has redeemed its reputation in the sense that a comparatively large manufacturing sector is no longer considered to reflect an outdated economic structure, inadequate for a post-industrial, services-dominated economy like the EU. Rather, nurtured by the observation that within the EU, countries which have maintained a larger manufacturing base fared better during and after the crisis (Reiner, 2012; Fürst, 2013), a dynamic manufacturing sector is again considered a prerequisite for an innovative and fast-growing economy. In a recent Communication, the European Commission, emphasises that a 'vibrant and highly competitive EU manufacturing sector' is a key element for solving societal changes ahead and a 'more sustainable, inclusive and resource-efficient economy' (European Commission, 2010a).

This altered perception of manufacturing raised concerns that manufacturing production had declined too much (Warwick, 2013) in some Member States leading to a loss of knowledge, capabilities and supplier networks which have been referred to as the 'manufacturing commons' (Pisano and Shih, 2009)[93]. Earlier arguments for a 'manufacturing imperative' (Rodrik, 2012) were re-discovered and the current structural shift out of manufacturing in advanced economies, including most EU Member States, started to look less advantageous. The urge felt by policy makers and the business community to maintain a broad manufacturing base in Europe also led to a renewed interest in industrial policy in Europe and elsewhere (including the United States).

The importance of industrial structures is widely accepted. The potential for economic policy to shape that structure, however, remains highly disputed, particularly in Europe where the track record of interventionist industrial policy experiments in the 1960s and 1970s was rather disappointing (Crafts, 2010; Owen, 2012). Industrial policy, understood as selective government interventions seeking to alter the structure of production towards industries that are expected to offer higher growth prospects (Pack and Saggi, 2006), can in principle try to foster structural change towards any sector or industry that government authorities consider to be 'strategic' or potential carrier of growth. Viewed through the lenses of a 'manufacturing imperative', the particular characteristics of manufacturing industries (such as externalities and increasing returns to scale[94]) call for industrial policies that re-direct the European economy towards manufacturing activities and aim at strengthening or restoring the industrial commons.

Despite this renewed debate about the objectives and instruments of EU industrial policy, it remains deeply rooted in the principles of competition, favouring general framework policies (such as the proper functioning of the Internal Market and competition rules) and 'horizontal' policies over sector-specific interventions[95]. Nevertheless, in the aftermath of the economic crisis the European Commission's focus on framework policies has been supplemented with more sector-specific policy objectives such as the definition of key priority areas which include inter alia the development of clean vehicles and vessels and smart grids (European Commission, 2012a). Sector-specific action may indeed be warranted in cases where the market is not able to bring about a resource allocation that is efficient and conducive to solving societal challenges. A potential reason for that is the existence of path dependency in technological trajectories as documented for example in an under-provision of clean technologies (Aghion et al., 2010). A corollary of this is that the state has an important coordination role, helping to remove lock-in effects in technological developments.

Against this background, this chapter revisits some of the main arguments in favour of a manufacturing imperative and discusses them in a European context. It also shows the limitations and caveats of these arguments in a world of strong inter-linkages between the production of manufactures and the services which enter the production process (Sections 4.1-4.6).

93 The industrial commons are a reference to the commons which is the land belonging to a (village) community as a whole and which could also be used by each member of the community (typically for grazing of animals). They can be described as the general stock of knowledge, competences and skills (often embodied in the workforce) and institutions (including supplier networks) relevant for modern manufacturing activities that can be shared and accessed by the manufacturing sector as a whole (Pisano and Shih, 2009).

94 Increasing returns to scale can also arise from network externalities which play a role in a number of sectors that can be referred to as utilities such as water, gas and electricity, telecommunication or rail services.

95 Among economists it is highly disputed whether horizontal measures are necessarily less distortive than sectoral interventions. De facto, horizontal policies are hardly neutral with regards to structure and sectors. Therefore, the dichotomy between horizontal measures and vertical measures may be blurred or even meaningless (Pelkmans, 2006; Cohen, 2006; Midelfart and Overman, 2002; Chang, 2006).

Sections 4.7-4.10 identify the main challenges ahead for European manufacturing given the structural changes that occurred in the EU over the period 1995 to 2011. Sections 4.11-4.15 analyse a number of industrial policy measures that are related to these structural challenges. Given the still prevalent use of State aid by EU Member States and the unique institutional framework which empowers the Commission to restrict its use, a quantitative analysis of State aid and its relationship with competitiveness and value added is undertaken. Due to the great importance that the European Commission attaches to innovation-related industrial policy, the study of public support measures continues with a firm-level study of the impact of public R&D support for firms on innovativeness and innovation output. Section 4.16 discusses the policy implications in the context of structural challenges.

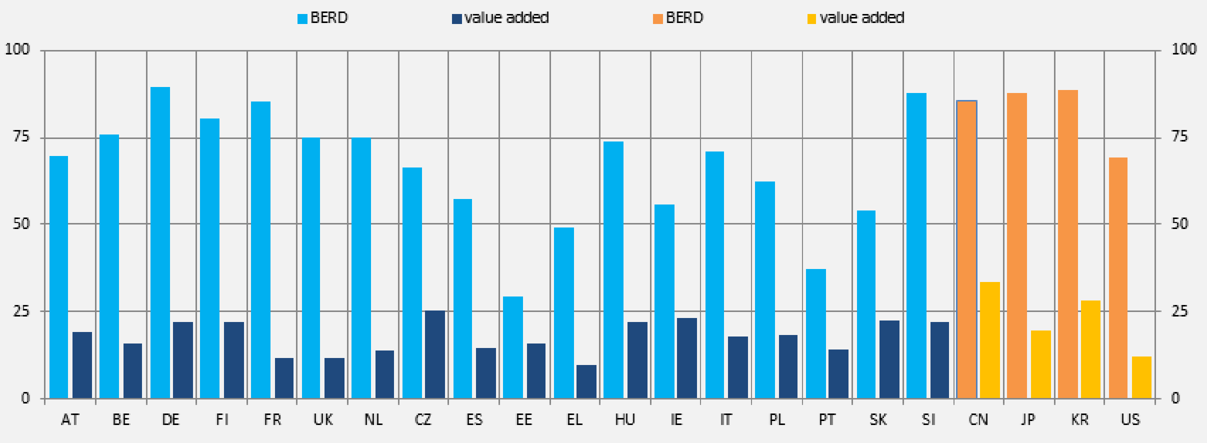
4.1. THE MANUFACTURING IMPERATIVE IN A EUROPEAN CONTEXT

This section lays the ground for the analysis of the structural shifts in the European manufacturing sector and the challenges ahead. In particular, it revisits some of the main arguments in favour of maintaining, re-building or creating – as the case may be – a strong any economy aiming for high growth and employment rates.

4.2. THE MAIN SOURCE OF INNOVATION AND TECHNOLOGICAL PROGRESS

One principle argument in favour of a strong manufacturing base is that the manufacturing sector is the major source of technological progress (e.g. Baumol, 1967; Kaldor, 1968; UNIDO, 2002; Aiginger and Sieber, 2006; Helper et al., 2012). Inspection of firms' business expenditure on research and development (BERD) in the EU and other countries clearly supports this claim (Figure 4.1). Manufacturing firms are more inclined to undertake R&D than firms in the rest of the economy, resulting in higher shares of the sector compared to its share of value- added. On average the share of the manufacturing sector in business R&D exceeds that of the value-added share by a factor close to four in the EU Member States; the same holds for the United States, Japan and South Korea. Despite marked variations in the business R&D share of manufacturing firms, ranging from almost 90% in Germany to 29% in Estonia[96], it exceeds the value added share of manufacturing in all Member States. Consequently the R&D expenditures of firms indicate that the overwhelming majority of R&D activities take place in the manufacturing sector which can therefore be identified as the main source of innovation and technological progress.

Figure 4.1. Share of manufacturing in value added and in business expenditure on R&D (BERD), 2005-2009



Note: Business Expenditure on R&D includes R&D by foreign enterprises. Averages over the period 2005-2009 of available data.
Source: WIOD, WIPO, OECD ANBERD, wiiw calculations.

manufacturing base in EU Member States while bearing in mind that modern manufacturing production is increasingly dependent on innovations and specialised services inputs. The latter have gained importance for product differentiation and quality improvements of manufactures which allow firms to charge higher prices and increase the value-added of their activities. Therefore the discussion of the particular role of manufacturing for the economy has to be considered in the context of increasing inter-linkages between manufacturing and services.

Many arguments have been brought forward for why a thriving manufacturing sector is a prerequisite for

While the essential role of manufacturing firms for innovation and technological progress is generally accepted, an important question is whether a thriving European manufacturing sector requires innovative European firms to keep their production facilities in the EU. For Member States at the technological

[96] The median value of the business R&D share of manufacturing firms is 70.5% for the EU Member States.

frontier it would, in principle, suffice if firms kept headquarter functions and in particular R&D activities in the domestic economy but move manufacturing production to low-wage locations in order to reduce costs and increase productivity. Such a vertical specialisation strategy could lead to a 'high-powered' manufacturing sector in Europe characterised by highly productive domestically innovating but internationally producing manufacturing firms.

While a successful vertical specialisation strategy supports firms' competitiveness and offshoring may also be seen as a necessity to survive international competition, a potential risk in this high-powered manufacturing strategy is a continuous 'leakage' of more complex activities to offshore destinations. The stepwise offshoring of more sophisticated production and engineering activities is the result of the building-up of capabilities in offshore destinations as well as communication and co-ordination failures. From a European perspective, the fact that offshoring is mainly taking place between EU Member States could be an advantage, as in this context, and in this case competences would not risk being shifted out of the region.

4.3. Increased linkages between manufacturing and services

R&D and innovation are not the sole ingredients for a highly productive and internationally competitive manufacturing sector. In order to differentiate products and charge higher price-cost mark-ups manufacturing firms depend increasingly on sophisticated services inputs. The mirror-image of this is that the manufacturing sector is an important source of demand for many services. Both aspects highlight the fact that goods and services often complement each other (Nordås and Kim, 2013). Moreover, evidence of the strong interdependences between manufacturing and services in the European economy is provided by the fact that manufacturing firms generate a growing amount of their sales from services. This 'servicisation' of manufacturing seems to be more developed among producers of complex manufactures (Dachs et al. 2013).

On returning to the issue of supply linkages between services and manufacturing sector, an interesting indicator is the service intensity of the manufacturing sector, measured as the cost share of services in manufacturing gross output. During the period 1995-2011 the service intensity of the European manufacturing sector increased from 22% in 1995 to 24% in 2011 with an interim high in 2009 (Figure 4.2).

Figure 4.2. Service inputs into the manufacturing sector relative to manufacturing gross output for the EU-27, 1995-2011

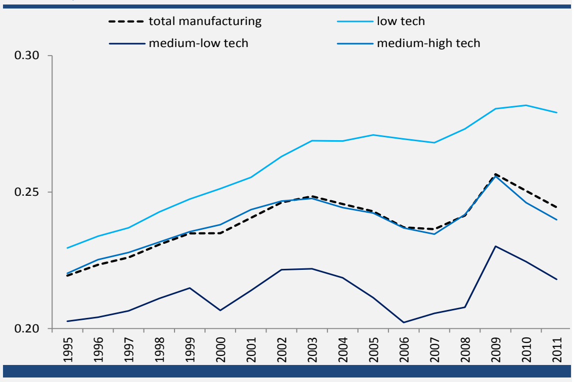
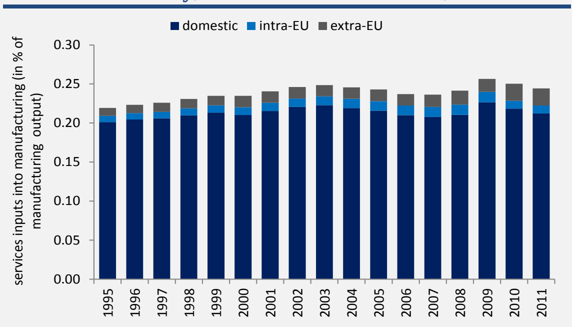


Figure 4.3. Service inputs into manufacturing (relative to manufacturing gross output) sourced from domestic economy, intra-EU and extra-EU, 1995-2011



Note: Calculations based on EU Member States and aggregated to the EU-27. Intra-EU includes the services sourced from EU Member States other than the Member States in question.
Source: WIOD, wiiw calculations.

This increase, which is discernible in low-tech, medium-low-tech as well as medium-high-tech industries, reflects the intensified linkages between manufacturing and services. It is noticeable that, in contrast to R&D efforts and innovation which tend to be concentrated in advanced industries such as pharmaceuticals, the electronic industry, machinery and transport equipment industries (particularly the aircraft industry), there is no systematic relationship between services intensity and the technology intensity of industries (see also Nordås and Kim, 2013). The reason for this is that transport and sales services are more intensively used by low-tech industries. It is true, however, that business services are most intensively used by the medium-high-technology industries, although the differences across the three groups of industries are not very large. This could mean that precisely because innovation plays a less important role or international competition is fiercer, low-tech industries must strongly rely on business services (such as marketing) in order to differentiate their products from competitors. An important feature of the inter-linkages between manufacturing and services is that EU manufacturing firms source intermediate services almost exclusively nationally. On average, the share of domestically sourced services amounted to 87% in 2011 (Figure

4.3). Another 4% were sourced from other EU Member States and 9% from third countries.

4.4. THE 'CARRIER FUNCTION' OF MANUFACTURES

Another important structural feature is that manufactures are highly tradable whereas this is only true for a subset of services. The higher tradability of manufactures combined with the increasing services intensity of manufactures imply that manufactures assume an important 'carrier function' for services. Just as many chemical processes require carrier substances, many services require manufactures to be 'carried' to foreign customers. This carrier function stems from the fact that many services by themselves are not easily tradable as evidenced by the relatively small (though growing) share of intermediate services sourced from abroad. The high tradability of manufactures and the carrier function this provides for services are of course highly relevant for the EU's external balance of payments.

While the share of services in the EU's gross exports to third countries has grown considerably over the past decades to about a third, it still falls far short of the (equally growing) share of services in both GDP[97] and value-added exports[98]. This can be seen by comparing the share of services in gross exports, i.e. 33%, to the share of services in extra-EU value added exports which amounted to 57%. Hence, in terms of value-added exports the share of services exceeded that of manufactures which amounted to 37% in 2011. The rising importance of services in terms of value-added exports results from the fact that more services are embodied in exports of the manufacturing sector than vice-versa[99]. Hence, for non-tradable services an internationally competitive manufacturing sector is needed in order to make services exportable and to create comparative advantages in services[100]. At the same time, services have become an essential factor in underpinning the competitiveness of manufactures.

4.5. PRODUCTIVITY GROWTH

Another common argument for the special role of manufacturing – which is strongly related to the innovation argument but distinct from it – is that productivity growth is higher in manufacturing than in the rest of the economy. The productivity argument is related to the innovation argument because R&D and innovation feed into technological progress and productivity growth. It is distinct because the sector of origin of technological progress need not necessarily be the sector that benefits most strongly from new technologies[101].

Irrespective of this distinction, it turns out that total factor productivity (TFP) growth in the manufacturing sector outperforms TFP growth in the total economy as well as that of business services across a sample of EU Member States and also the US (Figure 4.4). Within the EU, the TFP growth differential between the manufacturing sector and the total economy is particularly large in Austria and in Germany, but is also present in the service-oriented British economy. The sole exceptions to this EU-wide pattern are Spain and Italy which actually did not experience any TFP growth between 1995 and 2007. The result remains unchanged if TFP growth in manufacturing is compared to TFP growth in the market services sector instead of the total economy. Hence, the superior TFP growth trajectory in the manufacturing sector between 1995 and 2007 is not due to low productivity performance in typically low productivity services such as health care or personal services. TFP growth in the manufacturing sector also exceeds that of the total economy in the United States[102].

The reason for higher productivity growth in the manufacturing sector is partly related to technological aspects of manufacturing (increasing returns to scale, externalities, learning effects)[103]. An additional reason is that manufactures, being more tradable than services, are exposed to fiercer international competition which sets further incentives to increase productivity. This does not exclude the possibility of high productivity pockets within the services sector which is of course a very heterogeneous sector, comprising a number of high productivity industries like telecommunications.

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97 Typically, the share of services account for about 60-70% of GDP in advanced economies.

98 Value added exports are a measure based on input-output methodology that reflects the value-added created domestically in an industry or sector in order to satisfy foreign demand (see also Box 4.1).

99 Another factor is that vertical specialisation and trade in intermediates in general is more developed in manufacturing which 'inflates' the gross amounts of exports.

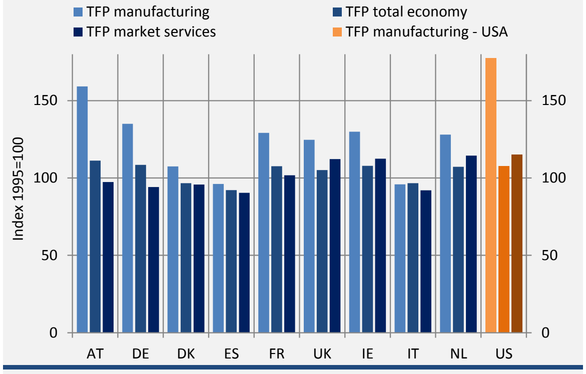
100 An alternative way to sell services internationally is by establishing a foreign subsidiary (Mode 3 of cross-border services trade in WTO terminology).

101 The relationship between innovation and productivity at the industry or sectoral level is blurred by the fact that in the case of product innovations the productivity gains (depending on market structures) may not accrue to the innovating industry but to downstream industries sourcing cheaper inputs or inputs of higher quality. By contrast, productivity gains from process innovation typically accrue in the innovating sector though they may spread to other sectors later on.

102 In the case of the United States, however, real productivity growth of manufacturing may be overstated due to strongly decreasing price deflators in the electronic equipment industry.

103 Another issue is the problem of measuring and comparing TFP across industries, but lacking alternatives this analysis relies on the best data source available which is the EU KLEMS database.

Figure 4.4. Comparison of total factor productivity (TFP) growth in the manufacturing sector, the total economy and market services, 1995-2007



Source: EU KLEMS, wiiw calculations.

An implication of these differentiated patterns of TFP developments is – in accordance with Baumol's arguments of structural change (see Baumol, 1967) outlined in more detail below - that in the longer term prices of manufactures will decline relative to services which – ceteris paribus - is leading to a lower share of manufactures in value added in nominal terms. Therefore a declining value added share of the manufacturing sector per se is not a reason for concern but the logical consequence of a European manufacturing sector that is constantly becoming more efficient.

To sum up, the comparison of TFP growth rates supports the view that the manufacturing sector is not only the most important source of innovation and technological progress but also the sector where innovations and new technologies are primarily implemented and turned into total factor productivity growth.

4.6. Does manufacturing offer higher wages in Europe?

A final argument in the context of a manufacturing imperative is that the manufacturing sector is capable of providing a large amount of well-paid jobs (Rodrik, 2012). This claim is typically put forward in the context of emerging economies but it could also be relevant for the cohesion countries among the EU Member States.

From a theoretical perspective, the argument that the manufacturing sector offers higher wages typically states that the production of manufactures is characterised by imperfect competition (e.g. due to learning effects or static economies of scale in production), combined with imperfect inter-industry labour mobility within a country[104]. For the EU-27, however, there is no evidence of higher wages in manufacturing compared to the services sector – neither at the general wage level, nor for wages set by educational attainment. Considering the EU as a whole, hourly wages have been lower in the manufacturing sector (EUR 13.39) than in the services sector (EUR 14.34)[105]. At the level of EU Member States the results are mixed, with manufacturing wages being higher in some EU-15 countries. But wages in the services sector are higher in all central and eastern European Member States as well as Malta and Cyprus (EU-12). The same comparison but taking the educational attainments of workers into account, suggests that in general wage differentials between the services and the manufacturing sector are small. The finding is in line with the results found for other countries, such as the United States (McKinsey Global Institute, 2012). According to economic theory, factor rewards should in the long run reflect factor intensities.[106] Simple correlations between wages in different sectors could therefore be misleading.

4.7. Structural change in the EU Economy

A general feature of the European economy (and advanced economies in general) is the structural shift to the services sector. This shift is observable for both value-added and employment and has been discussed in Chapter 2 of this report. The mirror image of the 'move into services' in Europe is a decline in the relative importance of manufacturing industries (Table 4.1) for which there is a whole series of explanations.

As shown above, productivity growth in the European manufacturing sector outpaces productivity growth in services and the economy in general.

This is a major reason why relative prices of manufactures decline relative to those of services. As a consequence, the nominal value added share of manufacturing declined by 4.2 percentage points between 1995 and 2011 (and by 5.3 percentage points between 1995 and 2009) as shown in Table 4.1. The relative decline in real terms was more moderate, amounting to 2.6 percentage points between 1995 and 2009 (see for example also Aiginger, 2007). In real terms, the value added share of the EU manufacturing sector is higher than in nominal terms amounting to 17.5% in 2009. The share of the manufacturing sector in terms of employment declined to a similar extent

[104] From a theoretical perspective differences in wages between industries will always depend on some limitations to inter-industry labour mobility. Differences in wages can be motivated by a number of economic models, e.g. a specific-factor model of trade. The differences in wages between industries depend on a number of factors including the capital intensity or whether one looks at the short or the long run.

[105] This result is based on 2010 Eurostat data of hourly gross earnings of employees working in companies with ten or more employees.

[106] Norman, V, D. & Orvedal, L. (2010).

Table 4.1. Nominal, real valued added and employment shares (%) in the EU and global economy for the years 2009 and 2011; changes for the periods 1995-2009 and 1995-2011 in percentage points

Industry	EU-27						World					
	Nominal value added		Real value added		Employment		Nominal value added		Real value added		Employment	
	2011	change 1995-2011	2009	change 1995-2009	2009	change 1995-2009	2011	change 1995-2011	2009	change 1995-2009	2009	change 1995-2009
Primary Industries	2.7	-1.21	3.1	-0.79	5.9	-3.73	9.6	3.29	4.9	0.22	32.2	-8.76
Manufacturing	15.8	-4.24	17.5	-2.55	15.6	-4.33	17.2	-2.43	18.3	-1.53	15.2	0.20
Food	1.9	-0.54	2.0	-0.45	2.2	-0.46	2.4	-0.20	2.1	-0.40	1.9	-0.20
Textiles	0.5	-0.55	0.6	-0.43	1.1	-1.04	0.8	-0.27	0.8	-0.25	2.6	0.29
Leather	0.1	-0.09	0.1	-0.11	0.2	-0.20	0.1	-0.02	0.1	-0.04	0.5	0.15
Wood	0.3	-0.15	0.4	-0.11	0.6	-0.21	0.4	-0.13	0.3	-0.15	1.0	0.27
Pulp & Paper	1.2	-0.64	1.5	-0.38	1.1	-0.42	1.1	-0.53	1.3	-0.37	1.0	0.22
Ref. Petroleum	0.3	0.00	0.3	-0.04	0.1	-0.06	0.9	0.27	0.7	0.04	0.1	-0.02
Chemicals	1.7	-0.39	2.2	0.12	0.8	-0.30	1.8	-0.17	2.0	0.06	0.8	-0.11
Plastics	0.7	-0.20	0.9	0.00	0.8	-0.04	0.7	-0.15	0.7	-0.11	0.9	0.28
NM Minerals	0.6	-0.34	0.7	-0.24	0.7	-0.23	0.7	-0.15	0.7	-0.19	0.9	-0.37
Metals	2.4	-0.29	2.2	-0.53	2.3	-0.40	2.4	-0.23	2.2	-0.48	1.3	-0.24
Machinery	2.0	-0.14	1.9	-0.30	1.7	-0.42	1.5	-0.20	1.7	-0.14	1.1	-0.19
Electrical Eq.	1.7	-0.56	2.6	0.27	1.7	-0.30	2.3	-0.18	3.3	0.78	1.4	0.22
Transport Eq.	1.7	-0.18	1.8	-0.16	1.4	-0.13	1.6	-0.36	1.9	-0.16	0.9	-0.01
Manufacturing n.e.s.	0.6	-0.17	0.6	-0.20	1.0	-0.12	0.5	-0.11	0.5	-0.12	1.0	-0.09
Electricity, gas, water	2.4	-0.29	2.2	-0.48	0.8	-0.25	2.1	-0.20	2.2	-0.28	0.5	-0.02
Construction	5.9	-0.10	4.8	-1.19	7.2	0.16	5.5	-0.38	4.4	-1.48	6.9	1.36
Services	73.2	5.84	72.4	5.01	70.5	8.15	65.6	-0.29	70.1	3.07	45.1	7.22

Note: Industry classification based on NACE Rev. 1.1. Food=15t16; Textiles=17t18; Leather=19; Wood=20; Pulp & Paper=21t22; Refined Petroleum=23; Chemicals=24; Plastics=25; Non-Mineral Metals=26; Metals=27t28; machinery=29; Electrical equipment=30t33; Transport equipment=34; Manufactures n.e.s.=36t37. World includes EU-27.
Source: WIOD, wiiw calculations.

as the nominal value added share (4.3 percentage points between 1995 and 2009).

This suggests that technological progress which lies behind the changes in relative prices is mainly labour-saving.

A second factor for the observable structural trend is rigid demand structures characterised by low price elasticities of demand and high income elasticities for some services, e.g. education, tourism, health, cultural activities (see Baumol, 1967). This factor helps to explain why the relative importance of manufacturing in value added terms has declined over time. Besides, outsourcing processes and vertical disintegration (with more service activities provided by external firms rather than produced internally) might be an additional cause for declining industry shares.

The structural shift out of manufacturing (both in the EU and globally) encompasses basically all manufacturing industries, implying that the aggregate decline of the manufacturing value-added share is the result of widespread trends across industries rather than driven by only a part of them.

Against the background of these general structural trends at the global and European level, important changes in the global economy such as the emergence of new players in international production and trade and the growing importance of ideas, skills and technology for international competitiveness, poses major challenges for European manufacturing.

To offset the effects of cyclical consumption patterns and sectoral relative productivity growth rates on manufacturing shares of GDP and total employment, manufacturing firms and industries in the EU need to become more competitive on the world markets.

Given the importance of service inputs in manufacturing production, the completion of the single market for services is expected to advance the level of services tradability. By raising their market shares, the production and employment in EU manufacturing can increase.[107]

Industrial policy also has a role to play here, by providing the rules and instruments necessary to increase the competitiveness of EU manufacturing industries.

Table 4.2. Employment developments within the manufacturing sector, EU-27 (1995-2009)

Industry	1995 number of jobs (in '000)	1995 share	2009 number of jobs (in '000)	2009 share	changes 1995-2009 number of jobs (in '000)	changes 1995-2009 percentage points
low-tech	17,257	43.1	13,795	39.3	-3,462	-3.78
medium-low tech	3,778	9.4	3,493	10.0	-285	0.52
metals	5,419	13.5	5,155	14.7	-264	1.16
chemicals	2,258	5.6	1,864	5.3	-394	-0.33
machinery	4,227	10.6	3,786	10.8	-441	0.23
electrical eq.	3,958	9.9	3,758	10.7	-200	0.83
transportation equipment.	3,142	7.8	3,235	9.2	93	1.37
manufacturing	40,038	100.0	35,084	100.0	-4,954	

Note: Value added price deflators for the electrical equipment industry of Finland, France, Sweden, Japan, South Korea and the US replaced by respective German deflation in each year. Industry classification based on NACE Rev. 1.1. Low-tech: Food=15t16, Textiles=17t18, Leather=19, Wood=20, Pulp & Paper=21t22, Manufactures n.e.s.=36t37; medium-low-tech: Refined Petroleum=23, Plastics=25, Non-metallic mineral products=26; Metals=27t28; Chemicals=24; Machinery=29; Electrical equipment=30t33; Transport equipment=34;
Source: WIOD, wiiw calculations.

4.8. TRENDS WITHIN EU MANUFACTURING

Over the period 1995-2009 almost 5 million jobs were lost in the EU-27. From 2009 to 2011 manufacturing employment in the EU-27 fell by another 1 million jobs[108].

To some extent the loss of manufacturing jobs may be offset by new jobs created in services sectors providing intermediate services to manufacturing.

An important explanation for the negative employment developments in European manufacturing is the increase in productivity that – as mentioned before – tends to be labour-saving[109]. In addition the structural shifts within the manufacturing sector are going in the direction of a mild but persistent shift towards more technology-intensive industries (chemicals, machinery, electrical equipment and transport equipment) which also tend to be less labour-intensive. These 'advanced industries' also registered negative employment trends between 1995 and 2009 (with the exception of transport equipment) but job losses were more pronounced in the low-tech industries (3.5 million) which accounted for 70% of total losses in manufacturing employment (Table 4.2.).

This trend towards advanced manufacturing industries reflects international specialisation patterns of EU Member States because in general technology-intensive industries offer more possibilities for building comparative advantages by product differentiation and quality aspects. At the same time low-technology-intensive industries still accounted for almost 40% of manufacturing employment in 2009. Overall, the EU manufacturing sector is well diversified. In order to maintain diversity, the structural upgrading should proceed at a moderate pace in order to ensure that the manufacturing base in the EU remains broad, encompassing all industries. In low-tech and medium-low-tech industries this will require a high degree of specialisation within these industries and the occupation of niche markets. Existing evidence suggests that many European firms

107 The effects on employment could however be negative if the main way to become more competitive is to increase productivity growth.

108 Development 2009-2011 based on Eurostat data.

109 This has to be considered in conjunction with the structures of price and income elasticities of demand which tend to work against compensating demand shifts towards relatively cheaper manufactures.

follow such a 'premium strategy' within their respective industry. Within industries and product categories featuring a low degree of complexity, European firms typically operate in the top quality segments (Reinstaller et al., 2012)[110].

Maintaining a broad and well-diversified manufacturing base in Europe is important in order to preserve manufacturing capabilities which, once lost are hard to develop again. Manufacturing capabilities specific to particular industries may at a later stage turn out to be important inputs for fast growing new products. It is argued that the United States has made this experience in several industries such as shoe production where the entire supply chain has been lost (Helper et al., 2012).[111]

Having stressed the diversification of the EU manufacturing sector and the specialisation into the premium segments within industries it is also important to note the high degree of heterogeneity across Member States. Figure 4.5 illustrates this with respect to the value added share of manufacturing and changes thereto between 1995 and 2011. While this is an imperfect indicator of the role of the manufacturing sector for the economy, the cross-country comparison still indicates which countries may have reason to be worried about their industrial commons. There is cause for concern either because the value added share of manufacturing is declining very strongly – as in the United Kingdom or Latvia – or because it was very low initially (i.e. in 1995) as in the case of France or Greece.

In principle, a declining share of manufacturing in the economy's value-added may be of little concern in Member States whose manufacturing industries produce sophisticated products with a high premium on world markets. Such Member States, e.g. Finland (despite some problems faced recently in the high-tech manufacturing sector) or the United Kingdom are potentially left with a high-powered manufacturing sector. The developments could be of more concern in countries such as Cyprus, Greece, Latvia or Malta where industries produce less sophisticated products and are therefore more vulnerable to competition from low-cost producers. (see Reinstaller et al., 2012). In contrast, there is a set of countries including Germany, Austria and a number of central and eastern European countries that have maintained a rather high-value added share of manufacturing. This shows that there is considerable dispersion among Member States.

4.9. External competitiveness

Figure 4.6. not only shows the competitive positions of the EU-27 as measured by shares in global value-added exports compared to major competitors among advanced economies – the US, Japan and South Korea – but also compared to large emerging economies like Brazil, China and India (for the concept of value-added exports see Box 4.1). Technological leadership and quality upgrading have become increasingly important to ward off competition from emerging economies.

Given the structural upgrading in emerging economies, competitive pressures from these countries are not limited to low-technology-intensive industries but are also felt in advanced manufacturing industries where emerging economies have also gained a foothold. Brazil, India and China all considerably increased their market shares in global value-added exports of manufactures. However, it is the outstanding performance of China, whose market share quadrupled between 1995 and 2011, which basically drives the reshuffling of competitive positions in the global economy.

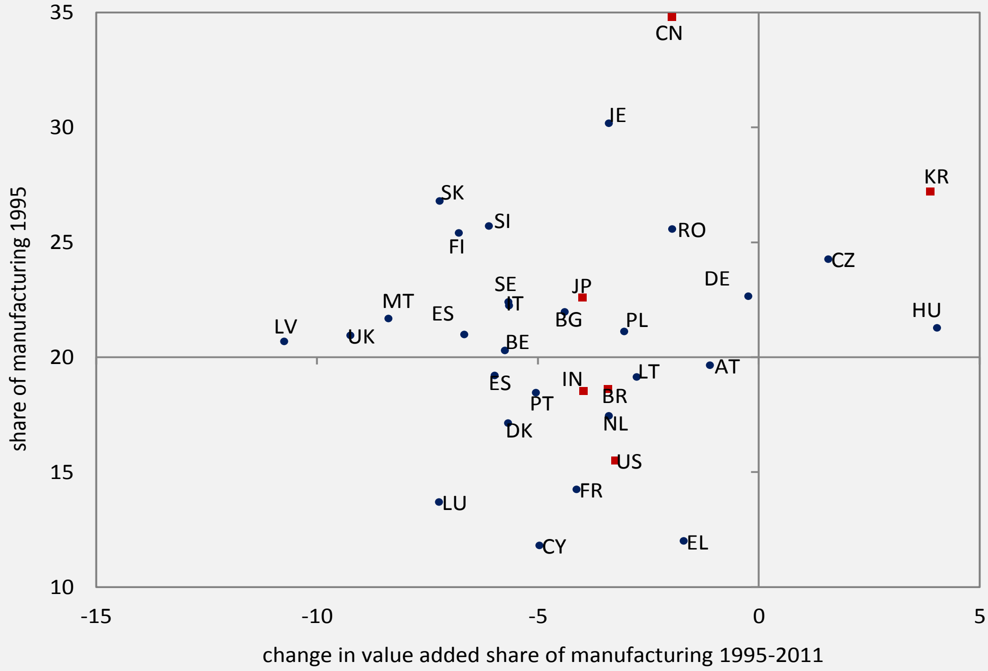
By 2011 China had almost caught up with the EU-27 in terms of value added exports of manufactures, with both economies having a market share of about 20%. China's rise to a first-class exporter of manufactures can be seen in the way it gained export market shares across all industries, with extremely strong positions in the export of textiles and leather as well as in the electrical equipment industry. While China is still specialised in the relatively more labour-intensive stages of production within the electrical equipment industry, the impressive gains in market shares also reflect a remarkable upgrading of industrial structures. The same holds true for other industries and also other emerging economies, e.g. the Indian pharmaceutical and automotive industries.

A factor that facilitated structural upgrading in emerging economies is the relative ease of international technology transfer in a global economy (through trade, FDI, labour mobility in the high-skill segment of the labour force and knowledge diffusion). This is particularly true for the manufacturing sector because the required technology and industrial know-how are to a large extent embodied in physical products which makes them more prone to imitation.

110 See also Chapter 2 of this Report.

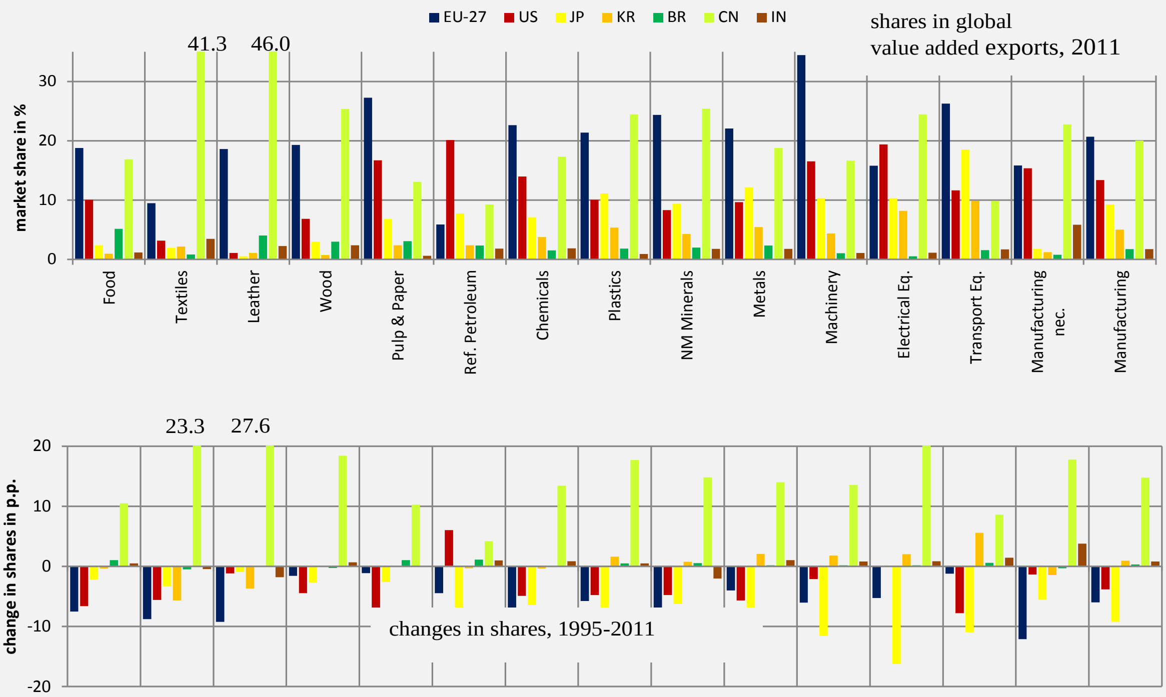
111 Maybe more important is the case of thin-film-deposition which has moved from the US to South East Asia together with semiconductor production which turned out to be important for producing solar panels.

Figure 4.5. Developments of the value-added share of manufacturing (nominal) across EU Member States and selected competitor countries, 1995-2011



Source: WIOD, wiiw calculations.

Figure 4.6. Shares in global value added exports of manufactures (in %), 2011 (upper panel) and changes thereto (in p.p.), 1995-2011 (lower panel), extra-EU exports



Note: Industry classification based on NACE Rev. 1.1. Food=15t16; Textiles=17t18; Leather=19; Wood=20; Pulp & Paper=21t22; Refined Petroleum=23; Chemicals=24; Plastics=25; Non-metallic mineral products=26; Metals=27t28; Machinery=29; Electrical equipment=30t33; Transport equipment=34; Manufactures n.e.s.=36t37. Global market shares in value-added exports and changes thereto exclude intra-EU value-added exports. Source: WIOD, wiiw calculations

Box 4.1. Why is it important to look at value-added exports?

International trade has not only expanded spectacularly over the past 25 years, it has also become increasingly complex. One important dimension in this complexity is the fact that the specialisation patterns have become more granular. Supported by declining trade costs, the ever finer specialisation on individual components of a product or steps in the production process – also referred to as fragmentation of production – makes the analysis of trade flows more demanding. International fragmentation of production heightens the importance of trade in intermediate goods. This in turn poses some difficulties for traditional trade statistics which record trade flows according to a gross concept thereby inflating trade figures.

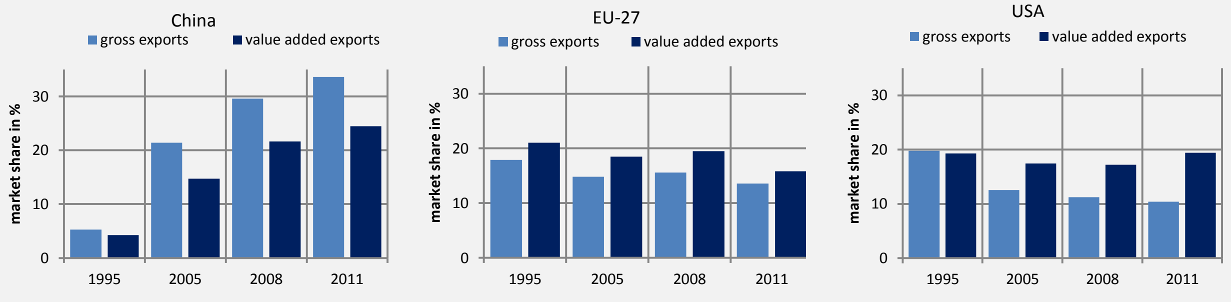
One possibility to adjust gross export flows for imported intermediates is provided by global input-output statistics. The present Report relies on the World Input-Output Database (WIOD) which provides such statistics for a set of 40 countries including EU Member States. The WIOD is used to calculate the value- added exports at industry level for each country or country groups. These value added exports capture only the value added that is generated domestically in the production of goods that are destined for export (see Johnson and Noguera, 2012; Stehrer, 2012) but exclude foreign value-added associated with imported intermediates.

Figure 4.7 illustrates how the differences between gross exports and value-added exports can be quite significant, particularly in industries characterised by intensive intra-industry trade such as electrical equipment. According to gross exports, China's market share in the electrical equipment industry for example rose from 5.27% in 1995 to 33.6% in 2011. Looking at value added exports, China's market share still rose but reached only 24.5% in 2011. While this is still a spectacular development, the resulting difference between China's market share in gross exports and value added exports is equal to about 33.6% and 24.5% in 2011, respectively.

For the EU and the United States the opposite is true. The EU's share in global value added exports in the electrical equipment industry is 2.2 percentage points higher than in terms of gross exports in 2011 and in the US the difference even reaches 9 percentage points. The figures above also indicate that the difference between gross exports and value added exports has increased between 1995 and 2011 due to the emergence of international production networks and more fragmented global production.

In the presence of international production sharing the value added exports probably give a more accurate picture of export market shares of the trading partners involved.

Figure 4.7. Differences between market shares in gross exports and value added exports in the electrical equipmen industry, 1995-2011



Source: WIOD, wiiw calculations.

As a result emerging economies like China not only have large export market shares in low-tech and medium-low-tech industries (where they can be expected to possess comparative advantages due to lower labour costs) but also increasingly in more technology-intensive industries.

The mirror image of the entry of China and other emerging economies into the global trade arena is a decline in market shares of the EU, the US– both lost about a fifth of their export market shares between 1995 and 2011 – and Japan, whose market share was halved. Even if the gains in market shares of China levels off in coming years as wages rise and the technology gap narrows[112], these industries in China will remain major competitors. Arguably, competition may become fiercer as the catch-up process of major emerging economies such as China, India and Brazil continues and these countries expand their skills and capabilities in the manufacturing domain.

In any case, the shifts in competitive positions discernible in Figure 4.8. suggest that the EU's losses of export market shares in manufacturing were primarily due to the integration of emerging countries into the global economy and to a lesser extent to competition from other advanced economies with the exception of South Korea, which made substantial inroads into the production and export of transport equipment (mainly the automotive industry).

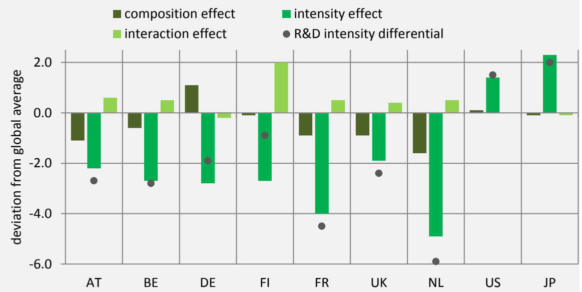
Given these trends in market shares in global value added exports, further shifts towards these emerging economies can be expected.

From a European perspective, however, the rise of China and other emerging economies not only constitutes a formidable competitive challenge but also means new and enlarged markets. Equally important is the fact that the benefits from new export opportunities and the potential costs of a deteriorating international competitiveness are not distributed evenly across EU Member States. This leads to another main challenge for European manufacturing which consists of the agglomeration of manufacturing activities.

4.10. R&D AS MEANS TO MEET COMPETITION

The gap between the innovation activities of firms in the EU and the United States has been a concern for European policymakers for decades. Indeed, the comparison of R&D intensity in manufacturing as an indicator of the intensity of innovative activity, measured as the business expenditure of manufacturing firms on R&D relative to manufacturing value-added, suggests that European manufacturing is characterised by lower R&D intensity in comparison to US and Japan.

Figure 4.8. Decomposition of differences in manufacturing R&D intensity in EU Member States, the US and Japan, average 2007-2008



Note: R&D intensity is Business expenditure on Research and Development in per cent of value added. Global average is the average of the nine countries. R&D intensity differential is the difference of the manufacturing-level R&D intensity to the mean of the nine countries. Methodology following Eaton et al. (1998). Industry classification based on NACE Rev. 1.1. For industry groupings and decomposition see Appendix .
Source: WIOD, OECD ANBERD, wiiw calculations.

These differences in R&D intensity at the manufacturing level can be split into a composition effect which reflects differences across countries in industry structure, and an intensity effect which reflects differences in the R&D intensity at the level of manufacturing industries, as well as an interaction effect (see Eaton et al., 1998 and European Commission (2011)). This decomposition shows that the differences in the R&D intensity of firms across EU Member States, the US and Japan at the manufacturing level are mainly driven by the intensity effect. The industry structure (composition effect) plays a role in some Member States but is never the primary factor[113].

This gap in R&D activities of the manufacturing sector in the seven EU Member States, characterised by the largest R&D intensities across Member States for which data are available, is partly compensated by higher public R&D expenditure in these countries. R&D intensity in the seven EU Member States with the relatively highest R&D intensities across the EU (Figure 4.8) is only 62% that of the United States.

However, there are also research findings based on BERD territorial official statistics and also company data that conclude that there is lower overall corporate R&D intensity for the EU as a result of sector specialisation (structural effect). In these cases,

[112] Gains in market shares in Chinese value added exports in manufactures seems to have levelled off somewhat since the mid-2000s although they continued to increase (by 4.2 percentage points between 2007 and 2011 compared to 5.3 percentage points between 2002 and 2006).

[113] The relative importance of the composition effect and the intensity effect in such a decomposition exercise depends on the level of aggregation of the industries. A more detailed industry break-down would assign greater importance to the composition effect. The EU R&D Scoreboard 2012 also identifies an R&D intensity gap which is particularly strong in the high-tech industries when using ANBERD data which are territory based. When using a more elaborate analysis based on company-level data, it is argued that industry composition becomes an important agent (see http://iri.jrc.ec.europa.eu/scoreboard12.htmlhttp://iri.jrc.ec.europa.eu/scoreboard12.html for details, particularly Chapter 7).

the US seems to have a stronger sectoral specialisation in the high R&D intensity (especially ICT-related) sectors than the EU does, and also has a much larger population of R&D investing firms within these sectors[114]. This issue calls for policy makers to pay further attention to the industrial structures differences and the need for Europe to favour the growth and emergence of new world leading innovative companies[115].

At the same time, it seems that the concern about a deterioration of relative positions in advanced manufacturing industries vis-à-vis the US and other economies at the technological frontier; should be limited to the electrical components industry. In all other advanced manufacturing sectors the market shares in global value-added exports of the EU are still much higher than those of the US. The EU is still the world's largest exporter of chemicals, machinery and transport equipment, with the latter two constituting the major strongholds of European manufacturing. Despite a 6 percentage point decline in its market share of global value added exports between 1995 and 2011[116], the EU still accounts for more than a third of global machinery valued-added that is exported, putting it far ahead of the United States[117]. The EU-27 also has considerable export market shares in low-technology industries such as the food industry or the pulp and paper industry which supports the claim that EU firms often occupy premium segments within industries to remain internationally competitive. An example for such high-quality specialisation in low-technology sectors is the production of protective textiles or extra-long hardened rail tracks. Figure 4.8 suggests that EU firms are more successful in this type of specialisation than their US rivals.

Offshoring implies that part of the value-added created by EU firms is generated in low-cost locations. The offshoring activities of EU multinationals were predominantly regional in scope, meaning that labour-intensive parts of the production process were re-located to central and eastern European Member States, which also still have relatively low labour costs by EU standards. It is worth mentioning that offshoring does not predominantly affect labour-intensive industries (as opposed to advanced manufacturing industries). The dividing line is rather the skill level of employees with low-skill (though often medium-paid) jobs in manufacturing being more prone to offshoring. This points towards a major role for education and training of the labour force, in particular in high-wage countries, in order to remain an attractive location for manufacturing activity.

4.11. Industrial policy measures in the European Union

Few people will doubt that the main responsibility for mastering the challenges facing the European manufacturing sector rests with firms. However, a recent survey of the top 1000 EU R&D investing companies has shown that public policies may constitute an important stimulus for company innovation[118]. According to that survey, national public support in terms of fiscal incentives and public grants had a positive effect on company innovation, as well as EU policies in terms of direct public aid and public private partnerships. In this sense, another question is whether the EU and its Member States have fully exploited the potential of industrial policies to support firms in mastering these challenges and ensuring a strong manufacturing base in Europe.

After a brief overview of industrial policies at the Union level and by Member States in Section 4.12, Section 4.13 provides a quantitative analysis of State aid by EU Member States which constitutes an important industrial policy tool. Since R&D is a key aspect in EU's industrial policy mix and it is directly linked to the challenges of European manufacturing, this section also investigates the impact of public funding for R&D on innovation activity and innovation output at firm level.

4.12. Industrial policies at the EU level and by Member States

With the Maastricht Treaty, the EU enshrined its industrial policy approach in primary law, stipulating that the 'Union and the Member States shall ensure that the conditions necessary for the competitiveness of the Union's industry exist'[119]. However, by defining industrial policy in a very broad sense including flanking measures, the EU had set a major industrial policy objective well before Maastricht. The creation of the European single market embedded the EU's competition rules, which were previously part of the earlier common market. The particularity of EU competition rules is that besides controlling the anti-competitive behaviour of firms (abuse of a dominant position, market and price rigging and later merger control), the European Commission was also empowered to control the State aid provided to firms

[114] See Moncada-Paternò-Castello; Ciupagea, C.; P., Smith, K; Tübke, A. and Tubbs, M.: "Does Europe perform too little corporate R&D? A comparison of EU and non-EU corporate R&D performance", Research Policy 39 (2010) pp. 523–536

[115] See Cincera, M. and Veugelers, R.: Young Leading Innovators and EU's R&D intensity gap. JRC-IPTS Working Papers on Corporate R&D and Innovation, nº11/2010.

[116] These figures exclude intra-EU value added exports.

[117] These figures exclude intra-EU value added exports.

[118] See Tübke, A.; Hervás, F. and Zimmermann, J.: "The 2012 EU Survey on R&D Investment Business Trends", European Commission, Joint Research Centre, EUR 25424 EN, www.jrc.eswww.jrc.es, pp.22.

[119] Article 173(1) of the Treaty on the Functioning of the European Union (TFEU).

by EU governments. Still today this is a quite unique feature in competition rules.[120] The control of State aid of sovereign governments is obviously a delicate issue and the Commission has exercised a large degree of pragmatism in this respect (Doleys, 2012). The Commission has tried to shift State aid by Member States from sector-based schemes to horizontal objectives such as aid to SMEs or support for R&D, or aid for employment and worker training. The European Commission's preference for horizontal State aid stems from the belief that horizontal aid distorts competition less than sectoral aid (Friederiszick et al. 2006), and that it contributes to the Commission's own market-correcting or redistributive policy goals which links it to an objective of 'common interest' (Blauberger, 2008)[121].

The latest revision of State aid policy (State Aid Modernization) favours a shift towards block-exempted aid. This aid is less likely to distort competition, due to lower levels of aid intensities and it is in line with the most prominent EU initiatives.

While at the Union level, the focus remained on general framework conditions, there were also early attempts to implement a kind of technology policy (Owen, 2012). Over time, the support for R&D, innovation and technology funded from the EU budget has become quite substantial, leading prominent economists to conclude that at the EU level industrial policy is essentially R&D policy (Van Pottelsberghe, 2007).

The EU's ambitions in the field of industrial policy (European Commission 2010a) have intensified in the aftermath of the economic crisis of 2008 with the focus largely remaining on framework measures and innovation. Hence, in the EU's new growth strategy, the Europe 2020 strategy adopted in 2010 (European Commission, 2010b), the 'Innovation Union' (European Commission, 2011c) figures prominently among the flagship initiatives. Moreover, the 2020 strategy also confirms the EU's horizontal industrial policy approach. This policy communication also proposes a fresh approach to industrial policy that complements its market-oriented horizontal approach with sector-specific elements. The Commission characterises its approach as 'bringing together a horizontal basis and sectoral applications' (European Commission, 2010a, p. 4). The mention of sectoral application of horizontal measures seems to take into account the claim that infrastructure and other public inputs tend to be highly context-specific, calling for a sector-specific definition of industrial policy (Hausmann and Rodrik, 2006). In the specification of the sectoral dimension of industrial policy, the European Commission identifies the development of clean and energy-efficient vehicle technologies as a priority area for industrial policy. The Commission's update of the industrial policy communication from October 2012 (European Commission, 2012a) contains six priority action lines which aim at improving the competitiveness of European manufacturing.

These priority lines highlight once more the importance of new technologies for a thriving manufacturing sector. At the same time these action lines are directly or indirectly related to the protection of the environment and the mitigation of climate change.

The priority action lines are accompanied by a number of additional objectives, such as the establishment of a European patent, and new elements such as the 'green public procurement', a demand-side policy instrument which has not previously featured among the main concerns of industrial policy.

The industrial policy approach at Union level is highly relevant for the industrial policies applied by Member States. The interdependence between policies at EU level and Member State level is most obvious in the field of competition policy including State aid where the Commission is responsible for controlling the activities of Member States. But the two layers are also linked by the fact that most of the projects paid from EU funds have to be co-financed by Member States.

During the 1980s, State aid to industry and services provided by EU Member States amounted to approximately 2% of EU GDP and went down to about 1% in the following decade (European Commission, 2011b). The general downward trend in State aid in the EU continued until 2007 where it reached an all-time low of 0.4% of GDP.

State aid also has a counter-cyclical component, i.e. the amount spent increases in times of recessions. This was the case in the economic crisis of 2008. As shown in Figure 4.9., State aid increased to 0.6% in 2008, which is still a very low amount by historical standards but represented a 50% increase from the year before. These figures include State aid granted under the Temporary Framework which allowed a temporary adjustment of State aid rules and was intended to encourage investment and ease the access

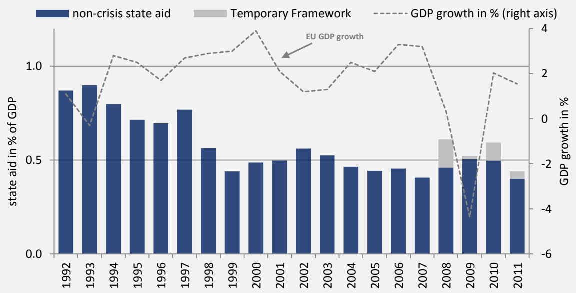
[120] Only EFTA has a comparable competition authority.

[121] For the various types of horizontal State aid there exist so-called block exemptions. These block exemptions specify a number of criteria that aid programmes must fulfil (e.g. maximum subsidy amount typically expressed in percentage of eligible costs). If the criteria are fulfilled the aid programme is considered to be compatible with State aid rules. The block exemptions constitute a major simplification of the procedure as they exempt eligible aid programmes from the requirement of prior notification and Commission approval. For Member States this means that they are able to grant aid that meets the conditions laid down in these regulations without the formal notification procedure. However, ex post information sheets on the implemented aid have to be submitted.

to finance for firms facing tightening credit conditions. It was targeted at the real economy.[122]

The Temporary Framework provided new measures specifically targeted to facilitate companies' access to finance[123].

Figure 4.9. State aid to industry and services in the EU 27, 1992-2011, in % of GDP



Note: Figures exclude crisis-related aid to the financial sector. The value for France in 1997 excludes the EUR 18 billion State aid to Crédit Lyonnais. Amounts refer to the aid element (or gross grant equivalent in the case of guarantees and loans) contained in the State aid measure.
Source: European Commission State Aid Scoreboard, Eurostat, wiiw calculations.

Due to the crisis, State aid by Member States rose to 0.5%-0.6% of GDP in the years 2008-2010 but in 2011 the amount dropped to 0.44% of EU GDP, which equals the pre-crisis levels of aid intensity.[124] Setting aside the crisis-related State aid, the amount of State aid in 2011 was back at the 2007 level. These very low figures are interesting for a number of reasons. First of all, they show that the amount of State aid provided by Member States has become relatively small. Secondly, the renewed interest in industrial policy both at the Member State and the EU level has not so far resulted in a substantial increase in State aid figures[125]. Thirdly, the impact of even small amounts of State aid is potentially very large. The total of State aid measures under the Temporary Framework by the 27 Member States sums up to EUR 4.8 billion over the period 2008-2010 but it consists of a large number of measures, including multi-billion loans to car producers. The aid elements implicit in such measures seem low but they can nevertheless have a great impact on individual companies (in particular when the State aid comes in the form of a rescue operation) but also at market level for the industry[126]. So the leverage of State aid measures may be quite high. EU governments have a great potential to affect market outcomes and also the position of EU companies in global competition without large fiscal implications.

The next sections analyse use of State aid by EU Member States in more detail by investigating the relationship between various types of State aid on the one hand and competitiveness and value added of the manufacturing sector on the other hand.

4.13. QUANTITATIVE ASSESSMENT OF STATE AID AND EXPORT ORIENTATED MANUFACTURING

Two different specifications are presented with the objective to quantitatively assess in what way different types of State aid provided by EU Member States, impact on the export-oriented manufacturing sector in the EU. For an overview of the selected categories of State aid see Box 4.2. The strategy follows recent empirical literature on the development of the internationally competitive manufacturing sector. The two base specifications (see Annex 4.3 for details) deal with the explanation of extra-EU export shares (following Aghion et al., 2011) and value-added per capita in export-orientated manufacturing (following Haraguchi and Rezonja, 2011). The two approaches are used in order to cover different aspects of the export-oriented manufacturing sector (value added per capita and export share).

The first regression model builds on the approach by Aghion et al. (2011). This model tries to explain the overall share of extra-EU manufacturing and services exports of the individual EU Member States in total EU exports with the help of a sectoral state aid indicator as well as a proxy for financial development. The regression also controls for non-linearities and interactions in order to see whether explanatory variables are substitutes or complements. The rationale of this estimation exercise is to find out whether state subsidies can act as a promoter of international competitiveness, especially in those cases where access to private finance is limited. It is important to note that this analysis is of a general nature and does not imply a specific link between a

122 Crisis-related aid measures to the financial sector were subject to a different set of rules and the amounts involved were much higher, reaching 1.9% of EU GDP in 2008 and 2.9% of GDP in 2009. These amounts are not included in Figure 4.9.

123 The measures of the Temporary Framework included the possibility to grant direct subsidies to individual firms up to an amount of EUR 500,000; the provision of state guarantees at reduced premia; additional interest-rate support for loans financing investments in green products; and the possibility for official export credit agencies (ECAs) to provide cover for short-term transactions which were previously considered to be 'marketable risk'.

124 The Temporary Framework expired by the end of December 2011. In the period 2008-2011 about EUR 4.8 billion of State aid (0.04% of EU GDP) was paid out under the Temporary Framework, mainly in the form of subsidies and direct grants (European Commission, 2012b). The Temporary Framework was open to all industries and sectors but de facto the majority of the aid was allocated to car producers which were hit hard by the crisis due to the crisis-related slump in car sales.

125 The priority for a fiscal consolidation affected considerably State aid measures in several Member States.

126 Note that so-called *de minimis* aid provided by Member States is not included in the State aid figures because *de minimis* aid need not be notified to the Commission. *De minimis* aid represents all aid measures with an aid amount below EUR 200,000 (this threshold applies since December 2006 when it was raised from EUR 100,000).

Table 4.3. Internationalisation measures and competitiveness
Dependent variable: Member States' share in total extra-EU exports

Specification	(1)	(2)	(3)	(4)
internationalisation measures	0.024 ***	0.020 ***	0.025 ***	0.022 ***
	(0.005)	(0.006)	(0.008)	(0.006)
internationalisation measures²	-0.001	-0.001	0.000	-0.001
	(0.001)	(0.002)	(0.001)	(0.001)
loans to GDP	0.071			
	(0.072)			
loans to GDP²	-0.269 ***			
	(0.033)			
loans to GDP, internationalisation measures	-0.009			
	(0.007)			
governance		0.437		
		(0.356)		
governance²		-0.105		
		(0.981)		
governance, internationalisation measures		0.142 ***		
		(0.017)		
wage share			0.179	
			(0.422)	
wage share²			2.224	
			(1.957)	
wage share, internationalisation measures			0.108 **	
			(0.045)	
tariff rate				0.071 *
				(0.040)
tariff rate²				-0.026
				(0.030)
tariff rate, internationalisation measures				0.066 ***
				(0.012)
R^2	0.993	0.990	0.989	0.990
adjusted R^2	0.992	0.988	0.987	0.989
Observations	373	380	341	391

*Note: Standard errors appear in parentheses. ***, **, * indicate statistical significance at the 1%; 5% and 10% level respectively. Regressions include country and year fixed effects as well as a constant term which are not reported. The standard errors are robust. All the data was logarithmised (observations of the value zero were changed to 0.01 in order to make the taking of logarithms possible) and centred in order to make the estimated coefficients interpretable. The model is described in Annex 4.3.*
Source: WIOD, European Union State Aid Scoreboard, Eurostat, UNCTAD-TRAINS, World Bank's Worldwide Governance Indicators (WGI) database.

certain type of aid and the trade performance of any particular product or sector.

The original specification is modified by analysing specifically Member States' shares in total extra-EU manufacturing exports. Apart from private credit, a number of additional variables were added: the government effectiveness rank to control for institutional quality, the wage share in value added as a readily available proxy for competition as well as the import weighted tariff rate as an indicator of trade protection.

As shown in Table 4.3, the main effect of horizontal commerce and internationalisation support measures is positive and significant at the 1% level throughout all four of the specifications presented in the table. Using specification (2) as an example, the interpretation of the results suggests that if the average EU country were to double its internationalisation measures, its share in total extra-EU manufacturing exports would increase by 2%. Although this effect appears to be tiny, given the generally very low levels of internationalisation

Box 4.2. Categories of State aid in the European Union

Non-crisis State aid granted by the Member States to industry and services broadly splits into two types: horizontal and sectoral.

The concept of horizontal aid, which is aid that is not granted to specific sectors of the economy, derives from the EU Treaty. It leaves room for the Commission to make policy judgements whereby State aid can be considered compatible with the internal market if it provides effective support for common policy objectives. Most prominent here is aid earmarked for research, development and innovation, safeguarding the environment, fostering energy saving and promoting the use of renewable energy sources; Those categories are followed by regional development, aid to SMEs, job creation and the promotion of training (European Commission, 2012b).

Research, development and innovation: R&D&I lies at the heart of the Europe 2020 strategy as one of its flagship initiatives because of its potential to contribute to strengthening the competitiveness of the EU economy and to ensure sustainable growth, with a target of spending 3% of EU GDP on R&D by 2020.

Environmental protection: State aid here can include aid measures to support energy saving and waste management or to improve production processes, which have a direct benefit to the environment.

Regional development and cohesion: The aim of regional aid is to develop the economic, social and territorial cohesion of a Member State and of the EU as a whole. The Commission encourages Member States to grant regional aid on the basis of multi-sectoral schemes which form part of a national regional policy.

Commerce, export and internationalisation: This is a less used measure that however showed some importance in the quantitative analysis. It consists of a number of different aid measures such as the promotion of brand image or sales networks but also officially supported export credits to the extent that they contain an aid element.

State aid earmarked for specific sectors, or sectoral aid includes a number of measures targeting for instance: rescue and restructuring of firms in difficulty; Sectors covered include shipbuilding; steel; coal; land, sea and air transport; agriculture; fisheries and aquaculture.

measures, the result is not negligible. In recent years the average annual internationalisation measures expenditure by Member States has been at about EUR 10 million only.

The other positive and significant result in this specification is the interaction term between internationalisation measures and the governance effectiveness rank. More internationalisation support is correlated with bigger export shares in countries with a higher level of domestic competition (i.e. a higher wage share or, in other words, a smaller profit share, such as in the Nordic and core EU countries), as can be seen from specification (3). Finally, countries with both more internationalisation support and more tariff protection have on average higher extra-EU export shares (see specification (4)). Ceteris paribus a higher tariff protection might support the development of domestic manufacturing capacity and induce additional exports. In fact, the positive coefficient is in line with the classical infant industry argument (which is based on the existence of externalities) if such tariff protection were assumed to be temporary.[127] The effects of sectoral State aid that directly targets the manufacturing sector were also analysed. In none of the estimated specifications did the conditional main effect of manufacturing aid appear to be significantly different from zero (see Table A4.2.3 in the Annex 4.2).

In a second approach, the methodology put forward in Haraguchi and Rezonja (2011) is applied to the provision of State aid by EU Member States. The aim here is to specify better the relationship by adding more control variables and to test for the determinants of the single manufacturing industry's importance separately, using a model that tries to explain the real value-added per-capita of the respective manufacturing sector.

Explanatory variables are the per capita gross domestic product, population density and natural resource endowment as well as different types of State aid per capita. The control variables which feature prominently in the growth literature account for developmental impact on manufacturing while other variables control for demographic and geographic conditions. In order to check the robustness of the estimated results, additional variables such as the private loans to GDP indicator have been included but the main results do not change very much. Moreover in the regression approach the individual manufacturing industries have been aggregated in two groups – export-oriented industries and industries focusing on the domestic market, based on an exportability measure.

[127] It should be noted however, that Member States do not set tariffs themselves because trade policy is a competence of the European Commission. Any differences in the tariff rate across Member States areis therefore due to differences in their export structures.

Table 4.4. State aid and value-added per capita – export orientated industries
Dependent variable: manufacturing value added per capita of export industries

Specification	(1)	(2)	(3)	(4)
per capita GDP	1.537***	1.455***	1.343***	1.615***
	(0.206)	(0.191)	(0.199)	(0.182)
per capita GDP²	0.443***	0.483***	0.458***	0.491***
	(0.086)	(0.090)	(0.083)	(0.087)
population density	-4.376***	-4.305***	-5.095***	-4.416***
	(1.026)	(1.030)	(0.949)	(0.981)
resource endowment	-0.006	0.008	-0.035	0.003***
	(0.046)	(0.047)	(0.041)	(0.047)
energy saving aid	0.009			
	(0.008)			
regional aid		0.023***		
		(0.007)		
risk capital aid			-0.027***	
			(0.005)	
training aid				0.008*
				(0.004)
R²	0.969	0.969	0.972	0.969
adjusted R²	0.964	0.964	0.968	0.964
Observations	286	286	286	286

*Note: Standard errors appear in parentheses. ***, **, * indicate statistical significance at the 1%; 5% and 10% level respectively. Regressions include country and year fixed effects as well as a constant term which are not reported. The standard errors are robust. The model is described in Annex 4.3 .*
Source: European Union State Aid Scoreboard, Eurostat, UN Comtrade.

The main findings for this second approach are reported in Table 4.4. The level of export-oriented manufacturing value-added per capita is not affected by sectoral specific manufacturing aid. It is rather a few horizontal aid spending items which show signs of correlation, Regional aid is found to be positively correlated with the value-added level. Somewhat surprisingly, risk capital aid tends to target economies with lower levels of per capita export-oriented value added. One explanation may be that regional aid is more likely to be absorbed by large, internationally operating firms, while environment and energy saving aid can more easily be absorbed by domestically operating smaller firms.[128] However, the negative sign found for risk-capital aid is not straight forward. A possibility might also be that firms in manufacturing-orientated countries such as Germany or Austria rely more on banks to finance their needs, and consequently risk capital and risk capital aid is less important. In contrast, risk capital is more important in countries were the manufacturing sector development was less dynamic over the past one and a half decades (e.g. the United Kingdom). This sign possibly illustrates a correlation pattern existing restrictively in the specific sample for this exercise.

4.14. Company-level analysis of commercialisation performance

Innovation has been placed at the heart of the Europe 2020 agenda as one of the main drivers of economic growth. In a globalised world, innovative ideas and products stimulate exports and sales in general, thereby securing growth and future jobs (Harrison et al., 2008). As the EU-27 is still behind other major economies when looking at simple innovation indicators such as overall R&D expenditures, the impact of innovation policies on firms' innovative behaviour has been a major concern of policy-makers.

Instruments to address shortage of funding for firms still differ greatly in the EU. Venture capitalists are more active in Scandinavian and Anglo-Saxon countries and public funding is on average more pronounced in EU-15 countries compared to the EU-12 countries. When looking at the different settings, an essential question that arises is about the effectiveness of public innovation support. In this section, the effects of public innovation support on the commercialisation of R&D effort will be evaluated.

128 As shown in the background study, regional aid and risk capital aid has no impact on value added for domestically oriented firms while coefficients for energy saving aid and training aid are significantly positive.

To that end, the effect of public funding on private R&D intensity and innovation output is estimated, using data from the Community Innovation Survey (CIS)[129]. Focusing on the commercialisation of R&D efforts, innovation output will be measured in terms of innovative sales.

The EU is usually perceived as less effective at bringing research to the market compared to its main competitors such as the US, Japan, and South Korea. The relative underperformance in research commercialisation in the EU has been attributed to a number of factors including the absence of an entrepreneurial culture and a less developed venture capital sector[130]. The discussion about the main factors explaining the European innovation gap dates back to the Dosi et al. (2006) much-cited criticism on the concept of the European paradox, a widely accepted opinion that Europe does not lag behind the US in terms of scientific excellence, but lacks the entrepreneurial capacity of the US to effectively commercialise inventions and step thereby on an innovation-driven growth path. In the literature there are a number of publications that investigate whether Europe's weak commercialization performance can explain the paradox and whether other explanatory factors are identified (examples of recent overviews can be found in Conti and Gaule (2011) and Carlsson et al. (2009)).

This section focuses on which specific innovation-related factors and which types of public funding can be identified as relevant for commercialization performance. By doing so, a firm-level analysis is provided with a particular focus on the commercialisation of R&D efforts. Among the activities examined are the actual R&D performed internally and/or acquired from external sources, the research collaboration activities with different players (such as customers, suppliers, public research institutions and other firms), and the firm's use of particular types of public funding for innovation.

The analysis of the market uptake of innovation at the firm-level is based on the Community Innovation Survey (CIS) micro-data. The CIS survey is a European-wide, harmonized data collection on innovation according to the guidelines of the Oslo Manual (Eurostat/OECD, 2005). The CIS survey is organized bi-annually and collects information on enterprise's innovation activities. For consistency and timing reasons, the anonymized CIS2008 and CIS2006 surveys were used which cover the time span 2006-2008 and 2004-2006 respectively.

The CIS2006 covers three countries from the EU-15, namely Greece, Spain and Portugal and 9 countries from the EU-12. The CIS2008 covers 15 countries. Germany, Spain, Italy, Ireland and Portugal are EU-15 countries. The other 10 countries represented in the CIS2008 are EU-12 countries which joined the EU after 2004. Additionally to differences in country coverage the two waves also differ with respect to sectoral classifications as the CIS2006 is based on the NACE Rev. 1.1 whereas the CIS2008 on the NACE Rev. 2 classification. Results reported below distinguish broader industry aggregates by broad technology intensity when considering manufacturing firms only.[131]

As a key variable for assessing a firm's commercialization performance, this analysis uses the firm's answers on the innovation commercialization question in the CIS survey; firms were asked about "the percentage of total turnover from new or significantly improved goods and services introduced that were new to your market".

The theoretical rationale of the contextual variable choices comes from to firm-level innovation analysis literature which also uses the CIS data. The importance of collaborative R&D for innovation and general firm performance is illustrated by among others Laursen and Salter (2006) and Belderbos et al. (2004). Cassiman and Veugelers (2006) confirm the importance of innovation activities. More specifically, they show that internal knowledge production as well as external knowledge acquisition is important for a firm to introduce products new to the market. The combination of internal and external R&D activities is often referred to in the literature as absorptive capacity (Cohen and Levinthal (1990)).

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129 Following to the Community Innovation Survey, public funding or public innovation support is defined as credits or deductions, grants, subsidised loans, and loan guarantees for innovative activities. The support may come from three authorities: the EU, national governments and regional authorities.

130 In this report 'research commercialisation' is defined as a sub-set of the innovation trajectory. Similarly, the 'commercialisation gap' is understood as a sub-part of the 'innovation gap', focusing here on the latest stages of the innovation trajectory.

131 The industry class dummies have been defined based on the post-anonymization NACE codes. These codes differ between the CIS2006 (derived from NACE Rev. 1) and CIS2008 (derived from NACE Rev. 2) waves of the survey. For the CIS2006 data the following industry class definitions were used: low-tech (nace_pro codes DA, DB, DC, 20_21, 22, DN), medium-tech (nace_pro DF_DG, DH, DI, 27, 28), high-tech (nace_pro DK, DL, DM). For the CIS2008 wave: low-tech (nace_pro C10_C12, C13_C15, C16_C18, C31_C33), medium-tech (nace_pro C19_C23, C24_C25), high-tech (nace_pro C26_C30).

Table 4.5. Results of the commercialisation output regressions with CIS2006

	All firms	EU-15	EU-12	Small firms	Medium and large firms	All manuf. firms	Low-tech	Medium-low tech	Medium-high and high tech
Commercialisation performance equation									
extramural R&D	0.278***	0.285***	0.261***	0.431***	0.166***	0.231***	0.252***	0.196***	0.242***
	(28.26)	(20.59)	(18.39)	(9.30)	(7.22)	(19.01)	(10.70)	(9.67)	(12.50)
log R&D expenditures	0.0521***	0.0446***	0.0615***	-0.279	0.170***	0.0874***	0.176***	0.0788***	0.0151
	(6.80)	(3.41)	(6.58)	(-1.74)	(3.53)	(8.67)	(8.32)	(4.67)	(0.96)
log 2004 sales	0.00578***	0.00650***	0.00480**	0.00247	0.0229***	0.00545***	0.00689**	0.00257	0.00652**
	(5.40)	(4.27)	(3.16)	(1.86)	(9.69)	(4.17)	(2.84)	(1.25)	(2.86)
vertical cooperation	0.316***	0.223***	0.389***	0.549***	0.182***	0.279***	0.314***	0.231***	0.273***
	(27.63)	(13.13)	(24.78)	(7.60)	(7.83)	(20.28)	(11.93)	(10.21)	(12.21)
horizontal cooperation	0.0640***	0.0822***	0.0165	0.193***	-0.00319	0.0273	0.0206	0.0296	0.0335
	(4.62)	(3.42)	(0.98)	(4.37)	(-0.15)	(1.56)	(0.59)	(1.02)	(1.23)
intra-group cooperation	0.0162	0.0600**	-0.0173	0.173***	-0.0287	0.0421*	-0.0901*	0.0146	-0.0328
	(1.15)	(2.61)	(-1.00)	(3.35)	(-1.22)	(2.48)	(-2.37)	(0.53)	(-1.17)
local public funding	0.178***	0.199***	0.181***	0.384***	0.0678**	0.150***	0.206***	0.137***	0.124***
	(13.90)	(13.14)	(4.99)	(4.98)	(3.04)	(9.78)	(7.10)	(5.62)	(4.84)
national public funding	0.108***	0.160***	0.038	0.506**	-0.0183	0.0421*	0.0148	-0.014	0.146***
	(7.78)	(7.91)	(1.91)	(2.91)	(-0.43)	(2.45)	(0.44)	(-0.49)	(5.29)
EU funding	0.0982***	0.0426	0.139***	0.295***	-0.00892	0.0741***	0.0445	0.118***	0.048
	(5.91)	(1.53)	(6.80)	(3.84)	(-0.23)	(3.58)	(1.17)	(3.44)	(1.38)
F-test for model's significance	11800.6***	5333.3***	6695.5***	6288.1***	5176.9***	5353***	2039.0***	1439.3***	1401.1***
observations	85238	38127	47111	53915	31323	43897	21677	13080	9140

*Note: t statistics appear in parentheses. ***, **, *indicate statistical significance at the 0,1%; 1% and 5% level respectively. Regressions include country and industry fixed effects as well as a constant term which are not reported.*
Source: Community Innovation Survey (CIS).

The literature concerning the introduction of new products into the market illustrates that it is important to take into account the firm's marketing efforts (market introduction activities) in the commercialisation model. As such, public funding plays a role not only in stimulating the R&D efforts of firms, but also in promoting successful commercialisation of research results (Griffith et al. (2006).

The model on which the analysis is based represents a slightly modified version of the so-called CDM model introduced in Crepon et al. (1998)[132]. A firms' choice to conduct/report R&D is estimated in the first stage (R&D selection equation). At the second stage of the model the R&D expenditures is the dependent variable which is influenced by its own set of factors (R&D equation)[133]. Finally, the commercialisation performance - expressed as turnover from products new to the market - is estimated on a set of factors including (estimated) R&D efforts measure. Thus, the commercialisation and the R&D equations are connected as the estimated values of the (log of) R&D expenditure from the latter serve as the input in the former equation. This procedure avoids the potential and well-known endogeneity problems. The details of the model applied together with results from the first and second stages are reported in the Annex 4.3.

The variables used for the analysis have been chosen in a way to ensure the highest possible compatibility in definitions between the CIS2006 and CIS2008. One should nonetheless be cautious when comparing the model's results from different waves of the CIS survey. Most of the conclusions below are therefore formulated based on the coefficients' signs and their statistical significance rather than their size.

132 The model is specified in Annex 4.3.

133 Ideally, one should include employment additional to turnover to control for size of firms. As this analysis is based on the anonymized CD-ROM version of the CIS data this variable is not available. Instead we used the two employment size classes available for all countries: small (<50) and medium and large (>50) for the estimation of the R&D levels.

Table 4.6. Results of the commercialisation output regressions with CIS2008

	All firms	EU-15	EU-12	Small firms	Medium and large firms	All manuf. firms	Low-tech	Medium-low tech	Medium-high and high tech
Commercialisation performance equation									
extramural R&D	0.231***	0.237***	0.227***	0.348***	0.330***	0.160***	0.170***	0.129***	0.183***
	(25.31)	(19.65)	(15.99)	(24.76)	(33.78)	(13.13)	(7.37)	(6.59)	(8.89)
log R&D expenditures	0.0416***	0.0262*	0.0526***	-0.00596	-0.237***	0.0796***	0.147***	0.0699***	0.00911
	(6.10)	(2.47)	(5.99)	(-0.91)	(-44.98)	(8.64)	(7.73)	(5.37)	(0.52)
log 2006 sales	0.00537***	0.00364***	0.00972***	0.00457***	0.00967***	0.00579***	0.00653**	0.00503*	0.00559*
	(5.85)	(3.35)	(5.60)	(3.80)	(5.46)	(4.75)	(3.09)	(2.55)	(2.44)
vertical cooperation	0.260***	0.218***	0.298***	0.376***	0.333***	0.227***	0.219***	0.223***	0.209***
	(26.18)	(16.62)	(19.38)	(24.17)	(29.57)	(18.48)	(8.67)	(11.61)	(9.62)
horizontal cooperation	0.0742***	0.0606***	0.0664***	0.0946***	0.0865***	0.0671***	0.0853**	0.0615*	0.0645*
	(6.40)	(3.60)	(4.09)	(4.62)	(6.71)	(4.35)	(3.01)	(2.43)	(2.42)
intra-group cooperation	0.0388***	0.0514**	0.0359*	0.141***	0.170***	-0.0311*	-0.0522	0.00386	0.0125
	(3.32)	(2.90)	(2.33)	(6.45)	(14.57)	(-2.02)	(-1.77)	(0.16)	(0.47)
local public funding	0.156***	0.167***	0.266***	0.205***	0.157***	0.120***	0.200***	0.0982***	0.0868***
	(14.87)	(14.43)	(8.12)	(12.65)	(11.68)	(9.19)	(8.45)	(4.55)	(3.83)
national public funding	0.138***	0.172***	0.105***	0.243***	0.383***	0.0665***	-0.0368	0.0850***	0.158***
	(11.57)	(10.67)	(5.58)	(14.12)	(31.76)	(4.40)	(-1.21)	(3.57)	(6.25)
EU funding	0.0815***	-0.0478*	0.167***	0.174***	0.258***	0.0831***	0.104**	0.034	0.105**
	(5.64)	(-2.02)	(9.26)	(6.84)	(17.11)	(4.65)	(3.27)	(1.13)	(3.25)
F-test for model's significance	14348.6***	7318.3***	7075.4***	7667.7***	6242.8***	6135.6***	2527.8***	1678.8***	1187.3***
observations	98070	48472	49598	60780	37290	47144	23615	15096	8433

*Note: t statistics appear in parentheses. ***, **, *indicate statistical significance at the 0,1%; 1% and 5% level respectively. Regressions include country and industry fixed effects as well as a constant term which are not reported.*
Source: Community Innovation Survey (CIS)

In addition, to triangulate the obtained results and check the model's robustness, separate analyses were performed on different types of firms according to size (small and large)[134], geographic location (EU-15 and EU-12 countries) and for manufacturing firms according to their production technology intensity (low-tech, medium-low tech, and medium-high and high tech as described above).

The results from the first CDM equation (the R&D intensity estimations presented in Table A4.3.1 and Table A4.3.2 in the Annex) give us particular insights into the factors which influence firms' innovation efforts. The patterns are rather consistent, and show that acquiring the R&D services externally and benefitting from national and EU public funding stand out as consistent factors positively influencing the firms' R&D activities in two waves of CIS and across different firm types and classes. R&D collaborations with suppliers and customers as well as inside the enterprise group are also found to be important determinants of the firms' R&D efforts.

Concerning the specific question on determinants of R&D commercialisation at the firm level (see Table 4.5 and Table 4.6), the relationships between the commercialization performance expressed in terms of the share of turnover from products and services new to the market and the main characteristics of the firms' innovation activities present several distinctive patterns.

First, the impact of the R&D efforts on commercialization is positive and statistically significant when looking at all firms in the sample as well as manufacturing firms only. Investigating different subgroups, a positive, significant effect is observed in low- and medium-low tech manufacturing industries, and also when looking at firms from EU-15 and EU-12 in general. The relationship between the R&D input and the

[134] Firms with less than 50 employees are classified as small and above 50 as medium and large. Due to differences in the size classification among different countries in CIS only these two classes can be consistently defined.

commercialisation results is mixed when looking at the performance of firms divided in groups by their size. The data from both 2006 and 2008 CIS waves show that for the small firms the relationship between the R&D expenditures and the share of turnover new to the market is not evident. For the large and medium enterprises CIS2006 indicates the statistically significant positive relationship between the R&D input and commercialisation, while in CIS2008 the opposite picture is observed.

It is observed that the firms which, in addition to their own R&D, also acquire R&D services externally tend to have higher share of turnover from innovative products. This external acquisition of R&D results can take place as a pure purchase of services, but also can be acquired in the framework of the inter-firm R&D cooperation.

Concerning the different forms of R&D cooperation activities the results are mixed across different groups and classes of firms. It can be seen that vertical cooperation (i.e. R&D cooperation with suppliers and/or customers) is positively associated with higher commercialization performance in firms coming from different size classes and different technology intensity groups.

The importance of customers and suppliers for the firm's innovation is further underlined by the finding that the R&D cooperation inside the group does not find broad and consistent support by the regression results. The R&D collaboration with other companies occupying the similar position in the value chain (horizontal cooperation) has been shown as a relevant positive factor by the CIS2008 data and partially by the CIS2006.

Finally, the effects of public funding on the commercialization performance of firms appear to be positive in most classes and groups of firms considered. The relationship between the use of local public R&D support and the commercialisation performance shows positive and statistically significant for both CIS waves and across all different technology intensity domains. The public R&D support at the national level is positively related to the share of innovative turnover in 2008 with results being somewhat more mixed for 2006. According to CIS2008, the firms appear to have higher commercialisation performance when making use of the EU-level public R&D support with the exceptions of the EU-15 and medium-tech subsamples. Results when using CIS2006 are more mixed though when significant these are always positive.

Across both CIS waves, a consistently strong and positive effect of public funding is found especially for firms in medium-high and high-tech industries and to a lesser degree for lower tech manufacturing firms. Regarding firm size, the results using CIS 2006 indicate a stronger effect of public funding on small firms.

Additional to the direct effect of public funding on the commercialization performance, there is also an indirect effect via the increase in R&D. As shown in the second stage, public funding positively affects R&D levels. In most cases, the increased R&D effort is estimated to have a positive effect on the commercialization performance.

Bringing the most important findings of the above analyses together allows one to formulate a number of conclusions regarding the general patterns of innovation and commercialisation performance of European firms. At the micro-economic level, when observing the behaviour of individual firms, the link between the R&D effort and the commercialisation performance is rather pronounced and a positive relationship has been observed in most cases.

But not only the R&D itself, also its origin and the patterns of R&D cooperation among firms play a role. It has been observed that acquiring results of external R&D and vertical cooperation with customers and suppliers is positively related to the firms' market uptake performance.

The above results provide especially pronounced evidence of the positive effect of the public R&D support at different levels. When looking at all firms as well as manufacturing firms only, a positive and significant effect of all types of R&D support on R&D levels as well as commercialisation performance is observed.

The analysis is also performed for a number of subsamples, which in turn exhibit some specific patterns. The results suggest that local R&D support does positively affect firm commercialisation performance in all technology intensity and size classes. The effects of national and EU funding are positive and significant for all firms and manufacturing firms only, but mixed results are found for smaller subsamples. Overall, public funding has consistently positive effects on innovative sales for medium-high and high-tech sectors firms, while this statement is true to a lesser extent for firms in lower tech industries.

4.15. Effects of public funding for firms' R&D

The previous results suggest there is generally a positive effect from public funding on R&D levels and commercialisation performance. Nevertheless, a major problem that the analysis faces is the possibility of selection bias. Neither the fact that a firm applies for funding nor the fact that it receives public support can be considered random. Firms receiving public support are, for example, more often exporting firms, which are likely to be more productive as well. Moreover, firms in higher-tech industries and those participating in joint R&D projects are more often supported, as are firms which are larger in terms of turnover. Thus, selection clearly has to be taken into account to be able to produce credible results.

In the analysis, matching techniques are applied to check for selection bias. According to a number of observable characteristics, each firm which receives public support is matched with a firm that does not. The two groups – the treatment group, those firms receiving public support, and the control group – should then be similar according to the considered observable characteristics.

One can then estimate the treatment effect on firms that receive public support. The complete procedure is an extended version of the one found in Czarnitzki and Lopes-Bento (2013) and is explained in Annex 4.3. The results shown in Table 4.7 to Table 4.9 indicate that for the full sample, public funding has considerable effects on the R&D input as well as output. The average R&D intensity in the treatment group is 1.6% higher than in the control group (Table 4.7). The probability of firms to apply for a patent (patent application propensity) increases by 8.4% with public funding (Table 4.8) and the share of innovative sales are on average 3.1% higher for firms that received public funding (Table 4.9).

A more detailed look at geographic aspects reveals that the R&D intensity as well as the patent application propensity of EU-15 firms is well above that of EU-12 firms. The difference in the patent application propensity is not a function of firm size distributions as firms in the matched sample are on average larger in the EU-12 and thus should have a higher patent application propensity. However, public funding has had a significantly positive effect in both country groups. The effects are quite different for the other innovation output measure – the share of innovative sales. Overall, this share is found to be larger in the EU-12 due to faster product upgrading, but the results indicate no effect of public funding on the commercialisation phase in this region. This finding is also rather stable over time when looking at different measurement waves (CIS4 and CIS5).

Interesting results also emerge from the investigation of effects along the dimension of firm size. Very pronounced effects of public support on R&D input as well as output can be found for small and medium-sized enterprises. SMEs often lack sufficient internal funds and support is vital for them to become strong entrants in a competitive market able to fill world market niches and deliver innovative products. Effects on patent application rates are especially pronounced for larger firms. At the same time, no significant effect of public support on the share of innovative sales can be found for large firms. One reason for this finding is that large firms often split research and production facilities geographically and thus output affects may be generated in other subsidiaries.

The most striking results were obtained with respect to the industry affiliation of firms. On the one hand, the analysis shows that innovation projects in higher-tech industries (which basically comprise advanced manufacturing industries, see Annex 4.1) benefit

Table 4.7. R&D intensity

R&D intensity	Treated	Control	Difference	T-stat
All firms	0.033	0.017	0.016	13.46***
EU-15 firms	0.035	0.018	0.017	13.23***
EU-12 firms (CIS4)	0.024	0.013	0.011	3.81***
EU-12 firms (CIS5)	0.024	0.012	0.013	4.48***
Small	0.041	0.019	0.022	10.25***
Medium	0.027	0.014	0.014	7.69***
Large	0.029	0.019	0.010	4.66***
High-tech	0.069	0.036	0.033	6.27***
Medium-high-tech	0.041	0.025	0.016	5.97***
Medium-low-tech	0.019	0.011	0.009	4.41***
Low-tech	0.020	0.013	0.007	3.22***
Food processing	0.015	0.006	0.008	2.23**

Note: The stratified sample overall contains all CIS4 EU-27 countries; the number of treated firms in each sample is: full sample: 5152, EU-15: 4338, EU-12: 814 (CIS4), 954 (CIS5), Small: 2090, Medium: 1827, Large: 1235, Domestic enterprise groups: 1580, Foreign enterprise groups: 411, High-tech 633 firms, Medium-high-tech: 1447, Medium-low-tech: 1131, Low-tech: 902, Food processing: 441
****, ** and * denote tests being significant at a 1, 5 and 10% level, respectively.*
Source: Community Innovation Survey (CIS), waves 4 and 5, wiiw estimations.

Table 4.8. Patent application propensity

Patent application propensity	Treated	Control	Difference	T-stat
All firms	0.303	0.219	0.084	7.54 ***
EU-15 firms	0.323	0.234	0.089	7.03 ***
EU-12 firms (CIS4)	0.192	0.138	0.054	2.62 ***
EU-12 firms (CIS5)	0.158	0.108	0.050	3.00 ***
Small	0.193	0.128	0.066	4.59 ***
Medium	0.284	0.201	0.082	4.62 ***
Large	0.516	0.399	0.117	4.09 ***
High-tech	0.404	0.288	0.117	3.38 ***
Medium-high-tech	0.435	0.317	0.117	5.08 ***
Medium-low-tech	0.249	0.195	0.055	2.55 **
Low-tech	0.121	0.127	-0.007	-0.35
Food processing	0.163	0.091	0.073	2.51 **

*Note: The stratified sample overall contains all CIS4 EU-27 countries; the number of treated firms in each sample is: full sample: 5152, EU-15: 4338, EU-12: 814 (CIS4), 954 (CIS5), Small: 2090, Medium: 1827, Large: 1235, Domestic enterprise groups: 1580, Foreign enterprise groups: 411, High-tech 633 firms, Medium-high-tech: 1447, Medium-low-tech: 1131, Low-tech: 902, Food processing: 441. ***, ** and * denote tests being significant at a 1, 5 and 10% level, respectively.*
Source: Community Innovation Survey (CIS), waves 4 and 5, wiiw estimations.

particularly from public funding. This can be seen from the significant and large effects on both the patent application propensity and the share of innovative sales.

Publicly funded firms in high- and medium-high-tech industries exhibit a higher increase in the share of innovative sales of 8.7 and 4.1 percentage points, respectively and an 11.7 percentage points higher application rate for patents.

On the other hand, the results indicate strong crowding out effects of public funding in lower-tech industries, especially with respect to innovation output measures. The finding is not an effect of lower-tech EU-12 firms, which overall exhibit no significant effects of public funds on the share of innovative sales, but can be found for lower-tech EU-15 firms as well. A possible explanation is that innovation projects in these industries take place in an environment which is changing less rapidly than that of high-tech industries. Thus, there is on average less risk and asymmetric information attached to innovation projects in low-tech industries. Banks and other financial intermediaries can therefore better evaluate them. Innovation market failures can be expected to be less pronounced in traditional industries meaning here is also less need for public funding. This is especially true for larger firms, which can either rely on internal funding or have easier access to external sources such as banks. The finding also indicates that the increased innovation support via Rural Development Policy, which is part of the European Common Agricultural Policy, has little effect on innovation output.[135] It might thus be more desirable to reallocate these innovation funds to a broader support of competitiveness, as is planned in the budget for the period 2014-2020.

4.16. Summary and policy implications

Despite of longer-term trends in advanced economies whereby the manufacturing sector accounts for a shrinking share of value-added of employment, there is a considerable case for preserving a 'critical size' of manufacturing activities in European economies.

The main arguments are the following: Firstly, manufacturing still accounts for a major part of innovation effort in advanced economies which translates into above-average contributions to overall productivity growth and thus to real income growth. Secondly, there are very important 'backward linkages' from manufacturing to services which provide important inputs for manufacturing (in particular business services). Thirdly, manufacturing has a 'carrier function for services which might otherwise be considered to have limited tradability. In the same direction goes the increased 'product bundling' of production and service activities in advanced manufacturing activities. This 'carrier function' – through international competitive pressure – has furthermore a stimulus effect for innovation and qualitative upgrading for service activities. Lastly, and related to the first argument, is the higher productivity growth in manufacturing which is important because the sector of origin of productivity

[135] 'Food processing' was analysed separately, as firms in this industry exhibit by far the highest support rate with respect to EU funds.

Table 4.9. Share of innovative sales

Share of innovative sales	Treated	Control	Difference	T-stat
All firms	0.232	0.201	0.031	4.11 ***
EU-15 firms	0.222	0.188	0.033	4.04 ***
EU-12 firms (CIS4)	0.288	0.269	0.019	1.09
EU-12 firms (CIS5)	0.285	0.277	0.009	0.57
Small	0.225	0.198	0.027	2.19 **
Medium	0.233	0.190	0.042	3.55 ***
Large	0.244	0.222	0.022	1.37
High-tech	0.336	0.249	0.087	3.84 ***
Medium-high-tech	0.261	0.220	0.041	3.04 ***
Medium-low-tech	0.178	0.166	0.012	0.83
Low-tech	0.200	0.190	0.010	0.60
Food processing	0.173	0.149	0.024	0.92

*Note: The stratified sample overall contains all CIS4 EU-27 countries; the number of treated firms in each sample is: full sample: 5152, EU-15: 4338, EU-12: 814 (CIS4), 954 (CIS5), Small: 2090, Medium: 1827, Large: 1235, Domestic enterprise groups: 1580, Foreign enterprise groups: 411, High-tech 633 firms, Medium-high-tech: 1447, Medium-low-tech: 1131, Low-tech: 902, Food processing: 441. ***, ** and * denote tests being significant at a 1, 5 and 10% level, respectively.*
Source: Community Innovation Survey (CIS), waves 4 and 5, wiiw estimations.

growth may not be the sector that benefits most from the actual productivity gain.

The main findings of the analyses of State aid and export-oriented manufacturing are the following. Regarding extra-EU manufacturing export shares of Member States, internationalisation measures appear to be a support item that has a positive effect. Also, in the case of internationalisation measures, there is a positive interaction effect with governance effectiveness.

As for the per capita levels of the export-oriented manufacturing sector in the EU-27 countries, regional aid and training aid were positively associated with value-added per capita growth while risk capital aid has a significant negative effect.

The results from the analyses of public funding of R&D&I suggest that it can be better targeted in the EU-12 and make it more effective. Especially in the EU-12, and irrespective of the actual objectives of the support programmes, de facto governments end up providing innovation support more often to larger firms than to their smaller competitors (for detailed evidence refer to the background study of the report).Given the substantial evidence that small firms in particular face considerable financial problems due to asymmetric information impacts, they should be the primary target of public funds.

In order to increase support to small firms, a special targeting of grants is one way to improve the allocation of public funds. Other initiatives could include information campaigns about credits, deductions and subsidised loans for new entrepreneurs. As problems lie mainly in the commercialisation phase, fostering venture capital investment would be another starting point.

Industrial policy is designed to improve the growth process (in its quantitative and qualitative aspects) through its impact upon economic structures (see also Pack and Saggi, 2006). This could be done by impacting economic structure in terms of the composition of activities or industries, or by influencing the directions in which technologies develop or within industries, by affecting the distribution of enterprises and plants according to different performance characteristics. There is also the influence on the distribution of economic activity over geographic area, so that industrial policy has an interface with regional policy. The impact of industrial policy on economic activity may take place directly (e.g. through direct support for particular types of industries, firms, technologies) or indirectly (through framework conditions such as the way financial markets operate or the legal and administrative system or the quality of educational and training institutions).

The second goal of industrial policy – in addition to growth – is external competitiveness, which means that one would pay particular attention to the development of the tradable sector (in all the dimensions cited previously: composition of activities and industries; intra-industry composition; technologies and product quality).

Furthermore, industrial policy has to be attentive to the different needs of countries and regions at different levels of economic development.

The maintenance of a competitive and diversified industrial base is part of the Europe 2020 strategy. The policy challenge could be seen as providing the right framework conditions and public inputs so that gaps do not open up in the spectrum of industrial activities which could be deemed strategic in terms of the future development of industrial activity. 'Strategic' in this context means that such segments of industrial activity do or could (in future) exert important 'spillover effects' in terms of backward or forward learning processes in linked activities and/or could also provide important inputs for various activities.

Industrial policy at the EU level should ensure that Europe has a broad and diversified industrial structure which is well-equipped to be a major actor in the development of new areas of activity such as environmental technology. In this it is able to benefit from the diversified character of European industrial and demand structures and benefit from the pooling of resources. This encourages innovations in existing areas, in which Europe draws on its specific comparative advantages, to be based on traditions of production specialisation (fashion in France and Italy, high-quality mechanical engineering and transport equipment in Germany and in a number of the central European economies), or on a diversified pattern of private and public demand. The latter includes features of the 'European model' such as the strong position of public transport, of high-quality health services or linked medical devices and pharmaceuticals.

Furthermore, the preservation of the 'industrial commons' includes nurturing manufacturing-services inter-linkages and exploiting specialisation advantages of different European economies. State aid measures to support structural change and structural adjustment have so far been used predominantly at national level and did not rely much on the coordinated use of State aid tools. In a highly integrated European economy, the preservation and development of 'industrial commons' should be seen as a joint responsibility because of strong externalities across the European economy. Such joint responsibility for 'industrial commons' includes rules for quality assurance and recognition of qualifications, supporting the mobility of skilled staff, learning from successful cluster policies, support for necessary transport and communications infrastructure.

It is important that the concept of industrial policy support the 'structural change enhancing' rather than the 'structure preserving' aspects. Industrial policy should play an active role in reducing entry barriers in four directions: supporting new firms, developing and marketing new products, moving into new markets or market niches.

Something well worth elaborating and increasing is demand-side industrial policy as an instrument to stimulate the commercial application of innovation. There is a broad consensus that the existing gap between European research excellence and the development of marketable products is a major weak spot in Member States' innovation systems. The US defence-related public procurement policy may serve as an example of how to remedy this shortcoming. As pointed out above, public procurement can provide the necessary incentive to invest in the development of marketable products. Given the strong political commitment of the EU to environmental protection and the mitigation of climate change, a long-term industrial policy targeted at the development of 'clean' products and technologies could well form the base for a major industrial policy initiative. Importantly, such a strategy should not only include a long-term funding commitment for research but also needs a reliable source of demand that should be provided by public procurement of EU Member States and the EU itself.

The industrial policy strategy laid out in the European Commission's Industrial Policy Communication of October 2012 (European Commission, 2012a) goes in the same direction: Five of the six priority areas (priority action lines) defined in this Communication are related to meeting the challenge of climate change and the degradation of the environment. It remains to be seen whether public procurement will have any role to play in the EU's policy initiatives for stimulating the commercialisation of innovations and the development of green and more resource-efficient products.

This issue has been much researched and forms the backbone of many policy initiatives (most prominently the Lisbon Agenda, and subsequently in the Europe 2020 Agenda). In the face of technological competition, particularly with the United States and more recently with a range of Asian economies, innovation has increasingly become the focus of industrial policy at EU level.

Analyses in this chapter have contributed to the evaluation of innovation policy in the way it is conducted at national and EU levels. They come out in favour of further efforts towards increased harmonisation of 'innovation systems' and the use of innovation policies across the EU Member States. Attempts at EU level have already been made to create an 'internal market for research', supporting the 'free movement of knowledge, researchers and technology, with the aim of increasing cooperation, stimulating competition and achieving a better allocation of resources and an improved coordination of national research activities and policies' (FREE, 2010). The attempts have been further reinforced through the Article 179 of the Lisbon Treaty, creating an unified research area based on the internal market, in which researchers, scientific knowledge and technology circulate freely and through which the Union and its Member States strengthen their scientific and technological bases, their competitiveness and their capacity to collectively address grand challenges (European Commission, 2012c).

However, the empirical analysis conducted also shows that innovation policies conducted at EU, national and regional levels partly address different needs, such as support for large firms vs. SMEs, national enterprise groups vs. multinationals, activities where the technological spillovers are more local vs. those which are international. It was also found that there can be different instances of misallocation of resources in the way programmes are conceived at EU or national levels. The different focus is understandable as issues of asymmetric information and knowledge of spillover effects are perceived differently at local, national and EU levels. Hence a clear view of division of tasks and use of resources at these different levels is important in the area of innovation policy as in many other areas.

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ANNEX 4.1
INDUSTRY LISTS AND COUNTRY ABBREVIATIONS

Table A4.1.1. Country abbreviations

AT	Austria
BE	Belgium
BG	Bulgaria
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
ES	Spain
EE	Estonia
FI	Finland
FR	France
UK	United Kingdom
EL	Greece
HU	Hungary
IE	Ireland
IT	Italy
LT	Lithuania
LU	Luxembourg
LV	Latvia
MT	Malta
NL	Netherlands
PL	Poland
PT	Portugal
RO	Romania
SK	Slovakia
SI	Slovenia
SE	Sweden
US	Unites States
JP	Japan
KR	South Korea
BR	Brazil
CN	China
IN	India

Table A4.1.2. Industry classification with detailed advanced manufacturing industries

15t16	Food, Beverages and Tobacco	Low technology
17t18	Textiles and Textile Products	Low technology
19	Leather, Leather and Footwear	Low technology
20	Wood and Products of Wood and Cork	Low technology
21t22	Pulp, Paper, Paper , Printing and Publishing	Low technology
23	Coke, Refined Petroleum and Nuclear Fuel	Medium-low technology
24	Chemicals and Chemical Products	Chemicals
25	Rubber and Plastics	Medium-low technology
26	Other Non-Metallic Mineral	Medium-low technology
27t28	Basic Metals and Fabricated Metal	Metals
29	Machinery, n.e.c	Machinery
30t33	Electrical and Optical Equipment	Electrical equipment
34t35	Transport Equipment	Transport equipment
36t37	Manufacturing, n.e.c; Recycling	Low technology

Note: Based on NACE Rev. 1 industry classification.

Table A4.1.3. Industry classification according to technology intensity

15t16	Food, Beverages and Tobacco	Low technology
17t18	Textiles and Textile Products	Low technology
19	Leather, Leather and Footwear	Low technology
20	Wood and Products of Wood and Cork	Low technology
21t22	Pulp, Paper, Paper , Printing and Publishing	Low technology
23	Coke, Refined Petroleum and Nuclear Fuel	Medium-low technology
24	Chemicals and Chemical Products	Medium-high and high technology
25	Rubber and Plastics	Medium-low technology
26	Other Non-Metallic Mineral	Medium-low technology
27t28	Basic Metals and Fabricated Metal	Medium-low technology
29	Machinery, n.e.c	Medium-high and high technology
30t33	Electrical and Optical Equipment	Medium-high and high technology
34t35	Transport Equipment	Medium-high and high technology
36t37	Manufacturing, n.e.c; Recycling	Low technology

Note: Based on NACE Rev. 1 industry classification.

Table A4.1.4. Industry classification according to Eaton et al. (1998)

15t16	Food, Beverages and Tobacco	Labour-intensive / Chemical-linked
17t18	Textiles and Textile Products	Labour-intensive / Chemical-linked
19	Leather, Leather and Footwear	Labour-intensive / Chemical-linked
20	Wood and Products of Wood and Cork	Resource-intensive / Earth-linked
21t22	Pulp, Paper, Paper , Printing and Publishing	Resource-intensive / Earth-linked
23	Coke, Refined Petroleum and Nuclear Fuel	Resource-intensive / Earth-linked
24	Chemicals and Chemical Products	Chemicals
25	Rubber and Plastics	Labour-intensive / Chemical-linked
26	Other Non-Metallic Mineral	Resource-intensive / Earth-linked
27t28	Basic Metals and Fabricated Metal	Metals
29	Machinery, n.e.c.	Machinery
30t33	Electrical and Optical Equipment	Electrical equipment
34t35	Transport Equipment	Transport equipment
36t37	Manufacturing, n.e.c.; Recycling	Resource-intensive / Earth-linked

Note: Based on NACE Rev. 1 industry classification.

ANNEX 4.2
ADDITIONAL RESULTS FROM THE QUANTITATIVE ANALYSIS OF STATE AID

Table A4.2.1. Percentile ranks of EU Member States' governance effectiveness, average 1995-2011

AT	93.4
BE	93.8
BG	56.4
CY	91.5
CZ	81.5
DE	91.9
DK	99.5
ES	82.0
EE	84.8
FI	100
FR	88.2
UK	92.4
EL	66.8
HU	73.0
IE	89.1
IT	66.4
LT	72.0
LU	94.8
LV	72.5
MT	82.9
NL	96.7
PL	71.6
PT	78.7
RO	47.4
SK	76.3
SI	79.6
SE	98.6

Note: Percentile range (globally) is from 0-100. Higher percentiles indicate higher governance effectiveness.
Source: World Bank’s Worldwide Governance Indicators (WGI) database.

Table A4.2.2. Aid to research, development and innovation and competitiveness[136]
Dependent variable: Member States' share in total extra-EU exports

Specification	(1)	(2)	(3)	(4)
R&D aid	-0.004	0.001	0.011	-0.013
	(0.018)	(0.022)	(0.026)	(0.020)
R&D aid²	-0.001	0.000	0.001	-0.004 *
	(0.002)	(0.002)	(0.003)	(0.002)
loans to GDP	0.035			
	(0.069)			
loans to GDP²	-0.253**			
	(0.035)			
loans to GDP, R&D aid	-0.002			
	(0.011)			
governance		0.454		
		(0.342)		
governance²		0.658		
		(0.964)		
governance, R&D aid		-0.134 ***		
		(0.033)		
wage share			-0.376	
			(0.401)	
wage share²			2.853	
			(2.276)	
wage share, R&D aid			-0.248 ***	
			(0.061)	
tariff rate				-0.046
				(0.052)
tariff rate²				-0.081 ***
				(0.029)
tariff rate, R&D aid				-0.020 *
				(0.012)
R^2	0.992	0.989	0.988	0.988
adjusted R^2	0.991	0.987	0.987	0.986
Observations	373	380	341	391

*Note: Standard errors appear in parentheses. ***, **, *indicate statistical significance at the 1%; 5% and 10% level respectively. Regressions include country and year fixed effects as well as a constant term which are not reported. The standard errors are robust. All the data was logarithmised (observations of the value zero were changed to 0.01 in order to make the taking of logarithms possible) and centred in order to make the estimated coefficients interpretable. R&D aid is aid to research, development and innovation.*
Source: WIOD, European Union State Aid Scoreboard, Eurostat, UNCTAD-TRAINS, World Bank's Worldwide Governance Indicators (WGI) database.

[136] It is important to note that this analysis is of a general nature and does not imply a specific link between a certain type of aid and the trade performance of any particular product or sector.

Table A4.2.3. Sectoral aid to manufacturing and competitiveness[137]
Dependent variable: Member States' share in total extra-EU exports

Specification	(1)	(2)	(3)	(4)
manufacturing aid	0.002	-0.008	0.000	-0.004
	(0.006)	(0.007)	(0.007)	(0.006)
manufacturing aid²	-0.001	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
loans to GDP	0.054			
	(0.070)			
loans to GDP²	-0.250 ***			
	(0.031)			
loans, manufacturing aid	0.004			
	(0.008)			
governance		0.446		
		(0.362)		
governance²		0.889		
		(1.020)		
governance, manufacturing aid		0.071 ***		
		(0.023)		
wage share			-0.091	
			(0.399)	
wage share²			1.436	
			(1.983)	
wage share, manufacturing aid			-0.091 **	
			(0.044)	
tariff rate				0.007
				(0.042)
tariff rate²				-0.090 ***
				(0.032)
tariff rate, manufacturing aid				0.004
				(0.007)
R^2	0.992	0.988	0.988	0.988
adjusted R^2	0.991	0.987	0.986	0.986
Observations	373	380	341	391

*Note: Standard errors appear in parentheses. ***, **, *indicate statistical significance at the 1%; 5% and 10% level respectively. Regressions include country and year fixed effects as well as a constant term which are not reported. The standard errors are robust. All the data was logarithmised (observations of the value zero were changed to 0.01 in order to make the taking of logarithms possible) and centred in order to make the estimated coefficients interpretable. Manufacturing aid is sectoral aid to manufacturing.*
Source: WIOD, European Union State Aid Scoreboard, Eurostat, UNCTAD-TRAINS, World Bank's Worldwide Governance Indicators (WGI) database.

[137] It is important to note that this analysis is of a general nature and does not imply a specific link between a certain type of aid and the trade performance of any particular product or sector.

ANNEX 4.3
METHODOLOGY

DECOMPOSITION OF MANUFACTURING R&D INTENSITY

The results for the decomposition of R&D intensities in Figure 4.6. are derived followings the approach of Eaton et al. (1998). The decomposition approach takes the following form:

$$R\&D_c^m - R\&D_w^m = \sum_i (va_{i,c} - va_{i,w}) \cdot R\&D_{i,w} + \sum_i (R\&D_{i,c} - R\&D_{i,w}) \cdot va_{i,w} + \sum_i (va_{i,c} - va_{i,w}) \cdot (R\&D_{i,c} - R\&D_{i,w})$$

where $R\&D^m$ denotes R&D intensity in the manufacturing sector and $R\&D_i$ denotes R&D intensity in industry i. Subscript c denotes countries and subscript w denotes the global average which for this purpose is the average of Finland, France, Germany, United Kingdom, Austria, Belgium and the Netherlands as well as the United States and Japan, i.e. the nine countries included in the decomposition exercise. The valued added shares of manufacturing are denoted by va.

Therefore the first term represents the composition effect, i.e. the differences in industry specialisation across countries and the second term captures the differences in the industry level R&D intensities. The last term is an interaction term between those two which has no particular economic interpretation.

CALCULATION OF VALUE ADDED EXPORTS

The concept of value added exports used throughout this Report is that of Johnson and Noguera (2012). The value added exports approach requires global input-output data. In this chapter the world input-output database (WIOD) is used for this purpose. The WIOD contains information on 40 countries plus the rest of the world (ROW) for 35 industries. The global input-output table in the WIOD that summarises the inter-industry linkages is therefore of dimension 1435 x 1435.

The starting point for calculating value added exports (VAX) is the basic input-output identity

$$q = (I - A)^{-1} \cdot f$$

where q denotes a vector of gross output for each country and industry (i.e. of dimension 1435x1), A is a matrix of intermediate inputs per unit of gross output (of dimension 1435x1435) and f is a vector of final demand by country and sector and therefore again of dimension (1435x1). A final product, e.g. a car, is made of many other parts produced in other industries maybe even in other countries.

The calculation of VAX consists of decomposing the output vector q of each country r in $(q^{1,r} \quad q^{2,r} \quad \cdots \quad q^{N,r})'$ where $q^{1,r}$ denotes the output absorbed in country r that was sourced from partner country 1 and likewise for the other partner countries. The elements of q are also referred to as output transfers. These output transfers are in turn used to calculate the value added produced in a source country i and absorbed in another country r which constitutes the bilateral value-added exports $(VAX_{i,r})$.

Bilateral value added exports are defined as $VAX_{i,r} = \frac{VA_i}{q_i} \cdot q_{ir}$, where $\frac{VA_i}{q_i}$ is the ratio of value added to gross output in country i and q_{jr} is the output produced in country i that is absorbed in r (see Johnson and Noguera, 2012). The global value-added exports of country r (VAX_{r}) are obtained by summing up the bilateral value added exports for all partner countries. The market share of each country in global value added exports used in the text is then simply $\frac{VAX_r}{\sum VAX_r} \cdot 100$.

QUANTITATIVE ANALYSIS OF STATE AID

Section 4.13 uses two approaches to estimate the relationship between the provision of State aid by Member States and export market shares, value added and value added growth respectively. The empirical approaches are briefly outlined below.

Aghion, Boulanger and Cohen (2011) type equation: In its basic form the following panel data equation is being estimated:

$$lnEX_{it} = \beta_1 lnSA_{it} + \beta_2 ln^2SA_{it} + \beta_3 lnPC_{it} + \beta_4 ln^2PC_{it} + \beta_5 lnPC_{it} lnSA_{it} + \gamma_i + \delta_t + \varepsilon_{it},$$

where $lnEX_{it}$ represents the log of the overall share of extra-EU manufacturing and services exports of an EU Member State *i* in the sample to total EU exports in year *t*. The variable *SA* covers total sectoral State aid to industry and services (also all the other types and sub-groups of State aid are being controlled for) and *PC* is a proxy for financial development, measured by the ratio of private credit by deposit-taking banks and other financial intermediaries to GDP (similarly also indicators of governance, competition and tariff protection are being checked). The squared terms control for non-linearity and the interaction term checks whether the two explanatory variables are substitutes or complements. Finally, γ_i and δ_t are country and time fixed effects respectively, while ε_{it} is the error term and the β's are the coefficients to be estimated. The rationale of this estimation exercise is to find out whether state subsidies can act as a promoter of international competitiveness, especially in those cases where access to private finance is limited. (It is important to note that this analysis is of a general nature and does not imply a specific link between a certain type of aid and the trade performance of any particular product or sector.) While the original sample of Aghion, Boulanger and Cohen (2011) included EU-15 data for the years 1992-2008, here EU-27 data for the period 1995-2011 are exploited.

Haraguchi and Rezonja (2011) type equation: The following modified base-line equation is being estimated:

$$lnVA^j_{it} = \beta_1 lnDP_{it} + \beta_2 ln^2DP_{it} + \beta_3 lnPD_{it} + \beta_4 lnNR_{it} + \beta_5 lnSA_{it} + \gamma_i + \delta_t + \varepsilon^j_{it},$$

where $lnVA^j_{it}$ is the log of the real value added per capita of the respective manufacturing sector *j* in country *i* and year *t*. The variable *DP* accounts for the per capita gross domestic product, *PD* stands for population density and *NR* is an indicator for natural resource endowment. Following Haraguchi and Rezonja (2011), the modified natural resource proxy variable can be calculated as the ratio between exports and imports of crude natural resource commodities. The commodities included are those categorised under SITC Rev. 1 in Code 2 (crude materials, inedible, except fuels), 32 (coal, coke and briquettes), 331 (petroleum, crude and partly refined) and 3411 (gas, natural).

These three explanatory variables are seen as mostly exogenous for the specific sample analysed. Here, SA is State aid per capita, and the β's, γ_i and δ_t are defined as in the earlier equation. ε^j_{it} is the error term. The value added data was taken from Eurostat's intermediate ISIC aggregation Rev. 2. GDP and population density data stems also from Eurostat. Data for constructing the natural resource endowment indicator were taken from the Comtrade database. In the preferred regressions the single manufacturing sectors have been aggregated in two groups – export-oriented industries and industries focusing on the domestic markets, based on an exportability measure, in order to make the results better interpretable. In following Rajan and Subramanian (2011) the exportability of an industry is assumed if the respective industry has a ratio of exports to value added that exceeds the industry median. For each industry, the median ratio of exports to value added was calculated using data from all EU-27 countries. The industries above the median are manufacturers of petroleum products, chemicals, pharmaceuticals, electronics, machinery and cars. Those below are manufacturing food, textiles, paper, plastics, metals, electric and other equipment.

ESTIMATION OF COMMERCIALISATION OUTPUT MODEL SPECIFICATION

The estimation procedure below for the commercialisation output model specification (used in 4.14) follows a so called CDM-approach (see Crepon et al. (1998) and Griffith et al. (2006) for more detail) towards estimating the innovation-driven economic performance of firms based on the CIS data. The CDM procedure uses a multiple equation econometric model estimate the economic outcomes from the firms' innovation efforts.

When estimating the R&D intensity equation using Heckman procedure, the firm's decision to perform/report R&D has been considered as depending on such specific factors as: the firm's size represented by the logarithm of total sales ($\log(S_i)$) in the previous period, whether or not the firm is a member of a group (GR_i):

$$RDperformer_i = \alpha_i + \beta_1 \log(S_i) + \beta_2 GR_i + \varepsilon_{it}$$

The first equation has the logarithm of the firm's R&D expenditures as dependent variable and is estimated conditional on the firm's decision to perform/report R&D above:

$$\ln(RD_i) = \alpha_i + \beta_1 exRD_i + \beta_2 VCoop_i + \beta_3 HCoop_i + \beta_4 GCoop_i \\ \beta_5 LPS_i + \beta_6 NPS_i + \beta_7 EUS_i + \beta_8 FSize_i + \varepsilon_i ,$$

where the explanatory variables are the following[138]:

- Extramural R&D indicator, $exRD_i$ (1/0);
- Vertical Cooperation indicator, $VCoop_i$ (1/0);
- Horizontal Cooperation indicator, $HCoop_i$ (1/0);
- Cooperation inside the group indicator, $GCoop_i$ (1/0);
- Local public funding indicator, LPS_i (1/0);
- National Public funding indicator, NPS_i (1/0);
- EU funding indicator, EUS_i (1/0)
- Firm size class, $FSize_i$ (0: <50 employees, 1: >=50).

The second equation is estimated by the means of the tobit regression where the dependent variable is the share of the turnover from products and services new to the market (Y_i):

$$\ln(Y_i) = \alpha_i + \beta_1 exRD_i + \beta_2 \ln(RD_i) + \beta_3 \log(S_i) + \beta_4 VCoop_i + \beta_5 HCoop_i \\ + \beta_6 GCoop_i + \beta_7 LPS_i + \beta_8 NPS_i + \beta_9 EUS_i + \varepsilon_{it}$$

The additional explanatory variables are the following:

- Predicted value of the logarithm of total R&D, $\ln(RD_i)$;
- The logarithm of total sales in the previous period, $\log(S_i)$.

The estimations also take into account the country-specific intercepts and industry class dummies in order to correct for individual effects.

EFFECTS OF PUBLIC FUNDING ON FIRM R&D

The econometric matching procedure described in section 4.15 is based on the work of Czarnitzki and Lopes-Bento (2013) and follows four steps:

1. Restriction of the sample to the innovative firms of interest: either all innovative firms, or a subsample of firms with respect to size, country or industry affiliation

2. Estimation of probability of a firm to receive public funding depending on the following observable characteristics: size based on employment and turnover, country and industry affiliation, exporter status, a dummy for multinationals and domestic enterprise groups as well as information on R&D cooperation and preconditions for R&D.

   The model capturing these considerations is given by:

   $$P(PIS = 1) = F(\beta_1 RD + \beta_2 COOP + \beta_3 EXP + \beta_4 GP_{DOM} + \beta_5 MNE_{EU} + \beta_6 MNE_{RoW} + \\ \beta_7 TURN + \beta_8 SIZE_{MED} + \beta_9 SIZE_{LRG} + \gamma_i + \tau_c + \varepsilon)$$

   In the estimated logit model, the dependent variable public innovation support (PIS) takes the value one if the firm receives public innovation support and zero otherwise. The probability of receiving public support is estimated based on a number of explanatory factors. RD denotes a composite factor capturing the preconditions for innovative activities of the firm – more on this will follow in the paragraph below. $COOP$ is

[138] The innovation activities and funding indicators are taking the value one if they engaged in the past three years in some innovation activities respectively if they received public funding for innovation activities and the value zero if not. The dummy variables for co-operation partner takes the value one if the firm indicated a certain type of collaboration in their country or other countries in Europe or the US or China/India or all other countries and the value zero if not.

equal to one if the firm is engaged in R&D cooperations with other firms. EXP is a simple exporter dummy indicating whether the firm serves other markets than the domestic one. The variable GP_{DOM} indicates whether the enterprise is part of a domestic enterprise group. If an enterprise is part of a foreign multinational firm, the headquarters can either be located in another country of the EU (MNE_{EU}) or a country outside the EU (MNE_{RoW}). It is not possible to identify domestic MNEs as there is no information on whether firms which are part of domestic enterprise groups also have affiliates in other countries.

In order to investigate the targeting of firms depending on size, controls for turnover ($TURN$) as well as employment are added. The Community Innovation Survey (CIS) holds information on three employment size classes: small firms with up to 50 employees, medium-sized firms with 50 to 250 employees and large firms with more than 250 employees. Finally controls for industry groups γ_i and countries τ_c are added.

3. Matching of firms receiving public support with firms which have a similar probability of getting public funds but do not receive them. Firms are only matched with other firms in the same country and employment size class (small: less than 50 employees, medium: between 50 and 250, large: more than 250). Firms with no similar counterpart are excluded from the sample using a threshold for the maximum allowed difference.

4. The average treatment effect is then can now be calculated as the mean difference of the matched samples.

Table A4.3.1. Results of the R&D regressions with CIS2006

	All firms	EU-15	EU-12	Small firms	Medium and large firms	All manuf. firms	Low-tech	Medium-low tech	Medium-high and high tech
R&D expenditures equation									
extramural R&D	0.367***	0.266***	0.504***	0.275***	0.414***	0.365***	0.375***	0.455***	0.253**
	(8.48)	(5.88)	(6.07)	(4.68)	(6.65)	(6.96)	(3.66)	(5.58)	(2.84)
vertical collaboration	0.429***	0.328***	0.557***	0.436***	0.398***	0.370***	0.455***	0.385***	0.242*
	(7.82)	(5.52)	(5.51)	(5.69)	(5.17)	(5.59)	(3.49)	(3.71)	(2.19)
horizontal collaboration	0.276***	0.349***	0.176	0.238*	0.306***	0.215*	0.129	0.409**	0.103
	(4.08)	(4.13)	(1.58)	(2.40)	(3.34)	(2.53)	(0.72)	(3.06)	(0.77)
intra-group collaboration	0.468***	0.507***	0.384**	0.283*	0.372***	0.541***	0.626***	0.449***	0.579***
	(6.52)	(6.09)	(3.12)	(2.24)	(4.16)	(6.22)	(3.30)	(3.33)	(4.20)
local public funding	0.381***	0.354***	0.707**	0.464***	0.317***	0.333***	0.211	0.308**	0.453***
	(6.19)	(6.69)	(2.84)	(5.96)	(3.32)	(4.57)	(1.44)	(2.73)	(3.76)
national public funding	0.986***	0.954***	1.003***	1.076***	0.853***	1.006***	0.915***	1.031***	1.037***
	(18.30)	(17.50)	(9.13)	(14.31)	(11.22)	(15.82)	(6.87)	(10.45)	(10.24)
EU funding	0.589***	0.666***	0.491***	0.444***	0.715***	0.561***	0.570**	0.466**	0.678***
	(7.58)	(7.17)	(3.77)	(3.86)	(6.85)	(5.67)	(2.94)	(2.88)	(4.26)
firm size class	0.984***	0.858***	1.104***			0.919***	0.773***	0.913***	1.045***
	(20.01)	(17.01)	(11.07)			(15.30)	(6.59)	(9.72)	(10.23)
R&D selection equation									
log 2004 sales	0.0370***	0.0230***	0.0646***	0.00322	0.111***	0.0442***	0.0502***	0.0374***	0.0450***
	(21.32)	(10.68)	(21.03)	(1.62)	(22.91)	(19.56)	(12.83)	(10.09)	(10.67)
member of a group	0.424***	0.418***	0.441***	0.357***	0.246***	0.501***	0.545***	0.505***	0.447***
	(33.72)	(24.65)	(23.17)	(18.15)	(13.37)	(29.47)	(19.21)	(17.54)	(14.14)
chi2 for model's significance	4895.0***	2832.6***	1591.3***	2861.4***	1743.0***	2216.9***	680.3***	892.3***	734.4***
observations	85281	38172	47109	53940	31341	43916	21686	13089	9141

*Note: t statistics appear in parentheses. ***, **, * indicate statistical significance at the 0,1%; 1% and 5% level respectively. Regressions include country and industry fixed effects as well as a constant term which are not reported.*
Source: Community Innovation Survey (CIS)

Table A4.3.2. Results of the R&D regressions with CIS2008

	All firms	EU-15	EU-12	Small firms	Large firms	All manuf. firms	Low-tech	Medium-low tech	Medium-high and high tech
R&D expenditures equation									
extramural R&D	0.619***	0.556***	0.729***	0.510***	0.633***	0.702***	0.745***	0.765***	0.542***
	(13.70)	(11.64)	(7.81)	(8.67)	(9.41)	(11.99)	(7.31)	(8.31)	(4.80)
vertical collaboration	0.559***	0.437***	0.769***	0.540***	0.567***	0.492***	0.807***	0.302**	0.424**
	(9.98)	(7.26)	(6.82)	(7.34)	(6.87)	(6.78)	(6.24)	(2.64)	(3.11)
horizontal collaboration	0.121	0.170*	-0.000436	0.162	0.0841	0.129	-0.117	0.364*	0.0484
	(1.74)	(2.10)	(-0.00)	(1.66)	(0.86)	(1.35)	(-0.67)	(2.46)	(0.27)
intra-group collaboration	0.514***	0.686***	0.23	0.267*	0.454***	0.588***	0.553**	0.571***	0.600***
	(7.30)	(8.55)	(1.79)	(2.30)	(4.97)	(6.42)	(3.16)	(3.97)	(3.66)
local public funding	0.219***	0.228***	0.218	0.250**	0.209*	0.157	0.0257	0.158	0.292*
	(3.44)	(4.01)	(0.78)	(3.26)	(2.05)	(1.93)	(0.17)	(1.24)	(1.97)
national public funding	1.032***	1.004***	1.098***	0.953***	1.044***	1.011***	1.080***	1.037***	0.890***
	(19.08)	(18.19)	(9.05)	(13.22)	(13.19)	(14.75)	(8.44)	(9.70)	(7.17)
EU funding	0.716***	0.960***	0.440**	0.740***	0.693***	0.666***	0.766***	0.533**	0.748***
	(8.77)	(9.61)	(3.12)	(6.25)	(6.14)	(6.20)	(4.08)	(3.04)	(3.76)
firm size class	0.957***	0.819***	1.151***			0.907***	0.722***	1.075***	0.923***
	(18.40)	(15.24)	(9.96)			(13.22)	(6.12)	(10.13)	(6.76)
R&D selection equation									
log 2006 sales	0.0380***	0.0253***	0.0880***	0.00792***	0.108***	0.0532***	0.0649***	0.0436***	0.0533***
	(23.99)	(14.27)	(23.92)	(4.37)	(24.77)	(22.83)	(15.69)	(11.99)	(11.63)
member of a group	0.450***	0.431***	0.451***	0.390***	0.289***	0.529***	0.543***	0.562***	0.462***
	(40.14)	(29.65)	(24.88)	(22.19)	(17.63)	(33.32)	(20.80)	(21.69)	(14.58)
chi2 for model's significance	4794.1***	3828.8***	1004.0***	2795.5***	1862.0***	2322.88***	829.8***	958.0***	596.3***
observations	98345	48831	49514	60845	37500	47306	23667	15152	8487

*Note: t statistics appear in parentheses. ***, **, *indicate statistical significance at the 0.1%; 1% and 5% level respectively. Regressions include country and industry fixed effects as well as a constant term which are not reported.*
Source: Community Innovation Survey (CIS)

Chapter 5.

EU PRODUCTION AND TRADE BASED ON KEY ENABLING TECHNOLOGIES

BACKGROUND

Previous chapters have discussed the specialisation, complexity and sophistication of economies basing their output on key enabling technologies (KETs). This chapter takes an in-depth look at the specialisation, strengths and weaknesses of the EU in the global production and trade in products based on KETs.

Two years ago, the High-Level Group on Key Enabling Technologies published its final report which estimated that the global market potential for products based on KETs would grow from USD 832 bn around 2008 to USD 1,282 bn around 2015 (HLG KETs 2011).

It was followed by the European Commission Communication 'A European strategy for Key Enabling Technologies – A bridge to growth and jobs' (European Commission 2012 a) which outlined a strategy to boost the industrial production of KETs-based products and enable maximum exploitation of the EU's potential in competitive markets.

In addition, in its Communication 'A stronger European Industry for Growth and Economic Recovery' (European Commission 2012 b), the Commission identified six priority action lines, one of which was the creation of markets for KETs. The European Commission expressed its intention to implement the European Strategy for KETs, ensuring better co-ordination of EU and Member State technology policies; funding of essential demonstration and pilot lines and cross-cutting KET projects; and the timely development of the internal market for KETs-based products (Peltomäki 2013). Moreover, the industrial deployment of KETs will be considered in future European Innovation Partnerships, while a 'knowledge and innovation community on added-value manufacturing' has been proposed as a forum for integration and promotion of skills and competences (European Commission 2013 c).

OBJECTIVES

The overall objective of this chapter is to analyse the current position of the EU in the global production of KETs-based products in order to assess upcoming challenges for the competitiveness of the EU. The chapter aims to:

- Provide a narrative overview of most recent technological and industry developments in each KET since 2009;
- Update estimations on future market potentials in each KET, building on the analyses of recent trends in 'market shares' in the production of KET-related technologies;
- Assess the EU position in the value chain by studying two promising KETs-based products;
- Analyse the EU position in international trade for certain subfields of KETs-based products, including changes in the competitiveness of the EU over time;
- Determine the EU position in value chains (in terms of 'technology content') within certain subfields of KETs-based products based on unit value analysis of exports and imports;
- Analyse the specialisation of a selection of EU Member States in production and trade of KETs-based products by combining production and trade statistics.

This chapter applies the following definition of KETs-based products (European Commission 2012 a). A KETs-based product is: (a) an enabling product for the development of goods and services enhancing their overall commercial and social value; (b) induced by constituent parts that are based on nanotechnology, micro-/nanoelectronics, industrial biotechnology, advanced materials and/or photonics; and, but not limited to (c) produced by advanced manufacturing technologies.

STRUCTURE OF THE CHAPTER

This chapter is structured as follows: Section 5.1 presents an update of market share calculations and market potential estimates. 5.2 analyses the position of the EU in international trade in KETs-based products. In 5.3 to 5.5, the value chain of two KETs-based products is analysed, namely lipase enzymes and the accelerometer. Section 5.6 summarises the main conclusions and potential policy implications.

5.1. TECHNOLOGY POSITIONS AND MARKET POTENTIAL

5.1.1. Introduction

Key Enabling Technologies (KETs) are defined as knowledge-intensive technologies associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly skilled employment. They are multidisciplinary, cutting across many technology areas with a trend towards convergence and integration.

The following technologies are identified as KETs: micro- and nanoelectronics, nanotechnology, photonics, advanced materials, industrial biotechnology and advanced manufacturing technologies for other KETs (HLG KETs 2011).

The objective of this section is to provide an overview of the competitive position of the EU in the generation of technology and to estimate the future market potential for KETs-based products and applications. As such, it provides an update of the analysis undertaken in the background study to the 2010 European Competitiveness Report (European Commission 2010). The calculation of technology market shares is based on the number of international patent applications. KETs-relevant patent activities are identified through a list of IPC codes developed for the 2010 report and recently updated in the 'Feasibility study for a KETs Observatory' commissioned by DG Enterprise and Industry (Van de Velde et al. 2013). In order to estimate the market potential of each KET, an analysis of existing studies, reports and reviews has been conducted. For each KET, several market segments have been selected, depending on KETs-based applications.

5.1.2. Approach

An important measure of a country's competitive position in KETs is its ability to produce new, commercially relevant technological knowledge. One way to measure this ability is to look at patent data. Patent data have certain advantages when it comes to measuring technological performance. Patents represent new technological knowledge that has a particular potential for economic application. Each patent is linked to technological areas through an internationally standardised system (International Patent Classification (IPC)) which enables patents to be 'linked' to KETs. Since patents are essential for the production and protection of new technologies and innovative products and processes, they are a commercial good which serves as an input to production and can be traded on technology markets (through licensing or by selling and purchasing patent rights). In contrast to many other goods, most patents are produced and used in-house while only a small part is actually traded between firms (see Gambardella et al. 2007; Arora et al. 2002; Serrano 2005; Lamoreaux and Sokoloff 1999).

When using patent applications to assess the competitive strength and weakness of an economy, some limitations need to be pointed out. First, not all new technological knowledge needed for innovations is represented by patents, while a number of patents will never be used for innovations. Secondly, the economic value represented by one patent can vary substantially. Thirdly, not all patents seek legal protection of new technological knowledge but some are used to block competitors from patenting activities or to keep strategic information away from competitors. For these reasons, patents represent only a fraction of the technology market.

As with any other market, one can analyse the technology market performance of individual actors as well as of countries. Here, for each country a 'market share' of the technology market for each KET is calculated based on the number of international patent applications. International patent applications are patents applied for at the European Patent Office (EPO) or through the Patent Cooperation Treaty (PCT) procedure at the World Intellectual Property Organization. Using international patent applications reduces the risk of an overly strong home-country bias and excludes patents of low (expected) commercial value since applying at the EPO or via the PCT is comparatively costly.

Technology market shares by KET are calculated using a conversion table that links IPC codes to KETs (see Van de Velde et al. 2013). Patent applications are assigned to countries using the country of the applicant and by applying 'fractional counting' in the event that a patent application is submitted by organisations from different countries. Patents are assigned to four regions: Europe (all EU Member States plus Albania, Andorra, Bosnia-Herzegovina, Former Yugoslav Republic of Macedonia, Iceland, Liechtenstein, Monaco, Montenegro, Norway, San Marino, Serbia, Switzerland); North America (US, Canada, Mexico); East Asia (Japan, China including Hong Kong, South Korea, Singapore, Taiwan); and the rest of the world (RoW). The April 2013 edition of the Patstat database published by EPO is used.

5.1.3. Industrial biotechnology

5.1.3.1. *Technology market share*

International patent applications in the field of industrial biotechnology have been decreasing over the past ten years. Globally, the number of patents fell by 33% between 2000 and 2010. Europe and North America report even greater drops (–46%). East Asia and RoW increased the number of international patent applications in industrial biotechnology by 28% and 14% respectively. As a consequence, the market shares of Europe and North America are declining (Figure 5.1). Nevertheless, North America remains the region with the highest market share in 2010 (39%). Europe lost its second position in 2010 even though its market share in that year (27%) was above the low level reported for the mid-2000s (23% in 2006). East Asia gained market shares and contributed 28% to global patent applications in industrial biotechnology in 2010. Rest-of-the-world countries showed increasing market shares up to 2008 but no further growth afterwards, contributing 5% to total patenting in industrial biotechnology in 2010.

In Europe, Germany gradually lost market share, declining from 44% (2000) to 27% (2010). France gained market shares and by 2008 had replaced the UK as the second largest European patent producer in industrial biotechnology. The Netherlands showed high market shares in the mid-2000s (ranking second in 2005 with a European market share of 15%) but clearly lost ground in recent years. Switzerland and Denmark hold position five and six in European patenting in industrial biotechnology.

5.1.3.2. *Market potential*

Industrial biotechnology is used in the production of chemicals and derived biomaterials. The use of biotechnology for chemical production has increased over the past decade and is likely to continue increasing, driven by rising energy costs, new chemicals legislation and increasingly stringent environmental regulations (OECD 2009).

According to Festel Capital, the sales of products made by biotechnological processes in 2007 was around EUR 48bn, or 3.5% of total chemical sales, while by 2017 predicted sales of products made by biotechnological processes will be around EUR 340bn, or 15.4% of total chemical sales in 2017. Based on Festel Capital research, the most important sub-segments in 2017 are expected to be active pharma ingredients and polymers and fibres (Festel 2010). Other sources start from a market share of 9–13% in 2010 and predict further growth to 22–28% by 2025. Major growth is expected to take place in polymers and bulk chemicals (Kircher 2012).

The global market for industrial enzymes is forecast to reach USD 3.74bn by 2015. Important factors driving the market include new enzyme technologies with a view to enhanced cost efficiencies and productivity, and growing interest in substituting petroleum-based products. BCC projects the industrial enzymes market to grow to USD 6bn by 2016 (BCC Research 2011a). Major growth is expected in the segments of food and beverage enzymes and technical enzymes. Two other segments with high growth potential are carbohydrases and lipases (see also 5.4).

5.1.4. Photonics

5.1.4.1. *Technology market share*

Over the past ten years, East Asia has gained significantly in technology market shares in the field of photonics (Figure 5.2). Since 2003, East Asian organisations have become the largest group of applicants for photonics patents and have been able to strengthen their position continuously, increasing their market share from 27% in 2000 to 50% in 2010. North American applicants lost the leading position which they held in the early 2000s. Their market share fell from 40% (2000) to 19% in 2010. Europe did significantly better: its market share increased until 2008, when it reached 32%. In 2009 and 2010, Europe's contribution to photonics patenting fell back to 29%. Countries from outside the three main regions slightly lost market shares.

Changes in market shares in photonics took place against the background of expanding overall patenting. The total number of international patent applications grew by 25% between 2000 and 2010, almost four times the growth rate for all KET patent applications and equal to the growth rate of patenting across all fields of technology.

Germany further strengthened its position as the main producer of new technological knowledge in photonics within Europe over the past decade. Its share of total European patent applications was 43% in 2010, compared to 33% in 2001–2002. Among the other five main European applicant countries in 2010 – France, Netherlands, UK, Austria and Italy – Netherlands and the UK lost market shares while France and Italy maintained their positions within Europe. Austria recently increased patenting in photonics and overtook Swiss patents applicants.

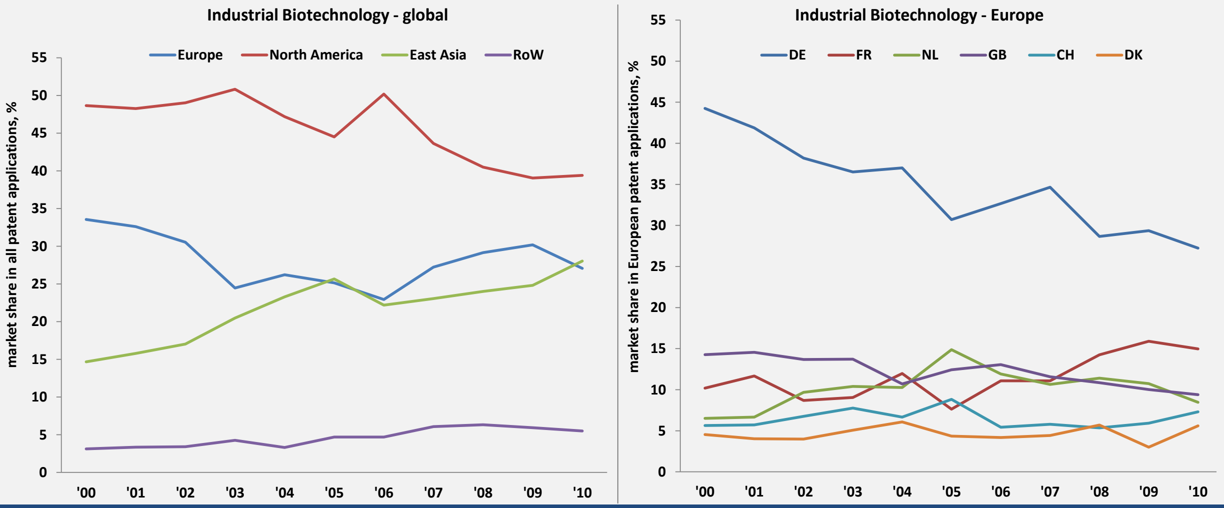
5.1.4.2. *Market potential*

The photonics industry is expected to grow significantly in coming years. The global market for photonic components and systems is forecast to be worth EUR 480bn by 2015, suggesting an annual growth rate of 8% (HLG KETs 2011).

Solar photovoltaic (PV) is the third most important renewable energy in terms of globally installed capacity. Its growth rate reached almost 70% in 2011. In terms of cumulative installed capacity, Europe leads the way worldwide with more than 51 GW installed as of 2011 (75% of world capacity). Internationally, significant market growth is expected until 2017, reflecting the large untapped potential of many countries (EPIA 2013).

By 2020, light emitting diodes (LEDs) are expected to account for around 95% of the market for light bulbs, currently estimated at EUR 11bn per year (J.P. Morgan Cazenove 2012). The expected growth in market demand for LEDs will be driven by product substitution. Other application areas of LEDs are: mobile applications including mobile phone notebooks and tablets; TV and monitor backlights; sign and automotive lighting. Japan accounts for the greatest portion of overall LED component revenues

Figure 5.1. Market shares in international patent applications in industrial biotechnology, 2000–2010 (percent)



Source: EPO: Patstat, ZEW calculations

(30%) followed by South Korea (26%), Taiwan and Southeast Asia (19%).

The optical communication industry is experiencing a recovery from the economic downturn. In 2010 and 2011, the sales of data communication systems started to pick up again. The global market for lasers for communications (data and telecoms) was estimated to be worth USD 1.95bn in 2010 and USD 2.22bn in 2011 (+14%) (Overton et al. 2011). While Europe is experiencing a decline in demand, the construction of optical communication is at a peak in China.

5.1.5. Micro-/nanoelectronics

5.1.5.1. *Technology market share*

East Asia has since 2002 been the largest producer of international micro- and nanoelectronics patent applications (Figure 5.3). Its market share is gradually increasing over time. In 2010, 56% of global patent applications in this KET originated in East Asia. North America and Europe are both losing market shares. In 2010, North America reported a market share of 23%, while the figure for Europe was 20%. Countries from the rest of the world are of little importance in the technology market for micro- and nanoelectronics: their market share is 1% to 2%. Dynamics in micro- and nanoelectronics patenting are high. Globally, patent applications grew by 35% from 2000 to 2010. The number of European applications in 2010 was 2% higher than in 2000, while applicants from North America reported a 17% lower figure in 2010 than in 2000. The highest growth is in East Asia, where patent applications increased by 116% over the same ten-year period.

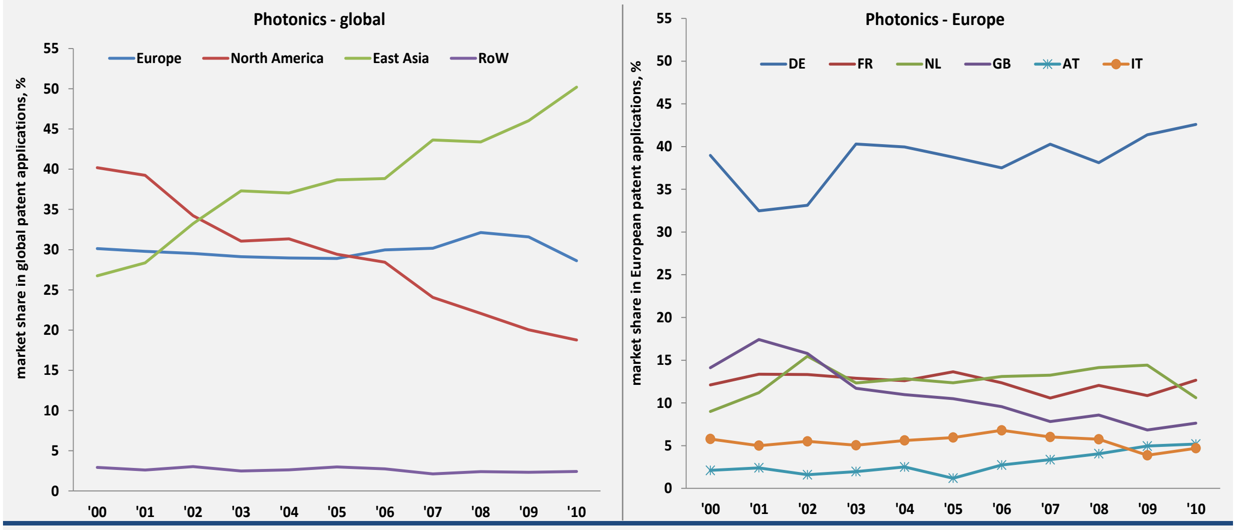
In Europe, Germany is clearly the largest patent producer in micro- and nanoelectronics and maintained a European market share of 42–45% from 2001 to 2010. France increased its European market share from 10% (2000) to 17% (2010), overtaking the Netherlands. The Dutch market share within Europe declined from 19% in 2003 to 8% in 2010. The UK is the fourth largest producer of micro-/nanoelectronics patent applications in Europe, followed by Switzerland and Italy.

5.1.5.2. *Market potential*

The global market for the semiconductor industry has increased significantly from USD 25bn in 1985 to USD 299.5bn in 2011 (SIA 2012). This growth is driven by the increasing need for microelectronic devices and smart sensors in intelligent products, such as smart phones, tablets, car driver assistance systems, smart grids, networked sensors, and other products. Smart sensors can also be used to detect and make risk assessments of disasters. That sort of risk management reduces the vulnerability of Member States, sectors and individual firms, thereby increasing competitiveness and sustainable growth.

From a total investment of EUR 28bn in microelectronics in 2007, only 10% was in the EU, compared to 48% in Asia. Europe's semiconductor market share has declined from 21% to 16% since 2000 (Silicon Europe 2012). After the global economic crisis, the semiconductor market recovered quickly and global sales reached a record high in 2010. While billings fell by 11% from their peak in 2007 to 2009, sales subsequently recovered by 33% from 2009 to 2010, an unprecedented growth rate which more than compensated for previous losses (Ballhaus et al. 2011). PWC estimates that the semiconductor market will grow by 7.4% per year on average from 2010 to 2015.

Figure 5.2. Market shares in international patent applications in photonics, 2000–2010 (percent)



Source: EPO: Patstat, ZEW calculations

According to IC Insights, worldwide processor sales are expected to regain strength in 2013 and grow 12% to USD 65.3bn, after a more modest increase in 2012 to USD 58.2bn (+5%). The slow growth in 2012 is attributed to weaknesses in the personal computer segment of the market and global economic uncertainty (Clarke 2013). The strongest growth is expected for microprocessor units, especially in the area of tablet computers and smartphones.

The total flash memory market grew by 2% to USD 30.4bn by end-2012, overtaking the DRAM [139] market for the first time, as the latter declined from USD 31.2bn to USD 28bn. This is because DRAM is used mostly in PCs while flash memory is used in smartphones, media tablets, and other personal media devices. IC Insights forecasts NAND [140] flash memory sales to increase by 14% annually from 2012 to 2017, growing to USD 53.2bn by 2017, while the DRAM market is forecast to grow by 9% over the same period.

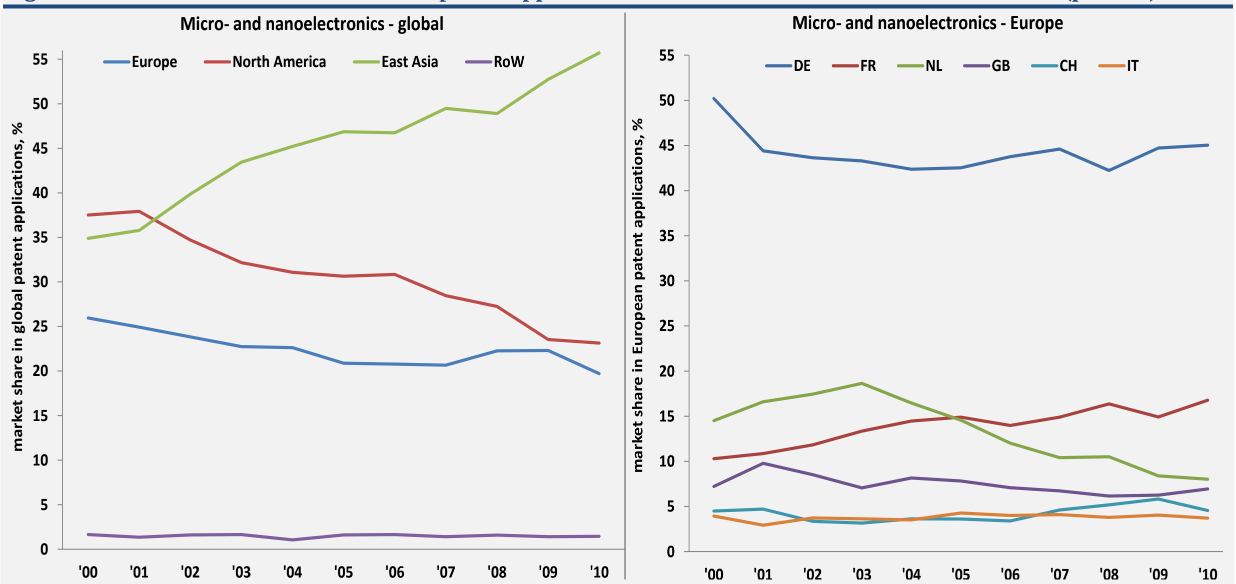
5.1.6. Advanced materials

5.1.6.1. *Technology market share*

East Asia is constantly increasing its market share in international patenting in the field of advanced materials (Figure 5.4). In 2010, 48% of all advanced materials patent applications originated in East Asia, compared to 28% from Europe and 21% from North America. North America's share of global patent applications is declining much faster than the European share.

Changes in market shares should be seen against the

Figure 5.3. Market shares in international patent applications in micro and nanoelectronics, 2000–2010 (percent)



Source: EPO: Patstat, ZEW calculations backdrop of low patent dynamics in advanced materials. Global patent applications fell by 4% between 2000 and 2010. While international patent applications in advanced materials are going down in Europe and North America, applicants from East Asian countries and the rest of the world are filing more applications each year.

Within Europe, the market shares of countries with the highest numbers of advanced materials patents have remained stable over time. Germany still accounts for more than 40% of European patent applications, followed by France (16% in 2010), Italy, Switzerland, the UK and Belgium. The Netherlands held third place in advanced materials patenting in Europe until 2008 but its patent activities have since decreased considerably.

5.1.6.2. *Market potential*

Advanced materials tend to outperform conventional materials with their superior properties such as toughness, hardness, durability and elasticity. The scope of advanced materials research is very broad. While some advanced materials are already well-known, like polymers, metal alloys, ceramics, semiconductors, composites and biomaterials, other advanced materials like carbon nanomaterials, activated carbon, titanium, are becoming increasingly important.

'Smart materials' are a class of materials that respond dynamically to electrical, thermal, chemical, magnetic, or other stimuli from the environment.

These materials are incorporated in a growing range of products, enabling these products to alter their characteristics or otherwise respond to external stimuli. The market for these materials was estimated to be worth USD 19.6bn in 2010 and was expected to approach USD 22bn in 2011 and exceed USD 40bn by 2016, a compound annual growth rate (CAGR) of 12.8% from 2011 to 2016 (BCC Research 2011b).

Lightweight materials are increasingly being used in the transportation industry as weight reduction is one of the most important ways of reducing fuel consumption. In 2010, the total global consumption of lightweight materials used in transportation equipment was worth USD 95.5bn. By 2015 this market is expected to reach USD 125.3bn, with a compound annual growth rate (CAGR) of 5.6% between 2010 and 2015.

Value-added materials (VAMs) are a group of advanced materials with strategic importance for economic growth, industrial competitiveness and societal challenges. Their market potential is estimated to reach EUR 1,000bn by 2050. In the environmental market segment, VAM growth will be driven by energy-efficient and carbon-capture technologies. VAMs in the ICT sector are expected to grow substantially in the coming years, with an average compound annual growth rate of 5%.

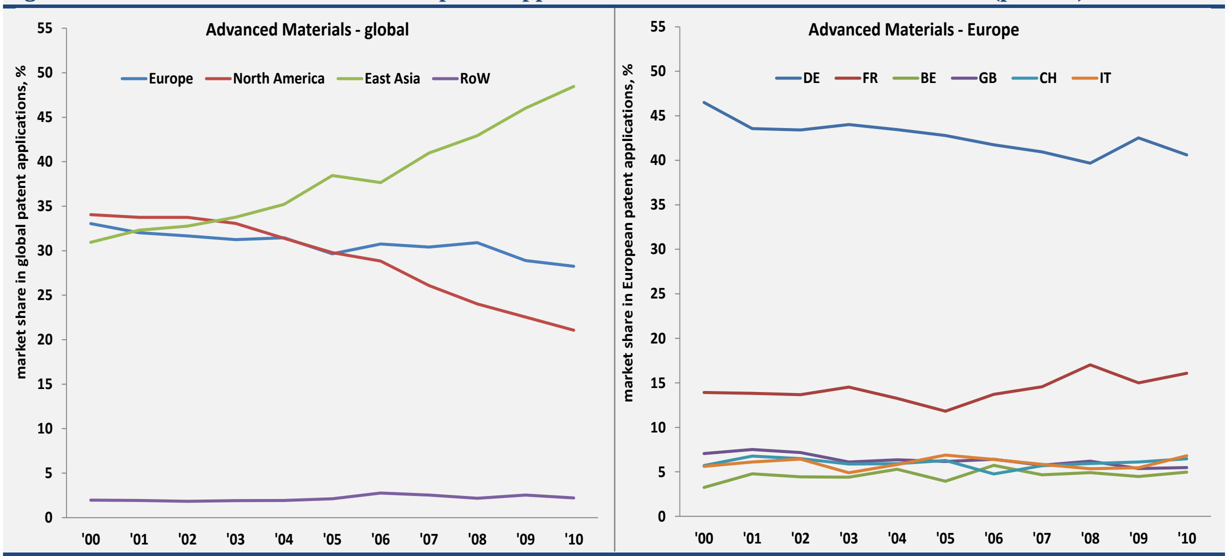
5.1.7. Nanotechnology

5.1.7.1. *Technology market share*

Trends in technology market shares in the field of nanotechnology significantly diverge from the general trends in KETs patenting. With a share of 39% of all applications in 2010, North America is still the most important origin of nanotechnology patent applications. While North America's share of all nanotechnology applications was falling until 2007 (when it reached 35%), the downward trend changed in 2008.

Europe and East Asia report similar market shares

Figure 5.4. Market shares in international patent applications in advanced materials, 2000–2010 (percent)



Source: EPO: Patstat, ZEW calculations over the entire period. In most years, the East Asian share of applications exceeded the European share but in recent years Europe has taken a slightly higher share (28% in 2010, versus 27% for East Asia). The total number of nanotechnology patent applications grew by 31% between 2000 and 2010, with all four regions reporting growing nanotechnology patenting.

Within Europe, Germany has lost market shares over the past decade, from 41% in 2000 to 23% in 2010. At the same time, France substantially increased its nanotechnology patenting and gained market shares, catching up with Germany in 2010. The market share of the Netherlands dropped from 14% in 2004 to 6% in 2010, while the UK was able to maintain its share of total European patent applications in nanotechnology at around 10%. Switzerland filed about 5% of European nanotechnology patent applications over the entire period, while Italy has recently increased its share.

5.1.7.2. *Market potential*

Nanotechnology has many applications in a broad range of industries. The global market for nanotechnology was valued at USD 20.1bn in 2011 and USD 20.7bn in 2012 (BCC Research 2012). Total sales are expected to reach USD 48.9bn in 2017 after increasing at a five-year compound annual growth rate of 18.7%. The US is the most prominent market and in 2011 accounted for an estimated share of around 35% of the global nanotechnology market – slightly less than its share of patent applications. Whilst it is expected to remain a major player, emerging economies such as China and South Korea as well as India and Brazil have started to catch up.

The global market for products based on the revolutionary new nanomaterial graphene is projected to reach USD 122.9 million in 2017 and USD 986.7 million in 2022, growing at a five-year compound annual growth rate of 51.7%. The segment made up of capacitors is projected to be the largest segment in 2022. Capacitors are expected to increase from USD 31 million in 2017 to USD 410 million in 2022, a CAGR of 67.6%. Others sources indicate a more conservative estimate of USD 100 million in 2018 and an annual growth rate of 40%, making the capacitors segment worth USD 216 million by 2020.

The global market for quantum dots, which in 2010 generated revenues of USD 67 million, is projected to grow over the next five years at a compound annual growth rate of 58.3%, reaching almost USD 670 million by 2015 – a tenfold increase. MarketsandMarkets estimate the total market for quantum dots to be worth USD 7.5bn by 2022, the result of a compound annual growth rate of 55.2% from 2012 to 2022. The US has a leading position in the quantum dots technology market, followed by Europe and Asia-Pacific (MarketsandMarkets 2012).

5.1.8. Advanced manufacturing technologies

5.1.8.1. *Technology market share*

Trends in market shares for advanced manufacturing technologies for other KETs are quite similar to those for micro-/nanoelectronics and advanced materials, since many patents classified as advanced manufacturing technologies for other KETs relate to the former two KETs and a significant overlap exists.

East Asia is producing the highest number of patents in the field of advanced manufacturing technologies for other KETs (46% in 2010), while Europe and North America have about 25% each of global patent applications. North America's contribution to the global patent output has fallen sharper (from 40% in 2000) than Europe's share (31% in 2000). Rest-of-the-world countries increased their share marginally between 2000 and 2010, contributing 3% to global patent applications in 2010.

Patent dynamics in this KET are low. The total number of international patent applications in 2010 was 9% below the 2000 figure. Declining patent output in Europe (–25 %) and North America (–41%) are partly outweighed by significant increases in East Asia (+57%) and RoW (+11%).

In Europe, Germany has lost market shares but is still the largest patent producer in this KET with a European market share of 38% in 2010. France follows second with 17% of European patent output in 2010. The Netherlands has fallen to rank 5 in 2010, overtaken by the UK and Switzerland. Sweden was the sixth largest patent producer in Europe in 2010, ousting Italy to rank 7.

5.1.8.2. *Market potential*

Manufacturing is an essential step to bring technological innovations to the market. The global manufacturing economy is estimated to be worth GBP 6.5 trillion (TSB 2012). In the 2013 Global Manufacturing Competitiveness Index, China was found to be the most competitive manufacturing nation, followed by Germany, US, India and South Korea. Five years from now, the report predicts China to maintain the first ranking, followed by India, Brazil, Germany and US (Deloitte 2013).

Additive manufacturing is a layer-by-layer technique of producing three-dimensional objects directly from a digital model. With markets such as prototyping, tooling, direct part manufacturing, and maintenance and repair, the industry has grown significantly to USD 1.3bn of materials, equipment, and services in 2010. The additive manufacturing market, including consumer products, business machines, medical, and aerospace industries, is expected to grow at a compound annual growth rate (CAGR) of 13.5% from 2012 to 2017.

In 2011, BCC Research estimated the global market for robots and robot-related products to grow to nearly USD 22 bn in 2011 and USD 30 bn by 2016, a compound annual growth rate (CAGR) of 6.7%. In a more recent report (BCC Research 2013), BCC forecast a slightly lower compound annual growth rate of 5.9% between 2013 and 2018. The Asian market is expected to see the fastest growth in the coming years, while growth in the European Union is anticipated to be concentrated in the latter part of the forecast period, when robotic development initiatives now being undertaken on an EU-wide basis will result in commercialised products.

5.1.9. North American decline, East Asian rise

The preceding analysis of shares of patent applications for KETs reveals a steady strengthening of East Asia as the main producer of new technological knowledge in KETs. Over the past ten years, East Asian organisations have increased their share in total patent activity in each of the six KETs. In four KETs – photonics, advanced materials, micro-/nanoelectronics, advanced manufacturing technologies for other KETs – East Asian applicants were the most important patent producers by 2010. At the beginning of the 2000s, North America held the leading position in all six KETs: nowadays industrial biotechnology and nanotechnology are the only two areas that still show North America as the region with the largest share of patent applications. While North America has lost market shares in all six KETs, Europe has performed relatively better. In photonics and nanotechnology, Europe has remained stable during the past decade, while in the other four KETs losses were less severe compared to North America. The decline in North America and general stability in Europe occurred despite productivity gains in North American manufacturing which have tended to be greater than in Europe.

These trends in KET patenting are very similar to the overall trend in international patenting: an increasing East Asian share and a declining contribution by North America, while Europe reports moderate losses in market shares. The main difference with respect to KETs is the speed with which East Asia captures market shares, giving this region a leading position globally. By contrast, the shift from West to East in general international patenting is taking place more slowly, with Europe still holding the largest share in 2010.

In Europe, Germany and France were the main sources of patent applications in 2010 in each of the six KETs. While Germany maintained its dominant position during the past ten years, France increased its share of total European patent applications in all six KETs. The UK and Netherlands both show decreasing market shares.

A more disaggregated analysis at the level of subfields within each KET reveals that Europe is the leading KET patent applicant in some subfields and has been able to gain market shares. In photonics, European strengths are in the fields of measurement and electro-optics as well as lasers. In nanotechnology, Europe is the leading source of patent applications in nano-analytics and has increased its market share in nano-materials. In micro- and nanoelectronics, Europe has been able to maintain its market share in the field of devices and shows an increasing market share in the small area of testing and amplifiers. In advanced manufacturing technologies for other KETs, Europe has a very high market share in the subfield of instruments and has been able to maintain its share in the global technology output of advanced manufacturing technologies for biotechnology and materials production.

The analysis of the market potential of KETs reveals that substantial market growth is expected in all six KETs over the coming years. Depending on the KET, growth potentials of 10–20% per year can be expected. For particular submarkets, the growth potential is even larger. The position of Europe with respect to market size differs for the various KETs, but in general the increasing importance of East Asia and the higher pace of market share gains can be seen here as well.

5.2. THE POSITION OF EUROPE IN THE PRODUCTION AND TRADE OF KETS-RELATED PRODUCTS

5.2.1. Introduction

Analysing the position of countries and regions within value chains of a certain production process typically requires information on input and output links between the countries or regions. Input-output tables, however, offer such information only at a highly aggregated level of industries, not for individual products which can be linked to KETs. For that reason, this section uses an alternative approach. In order to identify Europe's position in global value chains within each KET in relation to North America and East Asia, characteristics of production and trade and their relation to technology inputs are examined. The following metrics are complementary and will be used jointly:

1. The technology content of manufactured goods, i.e. whether products are more technologically advanced;

2. The type of competition of Europe's exports in KET-related products, distinguishing between quality and price competition;

Figure 5.5. Measuring technology content of manufactured products

p=1: high and increasing technology content $UV^X_{ijt} > UV^X_{wjt}$ $\Delta UV^X_{ijt} > \Delta UV^X_{wjt}$	p=3: low but increasing technology content $UV^X_{ijt} < UV^X_{wjt}$ $\Delta UV^X_{ijt} > \Delta UV^X_{wjt}$
p=2: high but decreasing technology content $UV^X_{ijt} > UV^X_{wjt}$ $\Delta UV^X_{ijt} < \Delta UV^X_{wjt}$	p=4: low and decreasing technology content $UV^X_{ijt} < UV^X_{wjt}$ $\Delta UV^X_{ijt} < \Delta UV^X_{wjt}$

UV ... unit value ($/kg)
X ... exports
Δ ... change over time
i ... country/region ($i \in w$)
w ... world (total trade)
j ... KET-related product
k ... KET
t ... time
TC ... technology content
p ... position in quadrant

$$TC(p)_{ikt} = \Sigma_j X_{pij(k)t} / \Sigma_{ip} X_{pij(k)t}$$

For each KET-related product, a country (region) can be positioned in the following way:

1. High and increasing technology content.
2. High but decreasing technology content.
3. Low but increasing technology content.
4. Low and decreasing technology content.

Source: NIW/ZEW

3. The links between the creation of new technological knowledge (measured by patent applications) and the technology content of manufactured goods.

By combining these three approaches, a comprehensive picture of Europe's competitive advantage vis-à-vis its main competitors in each KET will emerge. The analysis is based on data for individual products related to one of the six KETs, in the sense that the products represent certain technological features which are directly linked to a KET (a certain new material, a photonics element, a semiconductor, a biochemical entity or a machine tool) but which do not use KETs as an input for more complex goods (such as batteries, measuring instruments, medical devices, information and communication devices). The notion of 'value chain' as used in this chapter therefore refers entirely to the division of labour within the production of KET products. In order to identify products linked to KETs, the results of a recent feasibility study on monitoring KETs are used (Van de Velde et al. 2013). In that study, KET products were defined at an 8-digit level of the Prodcom product classification system. For the purposes of this report, a narrow version of the definition is used in order to avoid analysis of products that are only partially linked to a certain KET.

5.2.2. Technology content of products related to key enabling technologies

The concept of technology content assumes that similar products can be produced by using different qualities and quantities of 'technology'. Technology may refer to the sophistication of production methods, the variety of different technologies used in the production, or how technologically advanced inputs are. Products with higher technology content are supposed to be positioned further along the value chain. As high technology content products should be superior to products with lower technology content, they should also reflect a higher unit price. Therefore a common trade indicator will be used to measure technology content: the unit value of exports. Based on the assumption that a country's exports of a certain product represent that country's total production of the product, export unit values give the average value of a product manufactured in a country. The assumption is somewhat unrealistic, since many studies have shown that exports tend to contain more innovative products than the average since it is the more innovative firms that engage in exports (see Wakelin 1998; Bleaney and Wakelin 2002; Beise and Rammer 2006; Wagner 1996; Ebling and Janz 1999; Roper and Love 2002; Lefebvre et al. 1998). Here though, the possible bias of exports towards innovative products can be seen as an advantage because it means the analysis will focus on the more innovative products within each KET.

A country or region's export unit value of a certain product is compared with the export unit value of the same product in global trade. A value greater than one indicates that the country (region) exports (and therefore manufactures) products of a higher value per unit, hence products with a higher technology content. Comparing export unit values over time provides information about the dynamics in technology content, in other words whether a country (region) moves away from the average unit value or converges towards it. Combining both dimensions – the level and dynamics of unit values – produces a matrix with four quadrants.

The technology content (TC) of a country (region) *i* in a certain KET *k* is examined by determining the position *p* in the quadrants shown in Figure 5.5 ($p \in \{1,2,3,4\}$) of each individual product *j* belonging to KET area *k*, weighted by the product's share in total exports *X* of products related to KET area *k* of country (region) *i*.

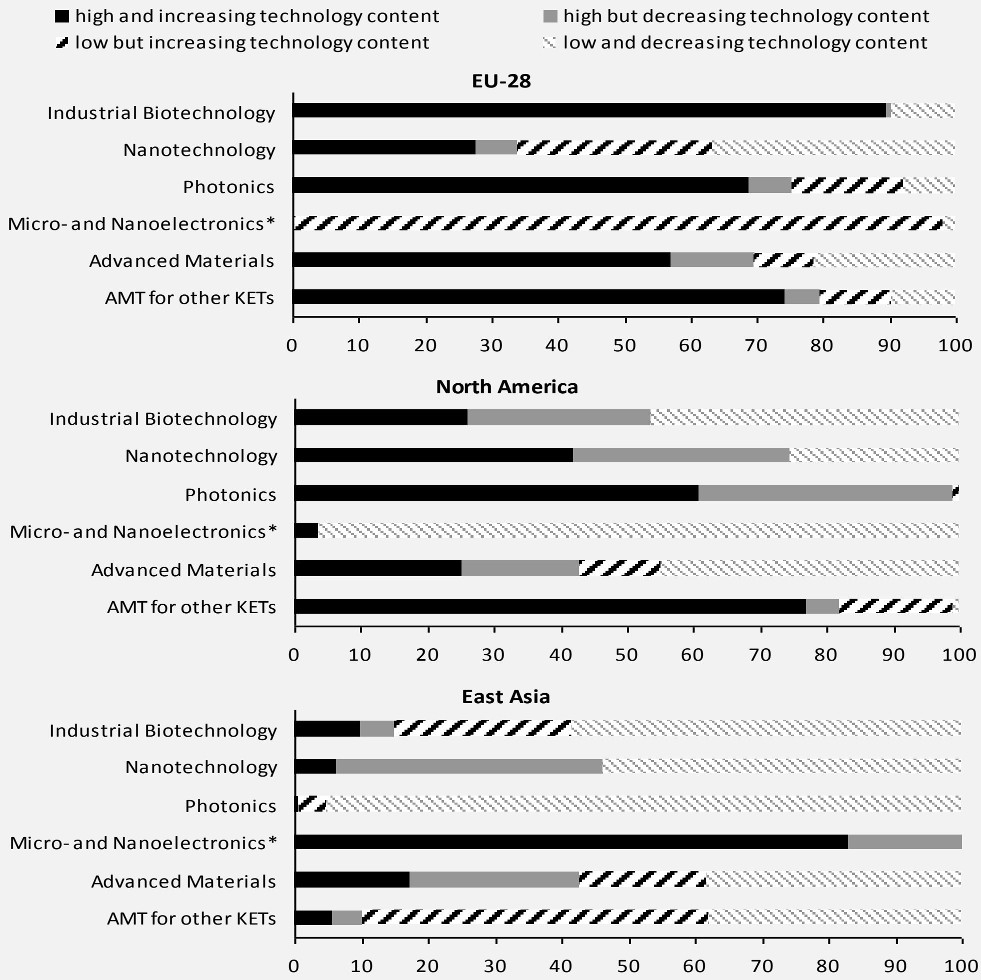
The analysis is conducted for three regions: EU-28 (EU Member States), North America (US and Canada) and East Asia (Japan, South Korea and China). The total exports of the three regions constitute 'total trade' *w*. Furthermore, separate analyses for 12 Member States (Germany, France, United Kingdom, Italy, Belgium, Netherlands, Austria, Sweden, Denmark, Poland, Czech Republic and Hungary) are carried out. The analysis is undertaken for individual KET-related products defined as 6-digit classes of the HS (harmonised system) product classification used in trade statistics. The 6-digit HS classes were identified using a conversion table from 8-digit Prodcom codes. Data on exports (in USD) and quantities (kg) were taken from the UN Comtrade database. The analysis covers the period from 2002 to 2011. Data for 2007 to 2011 rely on the HS 2007 classification while data for 2002 to 2006 are based on HS 2002. A conversion table was used to link the two classifications. To avoid picking up unit value fluctuations between single years, the analysis focuses on the development between two sub-periods, 2002–2006 and 2007–2011. In order to classify products by their technology content, changes in unit values between the average values for 2002–2006 and 2007–2011 are calculated.

The EU-28 reports a high and increasing technological content of its exports in four KETs. The strongest performance is found for industrial biotechnology. Here about 90% of the exports in the years 2007 to 2011 were generated by products with a higher unit value than in the main competitor regions and for which unit values increased more rapidly over time than in the other regions (Figure 5.6). In advanced manufacturing technologies (AMT) for other KETs, 74% of EU-28 exports were in products with high and increasing technology content. For photonics exports, the corresponding share was 69% and for advanced materials it was 57%.

Low technology content occurs for nanotechnology and micro- and nanoelectronics. In nanotechnology, 28% of the EU-28 export volume 2007–2011 was generated by products with high and increasing unit values, while 37% of exports were in products with low and decreasing technology content and another 30% with low but increasing unit values. For micro- and nanoelectronics, because of limited data availability only the 2002–2006 period can be analysed. In this earlier period, the EU-28 exported products related to micro- and nanoelectronics with a lower unit value compared to the same products exported by the main competitor regions (East Asia in particular). However, for almost all of these products, unit values increased more strongly in the first half of the 2000s (from 2002–2003 to 2005–2006) than in the competitor regions.

Whilst North America shows a similar pattern of technology content of exports of KETs-related products as the EU-28, it performs significantly better (in terms of having a higher technology content of exports) in photonics and nanotechnology but less well in industrial biotechnology and advanced materials. In photonics, North America is the leading technology region with broad and constantly increasing technological content. In nanotechnology, 75% of the 2007–2011 exports were based on products with high technology content, and for most of these products, unit values increased more rapidly than in the competitor regions.

Figure 5.6. Technology content of KET-related products by KET and triadic region, 2007 – 2011 averages



* 2005–2006 average, change in unit values for 2002–2003 to 2005–2006.

Source: COMTRADE Database, NIW calculations

In AMT for other KETs, the composition of North America's exports by technology content is very similar to the EU-28. This result indicates that both regions specialise in trade in different products, each region specialising in those products for which it has superior unit values. Like the EU-28, North America's exports in micro- and nano-electronics were focused on low technology content products, at least in the first half of the 2000s. In contrast to the EU-28, almost all export products faced decreasing unit values compared with the export unit values of the same products in the competitor regions. In advanced materials, North American exported products of varying technology content.

East Asia exports KET-related products which are classified mainly as low technology content products. The main exception is micro- and nano-electronics, where all products exported by East Asia have high technology content. In addition, 46% of nanotechnology exports in 2007–2011 were based on products with higher-than-average unit values, though most of these products reported decreasing export unit values compared with the same products in the competitor regions. In advanced manufacturing technologies for other KETs, most East Asian export products show an increasing technology content over time. In advanced materials, East Asia reports a similar pattern of technology content as North America: a mix of high and low technology content products. Photonics is clearly where East Asian exports focus on low technology content products, an indication of early stages in the value chain.

Within the EU-28, export performance with respect to technology content varies among Member States, though the main patterns for the EU-28 can be recognised for many of the largest Member States (Figure 5.7). In industrial biotechnology, a high share of exports with products showing a high and increasing technology content can be found for Denmark, the Czech Republic, Belgium, Austria, France, Netherlands, the UK, Germany and Italy.

In nanotechnology, only the UK, Netherlands, Belgium and Italy report a share above 50% for products with high and increasing technology content. For photonics, the high share of EU-28 exports products with high and increasing technology content is due mainly to the export activities of France and Sweden.

5.2.3. Type of competition and competitive advantages in international trade

In addition to technology content, the type of competition a country's or region's products face in international trade provides further, complementary information on the position of the country/region in international value chains. To simplify: product market competition can be driven either by price or by quality. Price competition dominates if the price elasticity is high while at the same time product differentiation (differentiating similar products by quality characteristics such as durability, usability, flexibility, additional performance characteristics) is of little relevance. Price competition often indicates that products are positioned earlier in the value chain, while quality competition may be associated with more complex products further along the value chain.

Aiginger (1997, 2000) proposed a method to classify products according to quality and price competition based on the relation of a region's export unit values to its import unit values on the one hand, and its trade balance on the other. Products are price elastic (price competition dominates) if export unit values which are higher (lower) than import unit values lead to a negative (positive) trade balance.

Conversely, products for which higher (lower) export unit values than import unit values result in a positive (negative) trade balance are price inelastic, in other words quality competition dominates. For both types of competition, a positive trade balance is an indication that the region can build on a competitive advantage for that type of competition. Combining the relation of export unit values to import unit values with the trade balance produces four quadrants (Figure 5.8) in which a region can be positioned for each KET-related product:

1. Quality competition with a quality advantage: where export unit values exceed import unit values and the trade balance is positive – a country or region can export more of a certain product than it imports, despite higher prices.
2. Quality competition without quality advantage: export unit values are lower than import unit values while the trade balance is negative – a country or region imports more than it exports despite lower prices, indicating that quality is the main driver for trade.
3. Price competition with a price advantage: a country or region shows lower export unit values than import unit values and can translate lower prices into a positive trade balance.
4. Price competition without a price advantage: export unit values are higher than import unit values in combination with a negative trade balance.

As for technology content, the type of competition that dominates the exports of country or region *i* in a certain KET *k* is determined by the position *p* in the quadrants shown in Figure 5.8 that each individual product *j* belonging to KET area *k* occupies, weighted by the product's share in total exports *X* of products related to KET area *k* of country or region *i*. To calculate the type of competition, the same data source is used as for calculating the technology content of trade.

The results for the three main regions are reported in Figure 5.9. Exports of KETs-related products by the EU-28 face very different competition on international markets. In advanced manufacturing technologies for other KETs, most EU-28 exports (64%) concern products for which trade is characterised by quality competition. For almost all these products, the EU-28 has a quality advantage; in other words, it is able to gain a positive trade balance based on superior product quality. In nanotechnology, industrial biotechnology and advanced materials, only 23% to 34% of EU-28 exports are based on quality competition. Although the majority of EU-28 exports in these KETs is characterised by price competition, most of these exports benefit from price advantages. This means that Member States specialise in those price-sensitive products for which a cost-efficient production in the EU is possible. In photonics and micro-/nanoelectronics, most of the products exported by the EU-28 are in price competition (89% and 94% respectively), and for the majority of these products the EU has no price advantage.

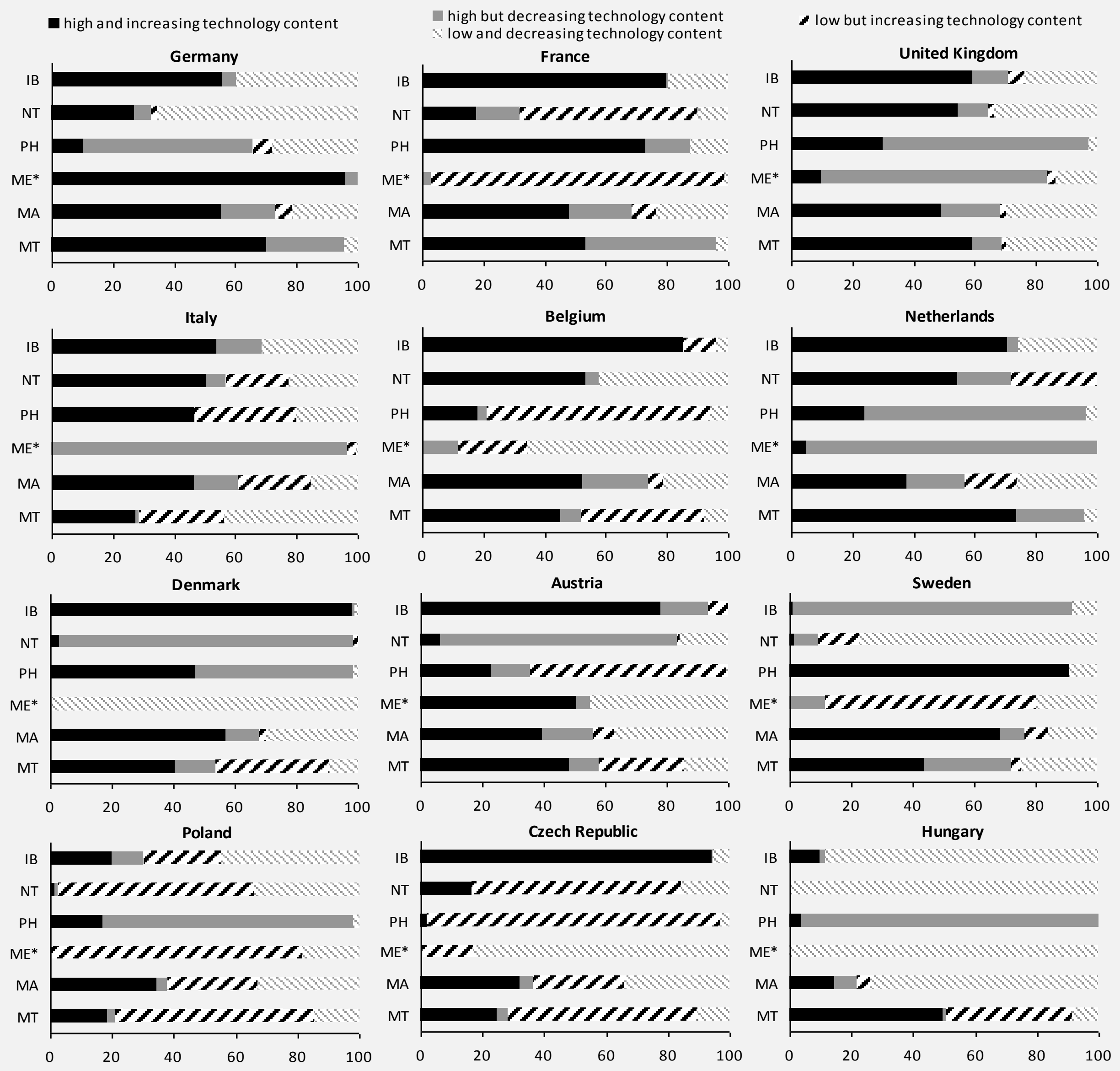
North America reports a strong focus on exports which face quality competition: it relies on a quality advantage in international trade in the fields of photonics (78% of all exports in this KET) and nanotechnology (54%). In micro- and nano-electronics, 41% of North America's exports fall into this category, while 15% are characterised by quality competition, without having a quality advantage. In the other three KETs, exports from North America mainly face price competition, with a price advantage over their main competitors.

East Asia's trade in KET-related products is strongly focused on price competition. In five KETs – industrial biotechnology, nanotechnology, micro- and nanoelectronics, advanced materials and advanced manufacturing technologies for other KETs – East Asia benefits from a price advantage, in other words a cost-efficient production. Photonics is the only area where East Asia's exports are under major pressure, as most of its products face price competition but cannot compete on a price advantage. In each KET, the share of KET-related products exported from East Asia which are in markets dominated by quality competition is lower than for North America, ranging from 10% (micro-and nanoelectronics) to 29% (photonics). The majority of these exports do not have a quality advantage.

When examining the development of competition types by KET over time, no clear trends for the EU-28 emerge. In advanced manufacturing decreased. In photonics, the share of EU exports in markets with price competition which could profit from an EU price advantage has fallen substantially in the last ten years, while the share of exports facing price competition without a price advantage has increased.

At the level of EU Member States (Figure 5.10), most countries face price competition for the majority of their KETs-related exports. Interestingly, for products facing price competition some large Member States (Germany, France, UK, Italy) and the Netherlands do

Figure 5.7. Technology content of KET-related products by KET for selected Member States, 2007 – 2011 averages



Notes: IB: Industrial biotechnology; NT: Nanotechnology; PH: Photonics; ME: Micro and nanoelectronics; MA: Advanced materials; MT: AMT for other KETs.
** 2005–2006 average, change in unit values for 2002–2003 to 2005–2006.*
Source: COMTRADE Database, NIW calculations.

technologies for other KETs, the share of EU exports based on quality competition and quality advantage increased during the 2000s, while the share of exports based on price competition and price advantage not appear to have any price advantage. By contrast, exports of price-sensitive KET-related products from Sweden, Austria, Belgium, the Czech Republic and Hungary rely mostly on price advantages, though in each Member State there are also some KETs with products that predominantly feature price disadvantages.

exports in advanced manufacturing technologies for other KETs rely on quality advantages and compete

Figure 5.8. Measuring the type of competition and competitive advantages of manufactured products

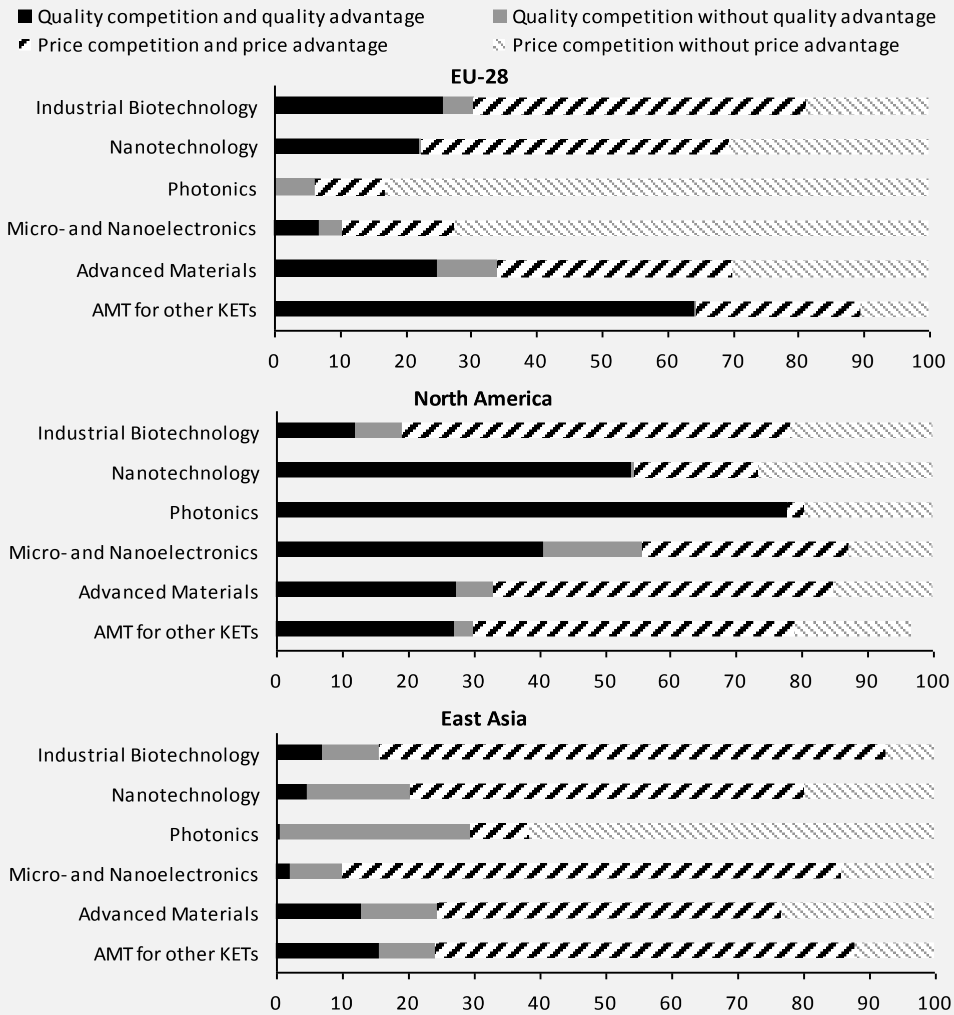
p=1: quality competition and quality advantage $UV^X_{ijt} > UV^M_{ijt}$ $Q^X_{ijt} > Q^M_{ijt}$	p=3: price competition and price advantage $UV^X_{ijt} < UV^M_{ijt}$ $Q^X_{ijt} > Q^M_{ijt}$
p=2: quality competition, no quality advantage $UV^X_{ijt} < UV^M_{it}$ $Q^X_{ijt} < Q^M_{ijt}$	p=4: price competition, no price advantage $UV^X_{ijt} > UV^M_{ijt}$ $Q^X_{ijt} < Q^M_{ijt}$

$$CP(p)_{ikt} = \Sigma_j X_{pij(k)t} / \Sigma_{ip} X_{pij(k)t}$$

UV ... unit value ($/kg)
X ... exports
M ... imports
Q ... quantity (kg)
Δ ... change over time
i ... country/region (i ∈ w)
w ... world (total trade)
j ... KET-related product
k ... KET
t ... time
CP ... Type of Competition
p ... position in quadrant

Source: NIW/ZEW based on Aiginger (1997)

Figure 5.9. Type of competition in trade with KET-related products, 2002 – 2011 averages

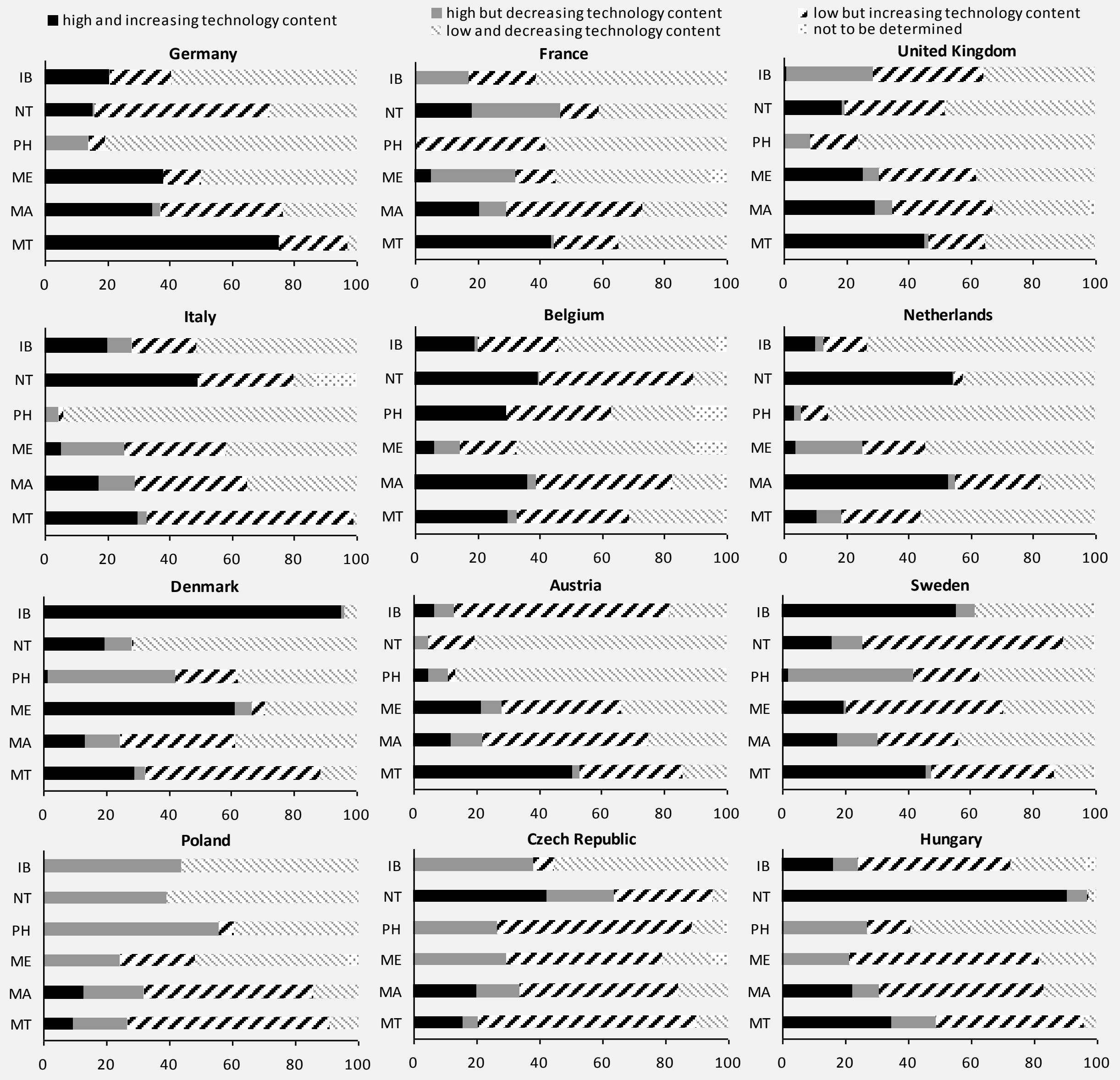


Source: COMTRADE Database. NIW calculations

Quality competition dominates for only a few KETs in each Member State. In Germany and Austria, most

on quality. In Denmark and Sweden, the same is true for industrial biotechnology. Exports from the

Figure 5.10. Type of competition in trade with KETs-related products for selected Member States, 2002–2011 averages



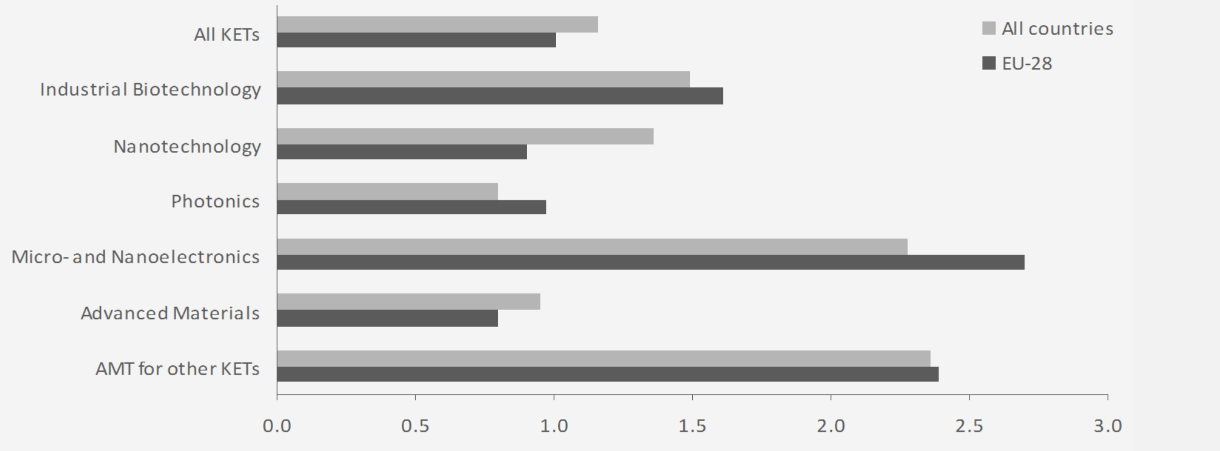
IB: Industrial biotechnology; NT: Nanotechnology; PH: Photonics; ME: Micro and nanoelectronics; MA: Advanced materials; MT: AMT for other KETs
Source: COMTRADE Database, NIW calculations

Netherlands and Hungary in products related to nanotechnology are also predominantly based on a quality advantage in markets where they face quality competition. In micro- and nanoelectronics, Denmark is the only Member State considered here which exports most of its products based on quality competition and a quality advantage. In advanced materials, only the Netherlands is in the same situation. In photonics, for all Member States considered here apart from Poland, most export markets are characterised by price competition, but most Member States do not possess a price advantage for these exports.

5.2.4. Link between patenting and technology content of products related to key enabling technologies

The link between patenting activities and the technology content of products provides another indication of a country's position in the value chains of KET-related products. If the production of new technological knowledge (as revealed through patent applications) has a direct impact on the technology content of traded products, one may conclude that these products are closer to the technological frontier and depend on a direct technology input from recent efforts in developing new technology. In order to examine this link, a country's unit values of exports of products based on a certain KET are regressed are

Figure 5.11. Link between patent output and unit values of exports, 2002 – 2011, change in unit values from a 10 % change of patent output, by KET, 2002 – 2011



Source: COMTRADE and PATSTAT data, ZEW calculations

regressed on the patent activities of that country in the same KET.

The level of export unit values (UV) for each product *j* belonging to a KET *k* in country *i* in period *t* are explained by the country's patent activity in the respective KET area *k* in a previous period *t–n*. Since unit values do not depend on country size, while patent activity does, the latter is divided by country population to derive a size-adjusted patent intensity (PINT). Country-specific variables such as size (GDP) and productivity (GDP per capita, PROD) are used to control for the effects of market size and the sophistication of the production system, while time dummies are used to capture changes in prices over time:

$$ln(UV^X)_{ij,t} = \alpha + \beta_1\ ln(PINT)_{ik,t-n} + \beta_2\ ln(GDP)_{i,t} + \beta_3\ ln(PROD)_{i,t} + \Sigma_t\ \chi_t\ d_t + \varepsilon_i \qquad \text{with } j \in k$$

The patent intensity indicates to what extent a country produces new technological knowledge in a certain subfield of KETs given the total resources available in that country. All variables are measured in logarithms. The model is estimated for each KET separately as well as across all KETs for the period 2002 to 2011 for 39 countries (EU-28, US, Canada, China, Japan, South Korea, Switzerland, Norway, Iceland, Israel, Former Yugoslav Republic of Macedonia, and Russia).

The estimation results confirm a positive link between lagged patent intensity and unit values. Across all six KETs, a 10% increase in patenting results in a 1.2% increase in export unit values (Figure 5.11). The impact of patenting on the technology content of exports is largest in advanced manufacturing technologies for other KETs (2.4% increase in unit values, or twice as high as for all KETs) and micro-/nanoelectronics (2.3% increase). In industrial biotechnology, the elasticity of unit values on patent intensity is 1.5%, in nanotechnology 1.4%, in advanced materials 1.0% and in photonics 0.8%.

The main findings also hold when only EU Member States are considered. For the EU, the link between patent intensity and unit values of exports is of similar magnitude as for the entire set of countries. A 10% increase of patent intensity would transfer into an increase of export unit values of 1.0%. For three KETs, the link between patenting and technology content of exports is stronger in the EU than for all 39 countries considered in this analysis. In micro-/nanoelectronics, a 10% increase in patent intensity in the EU-28 results in a 2.7% increase in export unit values.

In photonics, the elasticity in the EU-28 is 1.0% and 1.6% in industrial biotechnology. In advanced manufacturing technologies for other KETs, the EU Member States report the same elasticity for patenting as the total group of 39 countries. In nanotechnology and advanced materials, the EU-28 elasticity of patenting is somewhat lower (0.9% and 0.8% respectively).

5.3. VALUE CHAIN ANALYSIS OF PROMISING KETS-BASED PRODUCTS

5.3.1. Introduction

How do these general observations hold when focusing on a number of product-specific value chains? In this section, the value chains of two promising products based on key enabling technologies are analysed and discussed. First, the selection of the two products, lipase enzymes and accelerometers, is explained. A more detailed analysis of the value chain of lipase enzymes and the accelerometer is then provided.

The analysis begins with a detailed description of the value chain, after which all relevant players in each part of the value chain are identified, thereby analysing the position of EU companies vis-à-vis non-EU companies. The information and analyses are based on expert interviews, articles, news sites and market reports. The methodology used to analyse the value chain is the same methodology as in the feasibility study for an EU monitoring mechanism on KETs (Van de Velde et al. 2013).

The analysis points out that EU firms play an important role in essential parts of the value chain even though the exact proportions of value added captured by EU firms could not be retrieved.[141]

5.3.2. Selection of products

The economic importance and growth potential of the candidate product has been the main selection criterion. Furthermore, whether a candidate product constitutes a relatively new application or is well-established is another factor to consider. The value chain analysis aims to focus on upcoming products that are driven by technological innovation, and to analyse how the EU performs in developing and marketing new high technology products in the KETs area and how EU policies support this process. On the basis of an extensive literature review, the enzyme class lipases in industrial biotechnology and the accelerometer in micro- and nanoelectronics were chosen. The overall selection process is presented in Figure 5.12.

Figure 5.12. Different steps in the selection of products for the value chain analysis

Source: IDEA Consult

5.3.2.1. *Lipase enzymes*

The first key enabling technology selected is industrial biotechnology because of its fundamental role in the development of a bio-based economy. Bio-based products are one of the six priority action lines in the Communication ‘A stronger European Industry for Growth and Economic Recovery’ (European Commission 2012b). Within industrial biotechnology, enzymes have been selected as the product segment. Enzymes are one of the major promising areas in industrial biotechnology. They enable a broad range of applications and provide several advantages over traditional chemistry, including high selectivity, lower energy use and mild reaction conditions. The market for enzymes has grown rapidly over the past decade, and both households and industry are becoming more dependent on enzymatic catalysis. Even so, there remains a vast untapped potential in the enzyme market (Sarrouh et al. 2012). In 2010, the market for industrial enzymes was worth USD 3.3bn and is expected to grow to USD 4.4bn by 2015, a compound annual growth rate of 6% over those five years (BCC Research 2011a).

Within enzymes, lipases are, together with carbohydrases, considered to have the highest growth prospects (Global Industry Analysts 2012). Lipases – enzymes that catalyse chemical conversions of fats – have traditionally been used in detergents to remove fat and oily stains. In addition, they are increasingly used in the food industry, for instance in applications involving dairy products and baking. In recent years, lipases have also received more attention as highly effective, versatile and flexible biocatalysts for organic synthesis. This has opened up a whole new range of possibilities, including the production of basic chemicals, specialty chemicals, pharmaceuticals, cosmetics and biodiesel. Lipases have the potential to impact positively on several industries, both in terms of competitiveness and environmental friendliness (lower energy use, fewer unwanted by-products). Therefore this product is selected to analyse the position of the EU in the value chain of this class of enzymes.

5.3.2.2. *Accelerometer*

Micro- and nanoelectronics provide knowledge and technologies which generate some 10% of GDP. The expected market size for this key enabling technology is estimated to be USD 300bn in 2015, with an expected compound annual growth rate of 13% (HLG MNE 2011). It has enabled the rise of the information age, impacts deeply on everyday life and is expected to continue to do so. Given the increasing importance of ‘More-than-Moore’ (MtM) applications, a product within MtM and more specifically in the segment of micro-electro mechanical systems (MEMS) was chosen. MEMS products are elementary for many types of interactions of electronics with the outside world, and provide a good example of the continued integration of digital and non-digital functions over time (the MtM trend). This integration has enabled MEMS to grow rapidly in recent years. The MtM trend is a major evolution with potential for radical innovations, and the relative weight of MtM in the industry is expected to increase (ITRS 2010).

In the MEMS segment, rapid growth is expected for inertial sensors (Yole Développement 2012). One example of fast-growing inertial sensors is the accelerometer, which is the chosen product based on this key enabling technology. It is a motion sensor which measures the acceleration of a given object. It was first introduced on a large scale in the automotive sector but has since found its way into many consumer electronics applications. In mobile devices such as smartphones, accelerometers are key sensors

[141] A major difficulty here is the possibility of estimating the value added of a KETs-based product in the total product range of a company. For example, in the case of foundries, no information is disclosed on the share of the accelerometer production versus total production. Moreover, this share tends to change over time, particularly due to rapid shifts in market demand. There is also often a problem of corporate confidentiality to overcome.

as they enable gesture recognition, user interface control and activity monitoring. Other consumer electronics applications include measuring motion in gaming and sports applications. The accelerometer has been an important sensor in the evolution towards more 'intelligent' consumer electronics – devices becoming increasingly aware of the environment and the conditions of the device (Ryhänen 2010). As the accelerometer is representative of two major evolutions in micro- and nanoelectronics – the trend towards mobile, intelligent devices and the integration of heterogeneous functions – this product has been selected.

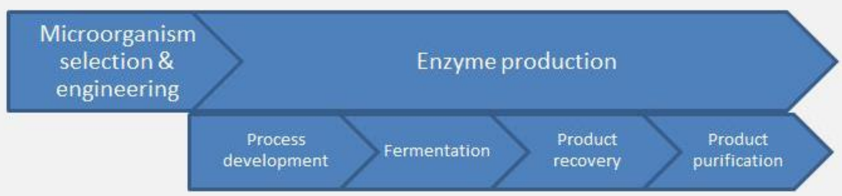
5.4. VALUE CHAIN ANALYSIS OF LIPASE ENZYMES

5.4.1. Value chain decomposition

Figure 5.13 shows the value chain of lipase enzymes, consisting of two broad phases. First there is the selection and genetic engineering of an appropriate microorganism capable of producing the enzyme of interest. Then there is the actual production of the enzyme. The latter phase can be subdivided into four major steps. The first step is the development of the production process, which entails discerning the right conditions for fermentation (the following step) and the up-scaling of production from laboratory scale to commercial scale. Once the production process is optimised, large-scale fermentation can occur. During fermentation, the microorganisms grow on a substrate and produce the enzyme of interest. Once fermentation is complete, the next step is to separate the enzymes from the fermentation mass (product recovery). In the final step, the enzyme product is purified. The necessity of this final step depends on the application.

The value chain in Figure 5.13 applies not only to lipase enzymes but to enzymes in general, and to a large extent even to industrial biotechnology in general.

Figure 5.13. Value chain decomposition for enzymes



Source: IDEA Consult

5.4.2. EU activity along the value chain

In what follows, the key players in the lipase enzymes value chain will be identified and discussed. First, the lipase enzyme producers – companies selling lipase enzymes – will be described. Next, companies that do not sell lipases directly but contribute to the value added of this product by executing a specific step in the value chain will be discussed. The focus will be on the companies providing services for the selection and engineering of the microorganism, followed by companies active in the second part of the value chain, namely enzyme production. Table 5.1 provides an overview of identified companies along the value chain.

5.4.2.1. *Lipase producers*

Fifteen companies selling lipases have been identified, almost half of them located in Europe. In Denmark-based Novozymes, Europe hosts the world's largest player in the overall enzyme industry with a market share of about 47% of global enzyme sales in 2011. With regard to lipase enzymes, the company offers a broad portfolio of enzymes for various applications, including as detergents and food processing, but also more recent applications such as biocatalysis for the pharmaceutical, cosmetics and chemicals industry. Netherlands-based DSM is larger than Novozymes in terms of revenue but has a lower market share in enzymes (6% compared with 47% for Novozymes [142]). DSM is active particularly in lipases for food applications and has recently underlined its interest in this field by acquiring lipase technology from US-based Verenium, primarily to extend its activities in food applications. However, its lipase portfolio is not as broad as that of Novozymes.

The other European companies active in the lipase segment are generally an order of magnitude smaller than DSM and Novozymes. Many of them focus on a number of specific applications. For example, AB Enzymes (owned by the UK-based ABF) produces lipases predominantly for food (baking) purposes, while Biocatalysts focuses on dairy applications. Eucodis Bioscience is a relatively young company with a high share of lipases in its product portfolio, targeting mainly pharmaceutical applications. Germany-based C-lecta is also a relatively young company, offering enzymes for a limited number of applications. With its lipase products it focuses notably on the production of specialty chemicals.

Outside the EU, the main emerging country is the US, where the largest player is Dupont, due to its recent

[142] Source: Novozymes

acquisition of Genencor. Genencor is the second largest enzyme producer in the world, with about half the sales of Novozymes. While Genencor holds a strong position in the food enzyme market, it has so far not been able to play a leading role in the lipase segment of the food market. In addition, unlike Novozymes it is much less present in the emerging markets for lipases, such as pharmaceutical and chemical market applications. The other US companies are significantly smaller than Genencor. Codexis produces enzymes used to improve production processes in the pharmaceutical industry and is currently developing its lipase activities. Verenium has achieved some success in the commercial development of lipases, as illustrated by the recent acquisition of its enzyme technology including lipases by DSM. Dyadic is another rather small company which owns a revolutionary technology platform for the discovery and production of enzymes, but it does not have a specific focus on lipases.

Japan has two companies in Table 5.1. Amano Enzymes has a long history as a specialty enzyme developer, with key strengths in hydrolases. One of its most successful products is a lipase which has been widely produced in the past. However, Amano does not serve the wide range of applications Novozymes does. The other Japanese company, Meito-Sangyo, is smaller than Amano but is also a recognised player in the field of lipases, especially in applications involving chiral transformations.

Two companies from India also appear in the list, both offering a broad portfolio of lipases. This reflects the emergence of India in the enzyme industry as one of the countries with the highest level of commitment to the development of industrial biotech in Asia.

European companies are well represented in each segment. In the detergent segment, Genencor and Novozymes are the two companies with the highest market shares. The food segment is dominated by Novozymes and DSM. Novozymes is the clear market leader in the biocatalysis segment.

5.4.2.2. *Companies active in microorganism selection and engineering*

Lipase producers are not necessarily active in all parts of the value chain. Other companies can be active in specific segments. Only three companies have been identified as providers of services for microorganism selection and engineering services, the first part of the value chain. This can be explained by the fact that the first step of the value chain can be considered as a core competence of most lipase producers. One example of a company offering such services is DSM, which provides guidance to other companies in the development of their technologies. For example, when a lipase producer is working on the commercialisation of its products, DSM can propose other microorganisms for expressing the gene of interest in order to facilitate the up-scaling of enzyme production. Similarly, Lonza possesses so-called ‘expression platforms’ – in-house engineered microorganisms enabling high enzyme production levels.

5.4.2.3. *Companies active in enzyme production*

The large-scale production of enzymes requires considerable investment in infrastructure, which often creates a hurdle, especially for smaller (start-up) companies. Outsourcing enzyme production can deliver specific benefits to enzyme companies, not only by reducing the financial risk, but also by gaining access to the fermentation service provider’s know-how. In this respect, it is important to note that in industrial biotechnology, the scaling up of the production of a given product (such as enzymes or vitamins) from laboratory to commercial scale is more difficult than in classical chemical production processes (Wydra 2012). Therefore the fermentation service providers often guide enzyme producers through the gradual up-scaling of production of a new enzyme, a service primarily used by smaller companies, whereas large industrial players typically organise the whole production in-house.

The companies identified as active in enzyme production are shown in the lower part of Table 5.1. These companies are known to be engaged in contract production of enzymes for industrial purposes. However, it should be noted that the importance of lipase production in their production services may vary over time, and is not fully disclosed by these companies. This list therefore applies to industrial enzyme production in general. Four companies are located in Europe. DSM, by far the largest company involved, is present also in the list of lipase producers. Apart from producing enzymes under its own brand name, it also offers a broad range of fermentation services to other companies. Two other companies, Eucodis Bioscience and Biocatalysts, are also identified as lipase producers. Finland-based Galilaeus is a small company focusing on fermentation services for various fields.

Table 5.1. Overview of companies active along the lipase value chain

Region	Country	Company name	Total revenue 2011 (USD million)
Lipase producers			
EU	**Netherlands**	**DSM**	**9 048**
	Denmark	**Novozymes**	**1 891**
	UK	**ABF (AB Enzymes)[a]**	**16 650 (127)**
	Germany	**C-lecta**	n.a.
	UK	**Biocatalysts Ltd**	n.a.
	Austria	**Eucodis Bioscience**	n.a.
Non-EU	US	Dupont (Genencor)[a]	38 000 (835b)
	US	Codexis	124
	US	Verenium	61
	US	Dyadic	10
	Japan	Amano	1 074c
	Japan	Meito-Sangyo	176
	India	Advanced Enzymes	34
	India	Aumgene Bioscience	n.a.
	China	Syncozymes	n.a.
Companies active in microorganism selection and engineering			
EU	**Netherlands**	**DSM**	**9 048**
Non-EU	Switzerland	Lonza	2 019
	India	Aumgene Bioscience	n.a.
Companies active in enzyme production			
EU	**Netherlands**	**DSM**	**9 048**
	Finland	**Galilaeus Oy.**	**1.9[b]**
	Austria	**Eucodis Bioscience**	n.a.
	UK	**Biocatalysts Ltd**	n.a.
Non-EU	Switzerland	Novartis (Sandoz)[a]	58 566 (10 700)
	Switzerland	Lonza	2 019
	Israel	Biodalia	n.a.
	Mexico	Fermic	n.a.
	India	Aumgene Bioscience	n.a.

Source: IDEA Consult. Company turnover and main production sites are based on corporate annual reports and company website information

Notes: a: in case the relevant activities are performed by a specific subsidiary, this subsidiary is listed in parentheses behind the parent company. b: total revenue 2010; c: total revenue 2012; n.a. = not available

Outside the EU, Switzerland hosts two companies. However, the presence of the large pharmaceutical company Novartis is due to its ownership of Sandoz, which offers a broad range of fermentation services to its facilities in Germany, Austria and Italy. Lonza is also a large company with a broad range of activities. Given that the main fermentation site of this company is located in the Czech Republic, it can be concluded that many activities of interest here of the two Swiss companies take place in Europe, particularly the fermentation services accessible to European firms. Fermic, based in Mexico, has an agreement with US-based Verenium for the manufacturing of all of the latter's enzymes.

Table 5.2. Dominant companies per lipase application field

Application field	Companies with highest market shares
Detergents	Genencor, Novozymes
Food	DSM, Novozymes
Biocatalysis	Novozymes

Source: IDEA Consult [143]

The world enzyme market is dominated by a select number of companies (Novozymes, Genencor, DSM). In a market where product innovation is very important, their extensive R&D capabilities allow these companies to remain at the forefront. However, a second important element in the enzyme industry is the capability to produce enzymes on a large scale (and therefore at a moderate cost). This is because the scaling of manufacturing processes in industrial biotech is far less straightforward than in classical chemistry. Currently Novozymes, Genencor and DSM (and to a lesser extent AB Enzymes) distinguish themselves in the large-scale effective production of enzymes. While many smaller firms are good at the discovery of new enzymes with interesting properties, the step to large-scale manufacturing is not easy to take. As a consequence, the technology of the smaller companies is often acquired by larger companies who then set up large-scale production of the enzyme. Europe is well-placed in this regard and should foster its capabilities in large-scale enzyme production since it gives an important competitive advantage.

5.4.3. EU position in the value chain of lipase enzymes

With Novozymes (the world's leading enzyme supplier) and DSM, Europe has leading companies in all lipase application fields (Table 5.2). In addition, Europe hosts a group of smaller companies which tend to specialise in certain applications. There is considerable competition from US companies, primarily Genencor. However, this company only has a leading market position in detergent lipases. Japan, on the other hand, hosts two recognised players which are strong in emerging applications such as pharmaceutical and chemical applications. However, the lipase activities of these companies do not have the scale of the large EU players.

Looking at more specific parts of the value chain, a significant share of fermentation services is provided within Europe, especially when taking into account several EU-based activities of companies with Swiss headquarters. No other major region emerges in this segment. As for the first step of the value chain, microorganism selection and engineering, only a few companies were identified, one of which is based in the EU. This represents a smaller segment though. The analysis – largely expert-driven – confirms that Europe is a key player in the global enzyme market and holds a strong position in the subfield of lipases.

It has not been possible to calculate the value added captured by European firms in the value chain of lipases. In order to assess the performance of EU companies, industry experts were asked to list the companies with the highest market shares for each of the three major application fields of lipases in order to gain insight into which regions lead in the segment. For companies not selling lipases but focusing on specific parts of the value chain, information on the relevance of lipases in their activities is typically more difficult to find since these activities are more remote from the end-product.

5.5. VALUE CHAIN ANALYSIS OF THE ACCELEROMETER

5.5.1. Value chain decomposition

The accelerometer consists of two main functional units: a mechanical component which senses the acceleration (the sensor) and an electronic unit which receives and translates the signals coming from the mechanical component. The electronic unit is often referred to as an application-specific integrated circuit (ASIC), as its sole purpose is to receive and translate signals from the mechanical component. Figure 5.14 is a schematic representation of the value chain of the accelerometer. It covers two major phases, the design and manufacturing of the ASIC and of the sensor. In the design phase, a complete plan of the ASIC and sensor is drawn, detailing all functional structures and how they will be interconnected. These plans will be translated into a format that can be used for manufacturing. The manufacturing process can be divided into four steps. The first step is the fabrication of the ASIC and sensor on a large silicon substrate (or wafer). The next step, wafer probing, is to inspect the wafer for malfunctioning ASICs and sensors. Then the two components are integrated into one package, followed by a final phase of tests of the accelerometer. Each step will be discussed in more detail below.

The value chain of the accelerometer consists of many steps. A company can opt to cover the whole value chain itself or focus on a specific number of steps. Companies covering the entire chain are integrated device manufacturers (IDMs) and are responsible for the design, manufacturing and sale of their own products. However, other business models exist as well. A company can focus on design but leave manufacturing to another firm (a 'fabless' company). Companies focusing exclusively on manufacturing chips commissioned by 'fabless' companies are referred to as foundries. Intermediate forms can also exist: a company can manufacture part

[143] Table 5.2. is based on replies from interviewees about the most important players in each application field.

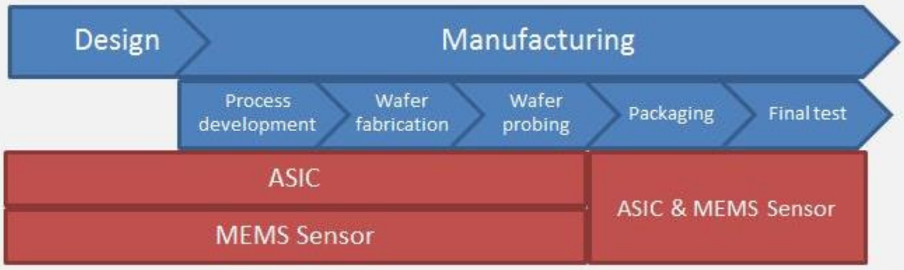
of its products and outsource the rest to a foundry, or be active only in the design phase by providing design services to other companies.

This illustrates that the value added from creating an accelerometer is divided among several companies, each covering particular stages of the value chain. It is therefore important to look not only at the end-producers of this product but at all parts of the value chain when assessing the competitiveness of the EU in this product. In the following paragraphs, the key players will be identified for each step of the value chain. First the end-producers of accelerometers (companies selling accelerometers) will be discussed, followed by companies active in the first part of the value chain (design) and then those active in the second part of the value chain (manufacturing).

facilities for that market. This has brought the company solid growth and a strong position in this segment. Robert Bosch is another key player in the consumer electronics market. Strength in both the automotive and consumer segments provides an opportunity to operate at a large scale, thus reducing costs. The main competition in the accelerometer market comes from US-based companies. Analog Devices and Freescale are two well-established competitors, while Memsic and Invensense are two young, promising and innovative companies with strong growth rates over the past years.

The accelerometer market was worth around USD 1.5bn in 2011 and dominated by companies such as STMicroelectronics and Bosch (around 20% each), Freescale (around 10%), Analog Devices,

Figure 5.14. Value chain decomposition for the accelerometer



Source: IDEA Consult

Denso and VTI. The success of STMicroelectronics and Bosch in both automotive and consumer electronics makes them the two largest players in the accelerometer market. The EU represents almost half of the market in this segment, making it the leading region. Two US companies, Freescale and Analog Devices, also capture a significant share of the market, although less than STMicroelectronics or Bosch. Together with other US companies with smaller market shares, the US has the second largest market share after the EU. The third player, Japan, has been able to capture a considerable share of the market with Denso and the acquisition of VTI and Kionix.

5.5.1.1. *Accelerometer producers*

Table 5.3 lists the most important players in the accelerometer industry. It is clear that Germany, the US and Japan are the three countries covering the majority of the market (in case of multinational companies, the country assigned is the location of the parent company).

Europe has a small group of large companies, while in the US there is a larger group of somewhat smaller companies. Japan has three major players on the market, but two are the result of recent acquisitions (Rohm Semiconductor acquired US-based Kionix, while Murata Electronics acquired Finland-based VTI). The widespread use of accelerometers started in the automotive industry, which remains an important market. All large companies in Table 5.3 have a strong presence in the automotive sector. In this respect it has been an advantage for companies in Europe to have a strong domestic automotive market.

The interest of consumer electronics manufacturers in accelerometers (and other MEMS) has grown gradually as a result of their drive to give electronics 'intelligent' attributes. This posed a number of technical challenges – smaller chips, higher production volumes and extreme cost consciousness. STMicroelectronics was one of the first sensor producers to spot the potential of the consumer electronics market and develop large-scale production

5.5.1.2. *Companies active in design*

Companies specialising in support for MEMS producers in the design phase are often referred to as 'design houses'. Their task involves helping other companies with the design and prototyping of a new product. Design houses can help deliver a faster 'time-to-market' (which tends to be quite long for MEMS in general) and ensure a good match of the design with more conventional manufacturing techniques.

Table 5.3 also lists companies active as design houses for MEMS. It should be noted that the importance of accelerometer design in the activities of these companies varies over time and is not disclosed. Therefore, the list applies to MEMS more generally.

Of the four identified actors, three are US-based. France-based Movea is a young, innovative company specialised in motion sensing. Design houses are a relatively small segment (much smaller than the foundry segment) since design is a core competence of most accelerometer end-producers and is often undertaken to a significant extent by these companies themselves.

5.5.1.3. *Companies active in manufacturing*

Companies active in accelerometer manufacturing are those which manufacture accelerometer products on behalf of a second party. Most of the large companies in Table 5.3 (Bosch, STMicroelectronics, Freescale, Analog Devices) are IDMs covering the whole value chain. However, this is not true for all accelerometer producers. The US-based company Invensense, for example, operates a fabless model by operating a simplified and innovative manufacturing process.

Outsourcing is not unique to small companies such as Invensense. Companies like Analog Devices also outsource part of their MEMS manufacturing. The main rationale behind outsourcing is cost reduction. The manufacturing equipment for integrated circuits is capital intensive and cost-competitive production is only possible if done on a large scale. A high-volume, quick-turnaround consumer segment can often be better served by dedicated large-scale foundries. An exception is the automotive market, where strict compliance requirements are in place and production is in most cases done internally. Another reason to use foundry services is the expertise these companies have in the successful up-scaling of production to large volumes.

Table 5.3 lists the most important foundries active in accelerometer manufacturing. This list consists of companies that undertake manufacturing of accelerometer products on behalf of a second party. It should be noted that while the companies listed in the table are known to have accelerometer production capabilities, the importance of accelerometer production in their total activities varies over time and is not disclosed. Two types of foundries can be distinguished: those making only MEMS products and those active also in the regular electronics markets (memory, microprocessors). The latter category of firms is referred to as silicon foundries. Foundries (whether MEMS-exclusive or not) often develop their own technological (manufacturing) competences and hold a number of patents on in-house manufacturing technology. MEMS foundries also tend to offer a number of services aimed at facilitating the translation of design into a successful product, going from co-design to custom-specific process development and packaging and testing.

In Europe there is considerable foundry activity in four countries. Silex Microsystems has grown strongly in MEMS and has become a strong player thanks to its in-house manufacturing technology which allows close integration of the ASIC and the sensor. However, the EU foundry companies are relatively small; and as only a part of their revenues stems from accelerometer production their weight is much smaller than accelerometer producers such as STMicroelectronics and Robert Bosch.

Outside the EU, US companies are somewhat less present in the foundry segment than the end-product market. Global Foundries is a leading silicon foundry, but in MEMS it is currently a small player as it has only recently moved into this field (including accelerometers), attracted by the good market prospects. Taiwanese companies have a stronger presence on the foundry list than on the list of accelerometer producers. The less prominent presence of US companies and the strong emergence of Taiwanese companies might be interrelated, as a number of US companies employ Taiwanese foundries for their manufacturing. For example, Invensense operates as a fully fabless company, with all the manufacturing done in Taiwan by TSMC.

In addition, Analog Devices also outsources the manufacturing of the electronic component (ASIC) of its accelerometer to TSMC.

The Taiwanese foundry giants TSMC and UMC are two examples of the successful development of the semiconductor industry in Taiwan, particularly of the foundry segment. These firms make the large majority of their sales in the mainstream semiconductor segments but are increasingly used by other companies for MEMS production because the large foundries are able to produce at low cost and in large volumes. The positive growth prospects of the MEMS segment have caught their attention, and both have been active in developing skills needed for mechanical sensor production in recent years. Other silicon foundries are also entering, or planning to enter, the MEMS segment. Germany-based Xfab has invested heavily in MEMS production capacities in recent years and has recorded positive growth figures in this segment. The competition from foundries in the mainstream semiconductor industry is expected to grow in the near future.

A possible future competitive threat for Europe is its low level of investments over the past decade in semiconductor production capacity. European companies have followed a strategy of prolonging the life of 150 mm and 200 mm fabs by using them for MEMS production. Investments in 300 mm fabs have been low compared to US and Asia. Europe currently has a very limited market share in the mainstream semiconductor segments, where production in most cases is done on 300 mm wafers and with advanced technology. On the other hand, MEMS production can be achieved competitively on 150 mm or 200 mm wafer fabs and without using the latest technology. However, with the on-going depreciation of the older

150 mm and 200 mm fabs and the expected move of the mainstream semiconductor industry to 450 mm technology, it is expected that within five to ten years all MEMS production will take place on 300 mm wafer fabs. Given that there is currently little 300 mm production technology in Europe, there is a risk that manufacturing of MEMS (and the associated value added and employment) will increasingly move out of Europe. Moreover, the increasing dependence on foreign countries for enabling technologies such as micro- and nanoelectronics may at some point also give rise to strategic concerns.

A study for the European Commission in 2012 suggests that Europe needs to take advantage of the shift to 450 mm production technology to catch up with its investment deficit in production capacity. Indeed, once the new 450 mm technology is installed, significant spare 300 mm capacity will become available in other regions, and it will not make economic sense for the EU to invest massively in 300 mm capacity. One of the proposed scenarios is to install 450 mm capacity initially to safeguard the current strong position in 'More than Moore' (including MEMS and the accelerometer) and later to expand the scope to more advanced technology for 'More Moore' (mainstream semiconductor) production. The investment costs will be so high that they will need to be spread over several years, which means that early commitment is needed.

5.5.2. The EU position in the value chain of the accelerometer

The analysis shows that EU companies have a solid position in the end-producers segment of the accelerometer market. The EU is represented by a relatively small group of large companies that have a strong base in the automotive market. These companies have also been able to take significant shares of the fast-growing consumer market. The strongest competition in the end-producers segment comes from US-based companies which consist of a mixture of well-established companies and some younger, more innovative companies. In the smaller design segment, only a few companies have been identified, all of which are located in the EU or the US. In the foundry segment the EU is also well represented, with four companies active in four different countries. Here the main competition comes from the US, Canada and Taiwan, where regular silicon foundries as well as MEMS foundries are increasingly used by producers.

EU companies perform well thanks to a strong background in the automotive industry, good R&D competence and – particularly in the case of the two large IDMs – a rapid understanding of the possibilities of new markets and the advantage of large-scale production. However, an important future competitive threat exists as investments in new (300 mm wafer) production capacity have been low in Europe in recent years. Currently this is not a problem for MEMS (accelerometer) production, but as the mainstream semiconductor industry migrates to 450 mm wafers, manufacturing of MEMS (accelerometers) will occur on 300 mm within five to ten years. Therefore there is a risk that manufacturing of these products will move to other regions, primarily Asia. For Europe it seems that the transition to 450 mm should be taken as an opportunity to safeguard its leading position in accelerometers, but also in MEMS as a whole.

Again, in the case of the accelerometer it has not been possible to calculate the value added captured by European firms in the value chain. For accelerometer producers however, market reports contain information on the market share of each company, providing insights into how different regions are performing in the accelerometer market. For companies focusing on specific parts of the value chain, information on the relevance of the accelerometer in their activities is typically more difficult to find since these activities are more remote from the end-product and is therefore not included in this chapter.

5.6. CONCLUSIONS AND POLICY IMPLICATIONS

The results of the analysis show that Europe holds varying positions in the different KETs. Asia is gaining ground as a main producer of new technological knowledge in KETs, thereby demonstrating fast market share gains.

Europe has a strong technological capacity, a substantial production base, is specialised in (mature) products with high technology content, but has to compete mainly on price. Moving to the higher end of the value chain is a real challenge.

Table 5.3. Overview of companies active along the value chain of the accelerometer

Region	Country	Company name	Total revenue 2011 (USD million)
Accelerometer producers			
EU	**Germany**	**Robert Bosch**	**70 539**
	Netherlands	**STMicroelectronics**	**9 735**
	Germany	**Infineon**	**5 479**
	France	**Sagem (Colibrys)[a]**	**16 438 (16)**
Non-EU	US	Freescale Semiconductor	4 572
	US	Analog Devices	2 993
	US	Invensense	96
	US	Honeywell	36 529
	US	MEMSIC	68
	US	Endevco	n.a.
	Japan	Denso	37 660
	Japan	Murata Electronics (VTI)[a]	7 130b (76c)
	Japan	Rohm Semiconductor (Kionix)	3 187 (n.a.)
Companies active in design			
EU	**France**	**Movea**	n.a.
Non-EU	US	A.M. Fitzgerald	n.a.
	US	Nanoshift	n.a.
	US	SVTC Technologies	n.a.
Companies active in manufacturing			
EU	**Sweden**	**Silex Microsystems**	**47**
	France	**Tronics**	**15.2**
	Germany	**Xfab**	n.a.
	UK	**Semefab**	n.a.
Non-EU	Norway	Sensonor	7.5
	Israel	TowerJazz	611
	US	Global Foundries	3 480
	US	Teledyne (Dalsa Semiconductor)[a]	1 941 (212c)
	US	IMT	24
	Canada	Micralyne	15
	Taiwan	Asia Pacific Microsystems	n.a.
	Taiwan	TSMC	12 914
	Taiwan	UMC	3 855
	Malaysia	MEMSTech	n.a.
	US/Japan	UT - SPP (Silicon Sensing Systems)[a]	n.a.

Source: IDEA Consult. Company turnover is based on corporate annual reports and company website information.
Notes: a= in case the relevant activities are performed by a specific subsidiary, this subsidiary is listed in parentheses behind the parent company; b= total revenue 2012; c= total revenue 2010; n.a. = not available

Looking at its position in the production and trade of KETs, Europe has both a strong technological capacity and a substantial production base in all KETs. Europe is, in contrast to emerging competitors from East Asia, specialised in key enabling technology products with high technology content. However, most of these products seem to be mature as they compete mostly on price, less on quality. There are, however, differences between and within KETs.

- **Industrial biotechnology: high and increasing technology content of exports, and a price advantage.** In industrial biotechnology, Europe specialises in products with high technology content, in other words products with higher quality or further along the production chain. During the past decade, Europe has been able to further strengthen its position. Despite Europe's technological advance, exports predominantly face price competition. However, Europe tends to have a price advantage in international trade in industrial biotechnology products which could point to a more efficient production. Patenting is a major driver for the technology content of industrial biotechnology products.

- **Nanotechnology: low and decreasing technology content of exports but with a price advantage.** In the nanotechnology sector, the EU position is less favourable. The technology content of most products is lower than in the two main competitor regions (North America and East Asia) and going down, indicating a specialisation in less complex products. EU exports in nanotechnology compete mainly on price and in most cases EU products enjoy a price advantage. Patenting is important to achieve high technology content but this effect is less pronounced in Europe than in North America and East Asia.

- **Micro- and nanoelectronics: low and decreasing technology content of exports with no price advantage.** The technology content of products is low and decreasing, accompanied by strong price competition for exports and no sign of a price advantage for Europe. To maintain high levels of technology content, patenting is extremely important, having an even stronger impact in Europe than in the other two regions. Patent activities in Europe have not been sufficient to improve its trade position, though.

- **Photonics: high and increasing technology content of exports and a price advantage.** In photonics, EU exports show high and increasing levels of technology content, which primarily face price competition. Most of its exports do not show a price advantage relative to competitors. The role of patenting is lower for the technology content of photonics products than for most other KETs. A conclusion could be that Europe is specialised in high-end products in photonics, while global markets are increasingly characterised by price erosion.

- **Advanced materials: high and increasing technology content of exports and a price advantage.** Advanced materials are in a similar position as industrial biotechnology products in Europe. The technology content is high and increasing for most of Europe's exports. International competition is driven by price competition and Europe can build on price advantages for most of its export products. Patenting is of secondary relevance for the technology content of products.

- **Advanced manufacturing for other KETs: Europe is leading; high technology content of exports; a clear quality advantage**. Advanced manufacturing for other KETs is the KET area in which Europe holds the most advanced position in production and trade. The technology content of exports is high, increasing and strongly based on patenting. Most of Europe's exports compete on quality and Europe holds quality advantages for most of its export products. Europe is the leading region in this KET, which is also confirmed by a high positive specialisation and a high positive trade balance.

The EU position in each of the key enabling technology value chains is summarised in Table 5.4.

A key challenge for European competitiveness policy is to bring **European industry onto a competitive path that rests firmly on more innovative and more complex products**. In many KETs this would mean a focus on more integrated technologies, including those which link several KETs. Such a product portfolio would imply a shift of competitive pressure towards quality competition. In such an environment, EU industry could better exploit its competitive advantages and create real value on several levels.

In order to achieve this, various approaches may be followed:

- Improving the links between producers of basic technological elements with producers of components and final products;

- Strengthening cross-fertilisation of technology developments across key enabling technologies;

- Fostering and reinforcing the development of clusters along value chains in key enabling technologies, including knowledge producers (such as universities and research institutes) and knowledge users.

Table 5.4. The position of the EU in the production and trade of KET-related products: summary overview

	Industrial biotechnology	Nano-technology	Micro-/nano-electronics	Photonics	Advanced materials	AMT for other KETs
Technology content of exports	high and increasing	low, mostly decreasing	low and decreasing	high and increasing	high and increasing	high and increasing
Type of competition	mostly price competition, price advantage	price competition, mostly with price advantage	price competition, no price advantage	price competition, no price advantage	price competition, mostly with price advantage	mostly quality competition, quality advantage
Impact of patenting	moderate	low	high	low	low	high

Source: ZEW and NIW

The strategy of moving European industry to the higher end of value chains could build on a strong base in each basic element within each key enabling technology. Policy should also consider the advantages of global cooperation in the development and deployment of new key enabling technologies and new applications. This could mean cooperation with specialised technology suppliers from other world regions. On the other hand, successful commercialisation of new applications often depends on cooperating with the right customers in those markets that set future trends ('lead markets'). It could be more beneficial for European industry to commercialise new key enabling technologies abroad – even if parts of the production will move to dynamic markets abroad – than to focus on European markets with less promising long-term prospects.

Moving to the higher end of the value chain is at the same time enormously complex and challenging. While monitoring the developments in the entire value chain, it is equally important to focus on promising segments and the position of the EU in the value chains of these segments. This is confirmed by the analysis of the two promising KETs products which have been analysed above.

Focusing on promising KET product segments: a starting point for moving up the value chain? On the basis of the analysis of the value chains of two products, lipase enzymes (industrial biotechnology) and the accelerometer (micro- and nanotechnology), a qualitative assessment has been made of the strength of the EU in these two selected value chains. Although precise figures on the value added captured by European companies are unavailable (due to confidentiality issues and the lack of insight into the share of a particular technology in the overall valued added of a company) the results show that **the EU is a key player in the area of lipase enzymes and the global enzyme market**. **Europe also has a solid position in the end-producers segment of the accelerometer**, as some EU companies have taken a significant share of the automotive and consumer electronics markets, two markets where accelerometers are applied. Competition is nevertheless strong, especially in the foundry segment.

It is interesting to note that although the general EU position in the entire micro- and nanotechnology value chain is weak, its position with respect to the accelerometer value chain is good. This suggests that, even if the overall position in a particular key enabling technology is not optimal, there may always be segments – existing or emerging – where the EU is in a good position and where active policy support can make a difference in the longer run. **It is important to observe and monitor these specific segments closely, for instance through the future KETs Observatory, and act in time in order to stay ahead of the competition. A focused and intensified policy in this respect might, in the long run, lead to Europe moving up the global key enabling technology value chains.**

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6.1. SECTORAL COMPETITIVENESS INDICATORS

6.1.1. Explanatory notes

Geographical coverage: all indicators refer to EU-27

Production index[144]: The production index is actually an index of final production in volume terms.

Labour productivity: this indicator is calculated by combining the indexes of production and number of persons employed or number of hours worked[145]. Therefore, this indicator measures final production per person of final production per hour worked.

Unit Labour Cost: it is calculated from the production index and the index of wages and salaries and measures labour cost per unit of production. “Wages and salaries” is defined (Eurostat) as “the total remuneration, in cash or in kind, payable to all persons counted on the payroll (including homeworkers), in return for work done during the accounting period, regardless of whether it is paid on the basis of working time, output or piecework and whether it is paid regularly wages and salaries do not include social contributions payable by the employer”.

Relative Trade Balance: it is calculated, for sector “i”, as (Xi-Mi)/(Xi+Mi), where Xi and Mi are EU-27 exports and imports of products of sector “i” to and from the rest of the World.

Revealed Comparative Advantage (RCA): The RCA indicator for product “i” is defined as follows:

$$RCA_i = \frac{\dfrac{X_{EU,i}}{\sum_i X_{EU,i}}}{\dfrac{X_{W,i}}{\sum_i xW,i}}$$

where: X=value of exports; the reference group (‘W’) is the EU-27 plus 109 other countries (see list below); the source used is the UN COMTRADE database. In the calculation of RCA, X_{EU} stands for exports to the rest of the world (excluding intra-EU trade) and X_W measures exports to the rest of the world by the countries in the reference group. The latter consists of the EU-27 plus the following countries: Albania, Algeria, Azerbaijan, Argentina, Australia, Bahamas, Bahrain, Armenia, Bermuda, Bhutan, Bolivia (Plurinational State of), Bosnia Herzegovina, Brazil, Belize, Belarus, Cambodia, Canada, Cape Verde, Central African Rep., Sri Lanka, Chile, China, Colombia, Costa Rica, Croatia, Dominican Rep., Ecuador, El Salvador, Ethiopia, French Polynesia, Georgia, Gambia, State of Palestine, Ghana, Greenland, Guatemala, Guyana, China, Hong Kong SAR, Iceland, Indonesia, Iran, Israel, Côte d'Ivoire, Japan, Kazakhstan, Jordan, Rep. of Korea, Kyrgyzstan, Lebanon, China, Macao SAR, Madagascar, Malawi, Malaysia, Maldives, Mauritania, Mauritius, Mexico, Other Asia, nes, Rep. of Moldova, Montenegro, Montserrat, Namibia, Nepal, Aruba, New Caledonia, New Zealand, Nicaragua, Niger, Nigeria, Norway, Pakistan, Panama, Paraguay, Peru, Qatar, Russian Federation, Rwanda, Saint Kitts and Nevis, Saint Vincent and the Grenadines, Saudi Arabia, Senegal, Serbia, India, Singapore, Viet Nam, South Africa, Zimbabwe, Suriname, Switzerland, Thailand, Togo, Tonga, United Arab Emirates, Tunisia, Turkey, Turks and Caicos Isds, Uganda, Ukraine, Former Yugoslav Republic of Macedonia, Egypt, United Rep. of Tanzania, US, Burkina Faso, Samoa, Yemen, Zambia.

Statistical nomenclatures: the indicators in Tables 6.1 to 6.6 are presented at the level of divisions of the statistical classification of economic activities in the European Community (NACE Rev.2[146]), while those in

[144] The data are working-day adjusted for production.
[145] The data are working-day adjusted for hours worked.
[146] Compared to the statistical annexes of the previous publications, the new activity classification is used: NACE REV 2. The correspondence tables from NACE Rev. 2 – NACE Rev. 1.1 and from NACE Rev. 1.1 to NACE Rev. 2, are available on: http://epp.eurostat.ec.europa.eu/portal/page/portal/nace_rev2/introductionhttp://epp.eurostat.ec.europa.eu/portal/page/portal/nace_rev2/introduction

Tables 6.7 to 6.9.2 are presented in terms of divisions of the statistical classification of products by activity (CPA).

Table 6.10 uses extended balance of payments services classification. In terms of data sources: Tables 6.1 to 6.6 are based on Eurostat's short-term indicators data. Tables 6.7, 6.8, 6.9 and 6.9.2 are based on United Nations' COMTRADE. Table 6.10 is based on IMF balance of Payments. Royalties and license fees were not included as it is not related to a special service activity.

Figure 6.1. EU-27 - Industry production index, annual growth rate (%)

Code (NACE Rev. 2)	Sector	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average 2007-2012
B	MINING AND QUARRYING	-2.8	0.5	-2.8	-1.9	-6.0	-3.8	-0.1	-3.6	-10.7	-0.3	-7.0	-5.8	-5.5
C	MANUFACTURING	0.1	-0.8	0.3	2.5	1.6	4.8	4.2	-1.9	-15.3	7.3	4.5	-2.2	-1.8
C10	Manufacture of food products	1.4	1.9	0.5	2.1	2.4	1.3	1.9	-0.5	-1.0	2.2	1.0	-0.7	0.2
C11	Manufacture of beverages	2.7	1.6	1.3	-2.3	0.9	3.7	1.2	-2.1	-3.2	-1.0	6.5	-2.8	-0.6
C12	Manufacture of tobacco products	-1.6	-2.1	-5.8	-11.4	-5.5	-4.7	1.5	-11.7	-0.7	-5.9	-6.2	-4.5	-5.9
C13	Manufacture of textiles	-2.9	-4.5	-3.4	-4.8	-5.9	-0.8	-1.1	-10.2	-18.0	7.8	-2.1	-6.0	-6.1
C14	Manufacture of wearing apparel	-4.7	-11.5	-7.3	-5.6	-10.4	-0.5	-0.6	-7.6	-14.0	-1.1	-4.1	-5.8	-6.6
C15	Manufacture of leather and related products	-5.7	-8.3	-6.8	-10.2	-9.0	-2.9	-5.7	-8.1	-14.1	2.1	5.4	-4.2	-4.0
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	-4.2	0.7	2.3	3.2	0.2	4.2	0.7	-9.1	-14.9	2.9	2.6	-4.3	-4.8
C17	Manufacture of paper and paper products	-2.0	3.4	1.4	2.9	-0.1	3.9	2.6	-3.2	-8.7	6.0	-1.1	-1.5	-1.8
C18	Printing and reproduction of recorded media	-1.9	-0.6	-1.2	1.4	2.4	0.2	0.7	-2.2	-7.9	-0.3	-0.5	-6.6	-3.6
C19	Manufacture of coke and refined petroleum products	-0.9	0.9	1.3	4.6	0.7	-0.9	0.4	1.0	-8.0	-2.0	-1.7	-1.9	-2.6
C20	Manufacture of chemicals and chemical products	-1.9	1.9	-0.1	3.3	2.0	3.4	2.9	-3.3	-12.5	10.3	1.3	-1.6	-1.4
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	10.9	8.6	5.0	-0.2	4.7	5.9	0.4	0.6	2.9	4.9	1.6	0.2	2.0
C22	Manufacture of rubber and plastic products	-0.3	0.0	1.9	1.8	0.9	3.9	4.5	-4.6	-13.9	7.3	3.8	-3.4	-2.4
C23	Manufacture of other non-metallic mineral products	-0.6	-1.7	0.3	1.7	0.5	4.2	1.8	-6.7	-19.4	1.9	3.2	-8.4	-6.2
C24	Manufacture of basic metals	-1.2	-0.4	0.2	4.9	-0.7	6.3	1.3	-3.6	-27.1	18.1	3.6	-5.1	-4.0
C25	Manufacture of fabricated metal products, except machinery and equipment	0.4	-0.6	0.9	2.6	1.5	4.8	6.1	-3.0	-22.6	6.9	7.2	-3.3	-3.6
C26	Manufacture of computer, electronic and optical products	-6.3	-10.2	0.5	6.4	2.8	9.0	7.6	0.7	-17.2	7.2	5.1	-2.0	-1.6
C27	Manufacture of electrical equipment	-0.7	-4.1	-1.6	2.3	0.9	8.4	4.3	-0.7	-21.0	11.4	4.3	-2.3	-2.3
C28	Manufacture of machinery and equipment n.e.c.	1.3	-1.8	-0.8	4.1	3.9	8.4	8.4	1.4	-26.8	10.6	11.5	0.5	-1.7
C29	Manufacture of motor vehicles, trailers and semi-trailers	1.6	0.7	1.6	4.5	1.4	3.3	6.1	-5.9	-25.1	21.6	12.1	-3.1	-1.4
C30	Manufacture of other transport equipment	1.2	-3.5	0.5	0.4	2.0	7.8	4.8	3.9	-5.7	-0.7	4.1	2.8	0.8
C31	Manufacture of furniture	-2.3	-5.1	-2.5	0.3	1.1	3.8	3.3	-5.0	-16.7	-1.0	2.0	-5.6	-5.5
C32	Other manufacturing	3.6	3.0	-2.2	1.2	0.9	5.3	1.7	-1.5	-6.9	8.2	3.1	0.0	0.5
C33	Repair and installation of machinery and equipment	0.3	-4.0	-2.0	4.5	1.1	7.9	4.5	3.7	-10.2	2.2	4.5	-1.5	-0.4
D	ELECTRICITY, GAS, STEAM AND AIR CONDITIONING SUPPLY	2.0	0.9	3.0	2.3	2.0	0.9	-0.7	-0.1	-4.5	4.1	-4.1	0.3	-0.9
E	WATER SUPPLY; SEWERAGE, WASTE MANAGEMENT AND REMEDIATION ACTIVITIES	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	CONSTRUCTION	1.1	0.3	1.7	0.7	2.8	3.4	2.7	-2.9	-7.5	-4.7	0.2	-5.2	-4.1

N/A: Data not available, Source: Eurostat

Figure 6.2. EU-27 - Number of persons employed, annual growth rate (%)

Code (NACE Rev. 2)	Sector	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average 2007-2012
B	**MINING AND QUARRYING**	-3.4	-4.6	-4.5	-4.6	-3.1	-3.8	-3.5	-1.5	-3.8	-4.1	-3.4	-1.4	-2.9
C	**MANUFACTURING**	0.0	-1.9	-2.0	-1.9	-1.3	-0.8	0.5	-0.3	-7.3	-3.7	0.6	-0.3	-2.2
C10	Manufacture of food products	-0.6	-0.9	-0.5	-1.2	0.1	-0.2	0.0	-0.1	-1.9	-0.5	0.5	-0.3	-0.5
C11	Manufacture of beverages	-1.8	-1.1	-1.8	-1.2	-1.3	-1.4	-0.1	-1.2	-6.4	-1.9	-1.5	-1.6	-2.5
C12	Manufacture of tobacco products	-4.2	-0.3	-5.0	-5.2	-2.1	0.1	-11.1	-9.9	-6.0	-6.8	-2.4	-4.9	-6.0
C13	Manufacture of textiles	-3.2	-5.0	-7.2	-6.3	-4.3	-5.9	-5.3	-6.3	-12.9	-5.9	-2.7	-2.4	-6.1
C14	Manufacture of wearing apparel	-3.1	-3.6	-3.9	-6.2	-7.7	-5.8	-5.9	-6.7	-13.1	-8.5	-1.8	-2.7	-6.6
C15	Manufacture of leather and related products	-1.2	-0.6	-4.4	-6.7	-5.6	-2.7	-3.7	-5.9	-12.5	-3.6	4.1	0.4	-3.7
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	-0.9	-1.5	-1.3	-1.4	-0.6	-1.3	0.6	-2.3	-12.6	-3.4	-0.1	-3.2	-4.4
C17	Manufacture of paper and paper products	-1.7	-0.7	-3.0	-1.6	-2.6	-2.6	-2.8	-2.2	-5.5	-2.3	-0.5	-1.9	-2.5
C18	Printing and reproduction of recorded media	-0.2	-2.1	-4.0	-1.9	-3.3	-1.6	-0.1	-2.3	-7.0	-4.8	-3.6	-3.6	-4.3
C19	Manufacture of coke and refined petroleum products	-1.9	-3.0	-3.2	-1.7	-2.9	-3.1	0.9	-0.7	-3.3	-2.8	-2.8	0.7	-1.8
C20	Manufacture of chemicals and chemical products	-0.8	-1.6	-2.6	-3.3	-2.2	-1.2	-0.6	-2.3	-4.5	-2.3	-0.2	-0.1	-1.9
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	1.8	2.2	-0.5	-2.4	-1.4	1.6	0.3	-2.5	-3.6	-1.0	-0.4	1.2	-1.3
C22	Manufacture of rubber and plastic products	1.0	-0.9	0.2	0.0	-0.8	-0.8	1.6	0.6	-7.0	-2.6	1.3	0.6	-1.5
C23	Manufacture of other non-metallic mineral products	-0.6	-2.3	-2.8	-2.1	-1.0	-0.7	1.2	-2.1	-10.7	-6.5	-1.9	-3.0	-4.9
C24	Manufacture of basic metals	-0.2	-4.0	-2.9	-4.2	-1.1	-1.0	-0.6	-0.6	-8.4	-5.4	1.0	-1.4	-3.0
C25	Manufacture of fabricated metal products, except machinery and equipment	1.0	-1.0	-1.1	0.2	-0.2	1.4	3.3	2.6	-8.4	-5.4	1.6	0.5	-1.9
C26	Manufacture of computer, electronic and optical products	1.9	-5.6	-4.4	-2.9	-1.3	-0.8	1.2	-1.8	-8.7	-3.9	1.2	-1.9	-3.1
C27	Manufacture of electrical equipment	0.5	-3.9	-4.1	-1.4	-0.6	0.9	2.5	1.1	-8.2	-2.0	3.3	0.5	-1.1
C28	Manufacture of machinery and equipment n.e.c.	1.0	-1.5	-2.2	-2.4	-0.9	0.7	3.0	1.9	-5.9	-5.0	2.7	1.9	-0.9
C29	Manufacture of motor vehicles, trailers and semi-trailers	1.7	-1.0	-0.4	0.2	-0.8	-1.0	-0.2	0.8	-8.9	-2.8	2.9	1.3	-1.4
C30	Manufacture of other transport equipment	0.0	-1.7	-2.7	-1.7	0.3	0.8	2.7	1.7	-1.5	-4.7	-0.3	1.0	-0.8
C31	Manufacture of furniture	0.5	-3.4	0.2	-2.6	-2.5	-1.3	0.3	-2.1	-9.6	-8.4	-1.7	-3.1	-5.0
C32	Other manufacturing	1.1	-1.6	-0.2	-1.0	-1.7	-0.5	0.3	-0.1	-3.1	-1.9	-0.9	0.8	-1.1
C33	Repair and installation of machinery and equipment	0.2	-2.3	-2.0	-0.5	-0.5	0.5	0.6	3.5	-1.8	-2.8	-1.4	1.0	-0.3
D	**ELECTRICITY, GAS, STEAM AND AIR CONDITIONING SUPPLY**	-2.7	-5.1	-4.9	-3.6	-2.4	-1.2	-1.6	-0.9	1.8	-0.2	0.4	-1.8	-0.1
E	**WATER SUPPLY; SEWERAGE, WASTE MANAGEMENT AND REMEDIATION ACTIVITIES**	-0.4	-0.3	0.5	-1.0	-1.8	1.9	0.7	-1.0	-0.3	-0.3	-0.3	1.1	-0.2
F	**CONSTRUCTION**	1.9	0.6	1.7	2.1	3.7	3.8	4.8	-0.3	-7.1	-5.5	-3.0	-3.9	-4.0

N/A: Data not available, Source: Eurostat

Figure 6.3. EU-27 - Number of hours worked, annual growth rate (%)

Code (NACE Rev. 2)	Sector	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average 2007-2012
B	**MINING AND QUARRYING**	-2.7	-4.7	-5.3	-3.8	-3.0	-4.8	-3.6	-1.3	-5.4	-2.5	-2.3	-0.1	-2.3
C	**MANUFACTURING**	-1.2	-2.4	-2.5	-1.4	-1.5	-0.1	0.1	-0.7	-9.6	-0.7	1.5	-0.7	-2.1
C10	Manufacture of food products	-1.1	-1.8	-2.0	-0.3	-0.5	-0.2	-0.5	0.2	-2.6	0.3	0.2	-0.7	-0.5
C11	Manufacture of beverages	-0.2	-3.5	-0.3	0.5	-2.9	-4.0	-1.2	-1.7	-4.6	-4.5	-0.3	-1.4	-2.5
C12	Manufacture of tobacco products	2.0	-2.3	-10.3	-1.9	-3.8	-8.7	-2.5	-10.6	-6.1	-4.1	-1.3	-1.2	-4.7
C13	Manufacture of textiles	-4.4	-5.6	-7.4	-7.2	-5.4	-5.7	-3.2	-5.7	-15.3	-0.6	-0.3	-1.4	-4.8
C14	Manufacture of wearing apparel	-3.5	-2.3	-3.1	-3.7	-4.1	-3.7	-5.8	-6.9	-15.3	-8.3	0.3	-3.1	-6.8
C15	Manufacture of leather and related products	-1.9	-0.6	-1.8	-2.6	-4.1	-0.9	-4.7	-7.1	-12.0	-0.6	3.9	0.4	-3.2
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	-3.3	-1.2	-1.9	-1.1	-2.2	-0.4	-0.3	-3.0	-13.6	0.1	0.2	-2.1	-3.8
C17	Manufacture of paper and paper products	-1.8	-0.4	-2.9	-1.9	-2.0	-0.9	-1.3	-4.1	-7.7	-0.5	0.2	-1.6	-2.8
C18	Printing and reproduction of recorded media	-1.2	-3.5	-4.4	-2.9	-2.3	-0.1	0.2	-2.0	-6.1	-3.7	-2.4	-5.1	-3.9
C19	Manufacture of coke and refined petroleum products	-1.9	-3.9	-2.1	-0.4	0.0	-3.7	0.4	2.0	-9.0	-2.2	-1.8	1.0	-2.1
C20	Manufacture of chemicals and chemical products	-2.3	-2.2	-2.7	-2.0	-3.2	-0.9	-1.6	-1.9	-5.5	-1.5	0.8	0.8	-1.5
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.4	1.9	-0.2	-0.7	-1.6	0.0	0.9	0.0	-1.9	-0.8	-0.1	1.8	-0.2
C22	Manufacture of rubber and plastic products	-0.3	-1.8	-1.5	-0.2	-1.4	1.6	0.6	-0.4	-9.4	0.9	2.2	0.3	-1.4
C23	Manufacture of other non-metallic mineral products	-2.6	-3.3	-3.2	-1.3	-1.0	-0.5	0.4	-2.7	-12.4	-2.4	-0.4	-3.5	-4.4
C24	Manufacture of basic metals	-1.6	-3.2	-4.7	-2.1	-2.1	0.0	-0.5	-0.9	-13.1	1.8	2.6	-2.1	-2.5
C25	Manufacture of fabricated metal products, except machinery and equipment	-0.5	-1.3	-2.0	-0.3	-1.0	1.7	2.2	2.9	-11.7	-0.7	1.9	0.4	-1.6
C26	Manufacture of computer, electronic and optical products	-0.3	-5.0	-4.4	-2.9	-1.5	-0.7	0.3	-1.0	-12.2	-2.4	-0.1	-1.7	-3.6
C27	Manufacture of electrical equipment	-1.2	-2.9	-3.8	-1.6	-1.9	2.5	1.7	0.6	-13.4	3.4	3.3	-1.2	-1.7
C28	Manufacture of machinery and equipment n.e.c.	-0.6	-2.3	-2.2	-1.2	-1.3	1.5	2.5	1.7	-11.2	-0.2	4.3	0.7	-1.1
C29	Manufacture of motor vehicles, trailers and semi-trailers	0.4	-1.8	-0.9	0.4	-0.3	-0.6	0.8	-1.4	-14.2	4.1	4.5	-0.2	-1.7
C30	Manufacture of other transport equipment	-1.4	-2.0	-1.8	-2.3	-0.4	1.0	0.9	1.3	-1.9	-3.8	-0.4	2.1	-0.6
C31	Manufacture of furniture	0.7	-4.6	-3.3	-0.5	-3.4	0.8	0.3	-2.9	-11.9	-5.5	-0.8	-2.8	-4.9
C32	Other manufacturing	0.2	-3.2	-2.5	0.3	-2.8	-0.8	0.6	0.4	-5.7	0.2	2.4	1.5	-0.3
C33	Repair and installation of machinery and equipment	-1.5	-3.0	-3.4	-2.7	0.0	0.9	0.6	1.6	0.1	-3.7	-0.1	0.6	-0.3
D	**ELECTRICITY, GAS, STEAM AND AIR CONDITIONING SUPPLY**	-1.8	-4.9	-4.6	-2.0	-0.3	-1.4	-1.0	-0.1	-0.9	-0.5	1.2	-2.7	-0.6
E	**WATER SUPPLY; SEWERAGE, WASTE MANAGEMENT AND REMEDIATION ACTIVITIES**	-1.2	-1.4	-0.9	1.2	-2.2	-0.2	0.2	0.7	-2.8	0.5	0.3	1.6	0.0
F	**CONSTRUCTION**	0.6	-1.7	0.7	1.0	7.2	2.9	2.7	-1.3	-9.3	-7.2	-0.8	-1.7	-4.1

N/A: Data not available, Source: Eurostat

igure 6.4. EU-27 - Labour productivity per person employed, annual growth rate (%)

Code (NACE Rev. 2)	Sector	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average 2007-2012
B	**MINING AND QUARRYING**	0.6	5.4	1.8	2.8	-3.0	0.0	3.5	-2.1	-7.1	4.0	-3.7	-4.4	-2.7
C	**MANUFACTURING**	0.1	1.2	2.3	4.5	3.0	5.6	3.7	-1.6	-8.7	11.4	3.9	-1.9	0.4
C10	Manufacture of food products	2.0	2.8	1.0	3.3	2.3	1.5	1.9	-0.4	0.9	2.7	0.5	-0.4	0.7
C11	Manufacture of beverages	4.6	2.7	3.2	-1.2	2.3	5.2	1.3	-0.9	3.5	1.0	8.1	-1.3	2.0
C12	Manufacture of tobacco products	2.7	-1.8	-0.8	-6.6	-3.5	-4.8	14.1	-2.0	5.7	1.0	-3.9	0.4	0.2
C13	Manufacture of textiles	0.3	0.5	4.1	1.6	-1.7	5.4	4.5	-4.1	-5.8	14.5	0.6	-3.7	0.0
C14	Manufacture of wearing apparel	-1.7	-8.2	-3.5	0.6	-2.9	5.7	5.6	-1.0	-1.0	8.1	-2.4	-3.2	0.0
C15	Manufacture of leather and related products	-4.5	-7.8	-2.5	-3.7	-3.7	-0.2	-2.1	-2.3	-1.8	6.0	1.2	-4.6	-0.4
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	-3.3	2.2	3.7	4.7	0.8	5.6	0.1	-7.0	-2.7	6.5	2.7	-1.2	-0.4
C17	Manufacture of paper and paper products	-0.3	4.1	4.5	4.6	2.6	6.6	5.5	-1.0	-3.4	8.5	-0.6	0.4	0.7
C18	Printing and reproduction of recorded media	-1.8	1.5	2.9	3.3	5.8	1.9	0.8	0.1	-0.9	4.7	3.2	-3.1	0.7
C19	Manufacture of coke and refined petroleum products	1.0	4.0	4.7	6.4	3.7	2.2	-0.5	1.7	-4.9	0.8	1.1	-2.6	-0.8
C20	Manufacture of chemicals and chemical products	-1.1	3.6	2.6	6.8	4.2	4.7	3.5	-1.1	-8.4	12.9	1.5	-1.5	0.5
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	8.9	6.3	5.5	2.3	6.2	4.2	0.1	3.2	6.7	6.0	2.0	-1.0	3.3
C22	Manufacture of rubber and plastic products	-1.3	0.9	1.7	1.8	1.7	4.7	2.9	-5.2	-7.4	10.1	2.5	-4.0	-1.0
C23	Manufacture of other non-metallic mineral products	0.0	0.6	3.2	3.9	1.5	4.9	0.6	-4.7	-9.7	9.0	5.2	-5.6	-1.4
C24	Manufacture of basic metals	-1.0	3.7	3.2	9.5	0.4	7.4	1.9	-3.0	-20.5	24.8	2.6	-3.8	-1.0
C25	Manufacture of fabricated metal products, except machinery and equipment	-0.6	0.4	2.0	2.4	1.7	3.4	2.7	-5.5	-15.5	13.0	5.5	-3.8	-1.7
C26	Manufacture of computer, electronic and optical products	-8.1	-4.8	5.2	9.6	4.2	9.8	6.3	2.6	-9.3	11.5	3.8	-0.1	1.5
C27	Manufacture of electrical equipment	-1.2	-0.2	2.6	3.7	1.5	7.4	1.8	-1.8	-14.0	13.7	1.0	-2.8	-1.2
C28	Manufacture of machinery and equipment n.e.c.	0.2	-0.3	1.5	6.7	4.8	7.6	5.3	-0.5	-22.2	16.4	8.5	-1.4	-0.7
C29	Manufacture of motor vehicles, trailers and semi-trailers	-0.1	1.7	2.0	4.3	2.2	4.3	6.4	-6.7	-17.8	25.1	8.9	-4.4	0.0
C30	Manufacture of other transport equipment	1.2	-1.8	3.3	2.1	1.7	7.0	2.0	2.2	-4.3	4.2	4.4	1.7	1.6
C31	Manufacture of furniture	-2.7	-1.7	-2.6	3.0	3.7	5.1	3.0	-3.0	-7.8	8.1	3.7	-2.5	-0.5
C32	Other manufacturing	2.4	4.7	-2.0	2.2	2.7	5.8	1.4	-1.4	-3.9	10.3	4.0	-0.8	1.5
C33	Repair and installation of machinery and equipment	0.1	-1.7	0.0	5.0	1.6	7.4	3.8	0.2	-8.6	5.1	5.9	-2.4	-0.1
D	**ELECTRICITY, GAS, STEAM AND AIR CONDITIONING SUPPLY**	4.8	6.3	8.3	6.1	4.5	2.1	0.9	0.8	-6.2	4.3	-4.5	2.1	-0.8
E	**WATER SUPPLY; SEWERAGE, WASTE MANAGEMENT AND REMEDIATION ACTIVITIES**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	**CONSTRUCTION**	-0.8	-0.3	0.0	-1.4	-0.9	-0.4	-2.0	-2.6	-0.4	0.8	3.3	-1.4	-0.1

/A: Data not available, Source: Eurostat

Figure 6.5. EU-27 - Labour productivity per hour worked, annual growth rate (%)

Code (NACE Rev. 2)	Sector	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average 2007-2012
B	**MINING AND QUARRYING**	-0.1	5.4	2.6	2.0	-3.1	1.0	3.7	-2.3	-5.6	2.2	-4.8	-5.7	-3.3
C	**MANUFACTURING**	1.3	1.6	2.9	3.9	3.2	4.9	4.1	-1.2	-6.3	8.0	3.0	-1.5	0.3
C10	Manufacture of food products	2.5	3.8	2.6	2.4	2.9	1.5	2.4	-0.7	1.6	1.9	0.8	0.0	0.7
C11	Manufacture of beverages	2.9	5.3	1.6	-2.8	3.9	8.0	2.4	-0.4	1.5	3.7	6.8	-1.4	2.0
C12	Manufacture of tobacco products	-3.6	0.2	5.0	-9.7	-1.8	4.3	4.1	-1.2	5.7	-1.9	-4.9	-3.3	-1.2
C13	Manufacture of textiles	1.6	1.1	4.3	2.5	-0.6	5.2	2.2	-4.8	-3.2	8.5	-1.8	-4.7	-1.3
C14	Manufacture of wearing apparel	-1.2	-9.4	-4.3	-2.0	-6.5	3.3	5.5	-0.7	1.5	7.8	-4.4	-2.8	0.2
C15	Manufacture of leather and related products	-3.8	-7.7	-5.1	-7.8	-5.1	-2.0	-1.1	-1.1	-2.4	2.7	1.4	-4.6	-0.8
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	-0.9	1.9	4.2	4.4	2.4	4.6	1.0	-6.3	-1.5	2.8	2.4	-2.3	-1.0
C17	Manufacture of paper and paper products	-0.2	3.8	4.4	4.9	2.0	4.8	3.9	0.9	-1.0	6.6	-1.3	0.1	1.0
C18	Printing and reproduction of recorded media	-0.7	3.1	3.3	4.5	4.8	0.3	0.5	-0.2	-1.9	3.5	1.9	-1.6	0.3
C19	Manufacture of coke and refined petroleum products	1.0	4.9	3.5	5.0	0.7	2.9	0.0	-0.9	1.1	0.2	0.1	-2.9	-0.5
C20	Manufacture of chemicals and chemical products	0.5	4.2	2.7	5.5	5.4	4.4	4.6	-1.4	-7.4	12.0	0.5	-2.4	0.0
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	10.4	6.5	5.2	0.5	6.4	5.9	-0.5	0.6	4.8	5.8	1.7	-1.6	2.3
C22	Manufacture of rubber and plastic products	0.0	1.9	3.5	2.0	2.3	2.2	3.9	-4.2	-5.0	6.4	1.6	-3.7	-1.1
C23	Manufacture of other non-metallic mineral products	2.1	1.7	3.6	3.1	1.5	4.7	1.4	-4.1	-8.0	4.4	3.6	-5.1	-1.9
C24	Manufacture of basic metals	0.4	2.8	5.2	7.2	1.4	6.3	1.9	-2.8	-16.1	16.0	1.0	-3.1	-1.5
C25	Manufacture of fabricated metal products, except machinery and equipment	0.9	0.7	3.0	2.9	2.5	3.1	3.8	-5.7	-12.4	7.6	5.2	-3.7	-2.1
C26	Manufacture of computer, electronic and optical products	-6.0	-5.4	5.1	9.5	4.4	9.7	7.3	1.7	-5.7	9.9	5.2	-0.4	2.0
C27	Manufacture of electrical equipment	0.5	-1.3	2.3	3.9	2.9	5.8	2.6	-1.3	-8.8	7.7	1.0	-1.1	-0.6
C28	Manufacture of machinery and equipment n.e.c.	1.9	0.6	1.4	5.3	5.3	6.8	5.8	-0.3	-17.5	10.9	7.0	-0.2	-0.5
C29	Manufacture of motor vehicles, trailers and semi-trailers	1.2	2.5	2.6	4.1	1.7	3.9	5.3	-4.6	-12.7	16.8	7.3	-2.9	0.3
C30	Manufacture of other transport equipment	2.7	-1.6	2.4	2.8	2.4	6.7	3.8	2.5	-3.9	3.3	4.6	0.7	1.4
C31	Manufacture of furniture	-3.0	-0.5	0.8	0.8	4.6	3.0	3.0	-2.2	-5.4	4.8	2.8	-2.9	-0.7
C32	Other manufacturing	3.4	6.4	0.3	0.9	3.8	6.2	1.0	-1.8	-1.3	8.0	0.7	-1.5	0.7
C33	Repair and installation of machinery and equipment	1.9	-1.1	1.4	7.4	1.1	6.9	3.9	2.1	-10.3	6.2	4.6	-2.1	-0.1
D	**ELECTRICITY, GAS, STEAM AND AIR CONDITIONING SUPPLY**	3.8	6.1	8.0	4.3	2.3	2.4	0.3	0.0	-3.6	4.6	-5.2	3.1	-0.3
E	**WATER SUPPLY; SEWERAGE, WASTE MANAGEMENT AND REMEDIATION ACTIVITIES**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	**CONSTRUCTION**	0.5	2.0	1.0	-0.3	-4.1	0.5	0.0	-1.6	2.0	2.7	1.0	-3.6	0.1

N/A: Data not available, Source: Eurostat.

Figure 6.6. EU-27 - Unit labour cost, annual growth rate (%)

Code (NACE Rev. 2)	Sector	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average 2007-2012
B	**MINING AND QUARRYING**	7.1	-0.7	6.4	4.2	-0.4	7.4	4.8	10.7	11.7	1.6	10.2	9.1	8.6
C	**MANUFACTURING**	3.0	1.7	0.3	-1.2	-0.5	-2.2	-0.1	6.0	10.6	-6.4	-0.6	4.5	2.7
C10	Manufacture of food products	2.1	0.9	2.1	-0.7	-0.7	0.4	1.4	4.9	1.2	-0.2	0.5	2.3	1.7
C11	Manufacture of beverages	1.3	-1.1	2.8	3.5	-1.2	-3.8	1.0	4.5	2.2	-0.7	-4.0	3.1	1.0
C12	Manufacture of tobacco products	5.2	2.2	5.8	19.1	6.8	2.2	-1.7	9.2	-3.1	0.9	1.3	4.2	2.4
C13	Manufacture of textiles	2.0	3.0	0.5	0.8	2.9	-2.3	0.4	9.6	6.3	-8.7	2.2	5.2	2.7
C14	Manufacture of wearing apparel	1.6	10.8	4.1	2.1	5.4	-0.9	2.1	8.2	4.9	-3.9	4.7	4.4	3.6
C15	Manufacture of leather and related products	9.8	8.2	4.1	8.1	5.7	5.8	9.2	10.9	5.5	-0.2	0.6	8.6	5.0
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	5.2	-1.4	-1.9	-0.6	0.7	-0.3	5.0	12.0	5.5	-3.9	-0.4	1.6	2.8
C17	Manufacture of paper and paper products	4.9	-2.5	-1.5	-1.5	0.7	-3.5	-1.3	3.6	3.8	-5.0	2.2	1.7	1.2
C18	Printing and reproduction of recorded media	4.8	0.3	-1.6	-1.5	-2.3	-0.5	0.4	4.2	2.4	-4.6	-2.5	3.0	0.4
C19	Manufacture of coke and refined petroleum products	1.7	4.8	-4.4	-0.5	2.2	3.8	2.2	5.1	6.4	3.5	3.2	4.0	4.4
C20	Manufacture of chemicals and chemical products	3.8	-1.1	1.7	-3.4	-0.9	-3.5	0.0	5.4	11.2	-9.1	4.5	3.7	2.9
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	-6.1	-2.6	-0.1	1.6	-2.6	-2.7	5.7	-0.1	-2.5	-3.6	0.2	4.1	-0.4
C22	Manufacture of rubber and plastic products	3.3	1.3	-0.1	0.6	0.1	-2.3	-0.6	7.7	8.3	-4.8	0.9	5.9	3.5
C23	Manufacture of other non-metallic mineral products	2.0	2.7	0.4	-0.8	0.5	-1.7	2.8	9.2	13.1	-3.0	-2.6	7.3	4.6
C24	Manufacture of basic metals	-2.6	-0.8	-0.2	-3.6	3.1	-3.0	2.9	7.2	23.7	-13.8	1.4	6.4	4.3
C25	Manufacture of fabricated metal products, except machinery and equipment	4.2	1.8	-0.2	0.0	0.1	-0.9	0.9	10.5	16.1	-6.5	-2.6	5.9	4.3
C26	Manufacture of computer, electronic and optical products	12.9	7.9	-4.7	-6.4	-2.6	-7.6	-4.1	1.7	11.3	-8.1	-2.7	4.4	1.1
C27	Manufacture of electrical equipment	3.4	3.3	-0.5	-0.5	-0.4	-4.2	1.2	5.8	12.6	-8.4	2.3	4.5	3.1
C28	Manufacture of machinery and equipment n.e.c.	3.1	2.5	1.7	-1.9	-2.5	-3.7	-1.5	4.3	27.9	-8.9	-3.6	3.9	4.0
C29	Manufacture of motor vehicles, trailers and semi-trailers	1.7	1.0	0.9	-2.1	0.2	-0.1	-5.2	9.2	17.6	-15.5	-3.5	7.3	2.4
C30	Manufacture of other transport equipment	3.4	7.7	1.5	-1.2	1.0	-4.1	0.1	2.4	8.1	2.1	-1.2	3.8	3.0
C31	Manufacture of furniture	6.0	4.7	-0.7	-0.9	-0.7	-0.8	0.3	7.4	10.5	-3.6	-2.5	4.4	3.1
C32	Other manufacturing	1.0	-1.2	3.3	1.1	-1.3	-3.0	4.2	3.7	4.4	-5.5	0.6	2.9	1.2
C33	Repair and installation of machinery and equipment	4.6	5.2	1.9	-2.7	1.6	-4.5	-0.2	3.8	14.0	-5.7	-3.9	4.1	2.2
D	**ELECTRICITY, GAS, STEAM AND AIR CONDITIONING SUPPLY**	0.6	1.6	-1.7	-1.4	0.0	4.0	4.9	4.5	8.4	-1.7	6.1	1.5	3.7
E	**WATER SUPPLY; SEWERAGE, WASTE MANAGEMENT AND REMEDIATION ACTIVITIES**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	**CONSTRUCTION**	7.2	5.8	2.6	3.5	9.3	3.0	6.5	6.7	0.4	-1.3	1.0	4.4	2.2

N/A: Data not available, Source: Eurostat

Figure 6.7. EU-27 - Revealed comparative advantage index

Code (NACE Rev. 2)	Sector	2007	2008	2009	2010	2011
C10	Manufacture of food products	1.20	1.12	1.10	1.09	1.06
C11	Manufacture of beverages	1.61	1.59	1.61	1.70	1.72
C12	Manufacture of tobacco products	1.52	1.56	1.61	1.67	1.72
C13	Manufacture of textiles	0.81	0.76	0.69	0.67	0.66
C14	Manufacture of wearing apparel	0.76	0.76	0.76	0.74	0.75
C15	Manufacture of leather and related products	0.96	0.91	0.91	0.87	0.91
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	1.15	1.18	1.18	1.16	1.15
C17	Manufacture of paper and paper products	1.28	1.30	1.35	1.35	1.34
C18	Printing and reproduction of recorded media	1.20	1.62	1.79	1.88	1.87
C19	Manufacture of coke and refined petroleum products	0.84	0.84	0.77	0.79	0.78
C20	Manufacture of chemicals and chemical products	1.13	1.13	1.16	1.16	1.13
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	1.47	1.53	1.54	1.65	1.62
C22	Manufacture of rubber and plastic products	1.18	1.21	1.18	1.19	1.19
C23	Manufacture of other non-metallic mineral products	1.22	1.19	1.18	1.15	1.13
C24	Manufacture of basic metals	0.92	0.88	0.82	0.85	0.86
C25	Manufacture of fabricated metal products, except machinery and equipment	1.18	1.19	1.16	1.20	1.20
C26	Manufacture of computer, electronic and optical products	0.60	0.60	0.57	0.57	0.58
C27	Manufacture of electrical equipment	0.98	0.99	0.98	0.97	0.99
C28	Manufacture of machineryand equipment n.e.c.	1.14	1.18	1.18	1.17	1.18
C29	Manufacture of motor vehicles, trailers and semi-trailers	1.22	1.22	1.30	1.28	1.32
C30	Manufacture of other transport equipment	0.85	0.88	1.15	1.21	1.15
C31	Manufacture of furniture	1.27	1.24	1.20	1.13	1.15
C32	Other manufacturing	0.80	0.78	0.75	0.77	0.72

Note: there was a transition from NACE REV 1 to NACE REV 2, therefore the data are only available from 2007
Source: own calculations using Comtrade data

Figure 6.8. EU-27 - Relative trade balance (X-M)/(X+M)

Code (NACE Rev. 2)	Sector	2007	2008	2009	2010	2011
C10	Manufacture of food products	-0.03	-0.03	-0.02	-0.01	-0.01
C11	Manufacture of beverages	0.21	0.20	0.20	0.22	0.24
C12	Manufacture of tobacco products	0.03	0.06	0.06	0.05	0.08
C13	Manufacture of textiles	0.00	-0.01	-0.02	-0.02	-0.03
C14	Manufacture of wearing apparel	-0.19	-0.19	-0.21	-0.22	-0.21
C15	Manufacture of leather and related products	-0.07	-0.07	-0.08	-0.08	-0.06
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	0.00	0.02	0.04	0.03	0.04
C17	Manufacture of paper and paper products	0.04	0.04	0.06	0.06	0.06
C18	Printing and reproduction of recorded media	0.08	0.05	0.04	0.08	0.09
C19	Manufacture of coke and refined petroleum products	-0.03	-0.01	-0.05	-0.05	-0.05
C20	Manufacture of chemicals and chemical products	0.03	0.03	0.06	0.04	0.03
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.07	0.08	0.08	0.10	0.10
C22	Manufacture of rubber and plastic products	0.04	0.04	0.04	0.05	0.05
C23	Manufacture of other non-metallic mineral products	0.08	0.08	0.09	0.08	0.08
C24	Manufacture of basic metals	-0.06	-0.03	0.01	-0.01	0.00
C25	Manufacture of fabricated metal products, except machinery and equipment	0.09	0.09	0.10	0.10	0.10
C26	Manufacture of computer, electronic and optical products	-0.11	-0.11	-0.11	-0.13	-0.10
C27	Manufacture of electrical equipment	0.07	0.08	0.08	0.07	0.07
C28	Manufacture of machineryand equipment n.e.c.	0.16	0.17	0.20	0.19	0.19
C29	Manufacture of motor vehicles, trailers and semi-trailers	0.06	0.08	0.08	0.12	0.13
C30	Manufacture of other transport equipment	0.13	0.11	0.11	0.10	0.14
C31	Manufacture of furniture	0.04	0.04	0.03	0.02	0.05
C32	Other manufacturing	-0.04	-0.04	-0.04	-0.02	-0.02

Note: there was a transition from NACE REV 1 to NACE REV 2, therefore the data are only available from 2007
Source: own calculations using Comtrade data

Figure 6.9.1. Revealed comparative advantage index in manufacturing industries in 2011 - EU countries, Japan and Brazil, China, India and Russia.

	Food	Bevarages	Tobacco	Textiles	Clothing	Leather & footwear	Wood & wood products	Paper	Printing	Refined petroleum	Chemicals	Pharma-ceuticals	Rubber & plastics	Non-metallic mineral products	Basic metals	Metal products	Computers, electronic & optical	Electrical equipment	Machinery	Motor vehicles	Other transport	Furniture	Other manufacturing
	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	C30	C31	C32
Austria	0.87	2.24	0.28	0.68	0.55	0.70	4.49	2.19	1.30	0.24	0.47	1.52	1.30	1.36	1.34	2.16	0.43	1.35	1.40	1.34	0.70	1.19	0.71
Belgium	1.28	1.00	1.10	0.78	0.72	0.93	0.85	0.92	7.34	1.21	2.20	3.17	1.00	1.06	1.11	0.68	0.22	0.42	0.70	1.09	0.16	0.49	1.26
Bulgaria	1.31	0.81	4.94	1.14	2.87	1.18	1.63	0.76	0.22	1.55	0.55	0.90	0.92	2.20	2.83	0.86	0.27	1.11	0.93	0.36	0.24	1.31	0.35
Cyprus	2.16	1.22	27.96	0.13	0.32	0.82	0.20	0.34	0.00	0.00	0.97	7.44	0.30	0.34	0.78	0.68	0.72	0.71	0.41	0.27	1.15	0.47	1.20
Czech Rep.	0.44	0.57	1.57	0.88	0.31	0.46	1.42	0.94	1.74	0.20	0.53	0.32	1.67	1.63	0.64	2.14	1.11	1.66	1.16	2.00	0.39	1.52	0.73
Denmark	3.05	1.29	1.34	0.68	1.75	0.77	1.00	0.69	0.84	0.67	0.64	1.65	1.09	0.97	0.34	1.69	0.56	0.95	1.56	0.34	0.79	2.51	0.84
Estonia	1.00	2.10	0.20	1.17	1.04	0.86	7.71	0.83	0.73	2.33	0.64	0.10	1.29	1.38	0.49	1.79	0.95	1.40	0.75	0.61	0.24	2.74	0.53
Finland	0.35	0.49	0.04	0.26	0.19	0.25	5.28	9.87	0.74	1.60	0.85	0.62	0.92	0.77	1.66	1.04	0.47	1.32	1.46	0.27	0.37	0.23	0.46
France	1.18	4.63	0.59	0.54	0.70	1.18	0.63	1.03	1.80	0.51	1.30	1.70	1.10	0.99	0.75	0.90	0.48	0.88	0.87	1.15	3.97	0.52	0.76
Germany	0.74	0.65	2.05	0.53	0.50	0.39	0.81	1.20	2.49	0.21	1.00	1.34	1.29	1.02	0.76	1.31	0.58	1.22	1.60	1.91	1.30	0.85	0.57
Greece	2.16	1.52	4.89	1.08	1.47	0.55	0.55	0.58	1.14	4.56	0.71	1.26	0.98	1.33	1.93	0.84	0.22	0.65	0.29	0.09	0.50	0.31	0.32
Hungary	0.85	0.40	0.62	0.35	0.27	0.50	0.74	0.88	0.08	0.42	0.58	1.11	1.44	1.18	0.33	0.80	1.68	1.89	0.86	1.78	0.17	1.00	0.27
Ireland	1.44	1.76	0.53	0.10	0.15	0.09	0.41	0.11	0.00	0.23	2.85	9.43	0.32	0.22	0.08	0.28	0.65	0.24	0.31	0.03	0.41	0.09	1.49
Italy	0.87	2.30	0.03	1.35	1.58	3.09	0.53	1.03	0.98	0.70	0.70	1.10	1.35	1.90	1.09	1.68	0.23	1.05	1.82	0.73	0.75	2.38	0.95
Latvia	1.48	6.43	1.67	0.99	1.07	0.32	19.91	0.95	1.92	0.96	0.55	1.17	0.98	2.04	1.26	1.55	0.50	0.63	0.48	0.73	0.32	2.31	0.40
Lithuania	1.64	1.58	7.16	0.94	1.22	0.34	3.42	1.08	0.23	4.21	1.32	0.39	1.05	0.86	0.20	0.98	0.24	0.51	0.56	0.78	0.21	5.67	0.40
Luxembourg	0.89	1.02	6.08	2.17	0.32	0.45	2.24	1.79	0.01	0.01	0.49	0.15	4.16	2.51	3.86	1.20	0.28	0.74	0.74	0.63	1.09	0.12	0.21
Malta	0.53	0.31	0.69	1.05	0.10	0.12	0.01	0.02	0.93	4.67	0.13	2.04	1.12	0.33	0.05	0.23	1.87	0.92	0.24	0.03	1.64	0.08	1.78
Netherlands	1.94	1.29	5.35	0.45	0.61	0.66	0.31	0.86	0.29	2.02	1.62	0.95	0.79	0.49	0.61	0.79	1.05	0.54	1.07	0.39	0.32	0.40	0.80
Poland	1.46	0.45	4.79	0.60	0.71	0.41	2.33	1.66	0.54	0.59	0.76	0.32	1.85	1.61	0.92	1.79	0.60	1.35	0.57	1.64	1.29	5.03	0.27
Portugal	1.12	3.70	4.25	1.86	2.15	3.08	4.15	3.22	0.77	0.60	0.76	0.46	1.85	3.19	0.69	1.77	0.32	1.01	0.43	1.46	0.19	2.80	0.28
Romania	0.49	0.28	5.73	1.04	2.18	2.40	4.18	0.31	1.90	0.85	0.53	0.47	1.61	0.54	0.98	1.12	0.61	1.48	0.77	1.82	0.91	3.61	0.23
Slovakia	0.50	0.47	0.00	0.35	0.57	1.38	1.19	1.07	0.40	0.82	0.45	0.17	1.53	1.09	1.05	1.56	1.22	1.01	0.74	2.49	0.17	1.52	0.27
Slovenia	0.51	0.59	0.00	0.80	0.37	0.61	2.93	1.87	0.27	0.45	0.86	2.54	1.84	1.59	1.02	2.07	0.22	2.28	0.95	1.46	0.19	2.78	0.46
Spain	1.55	2.27	0.46	0.76	1.21	1.19	0.82	1.43	0.51	0.79	1.09	1.28	1.26	2.10	1.06	1.25	0.17	0.95	0.65	2.17	1.15	0.73	0.36
Sweden	0.49	0.84	0.28	0.29	0.36	0.21	3.54	5.49	0.22	1.06	0.67	1.37	0.85	0.60	1.11	1.11	0.82	1.01	1.25	1.34	0.31	1.55	0.43
United Kingdom	0.67	3.99	0.60	0.50	0.63	0.48	0.18	0.66	1.88	1.27	1.17	2.51	0.92	0.72	0.80	0.73	0.65	0.72	1.11	1.30	1.61	0.42	1.01
EU-27	1.06	1.72	1.72	0.66	0.75	0.91	1.15	1.34	1.87	0.78	1.13	1.62	1.19	1.13	0.86	1.20	0.58	0.99	1.18	1.32	1.15	1.15	0.72
USA	0.88	0.76	0.24	0.52	0.15	0.20	0.61	1.19	0.56	1.29	1.41	0.99	0.97	0.73	0.72	0.89	1.00	0.86	1.36	1.04	0.41	0.48	1.52
Japan	0.07	0.06	0.08	0.43	0.02	0.02	0.02	0.26	0.18	0.32	0.94	0.17	1.09	1.04	1.11	0.73	1.08	1.09	2.09	2.01	1.35	0.14	0.45
Brazil	5.17	0.11	0.47	0.37	0.04	1.74	1.73	2.99	0.34	0.38	0.94	0.39	0.72	0.98	1.75	0.73	0.10	0.43	0.82	1.04	1.42	0.52	0.17
China	0.37	0.09	0.15	2.54	2.72	2.52	0.93	0.43	0.23	0.21	0.53	0.23	1.00	1.53	0.53	1.34	1.88	1.47	0.74	0.28	0.86	2.12	1.29
India	1.35	0.10	0.47	2.82	1.94	1.18	0.11	0.23	0.74	3.07	0.93	1.02	0.61	0.74	0.77	0.94	0.19	0.38	0.39	0.32	1.23	0.32	5.37
Russia	0.49	0.22	1.07	0.05	0.02	0.11	3.45	0.99	0.15	7.83	1.50	0.05	0.22	0.35	2.61	0.27	0.10	0.17	0.13	0.10	0.46	0.12	0.03

Source: Own calculations using COMTRADE data

Table 6.9.2. Relative trade balance (X-M)/(X+M) in manufacturing industries in 2011 - EU countries, Japan and Brazil, China, India and Russia.

	Food	Bevarages	Tobacco	Textiles	Clothing	Leather & footwear	Wood & wood products	Paper	Printing	Refined petroleum	Chemicals	Pharma-ceuticals	Rubber & plastics	Non-metallic mineral products	Basic metals	Metal products	Computers, electronic & optical	Electrical equipment	Machinery	Motor vehicles	Other transport	Furniture	Other manufac-turing
	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	C30	C31	C32
Austria	-0.06	0.53	-0.71	-0.03	-0.42	-0.20	0.42	0.23	-0.37	-0.55	-0.27	0.03	-0.04	-0.01	0.03	0.11	-0.09	0.11	0.06	0.02	0.15	-0.21	-0.10
Belgium	0.12	-0.02	0.08	0.23	-0.01	0.22	-0.01	-0.05	0.04	0.02	0.13	0.13	0.04	0.11	0.18	-0.04	-0.19	-0.06	0.05	-0.04	-0.12	-0.21	0.03
Bulgaria	-0.12	-0.19	0.49	-0.43	0.56	0.09	0.25	-0.34	-0.75	0.07	-0.34	-0.21	-0.23	0.21	0.40	-0.14	-0.38	-0.01	-0.04	-0.27	-0.23	0.27	-0.16
Cyprus	-0.67	-0.87	-0.32	-0.92	-0.93	-0.82	-0.96	-0.92	-1.00	-1.00	-0.62	0.03	-0.91	-0.95	-0.55	-0.80	-0.54	-0.78	-0.77	-0.89	-0.52	-0.93	-0.61
Czech Rep.	-0.20	0.02	0.32	0.09	-0.20	-0.17	0.34	-0.06	0.01	-0.22	-0.20	-0.39	0.01	0.21	-0.20	0.18	-0.04	0.15	0.16	0.34	0.34	0.28	0.18
Denmark	0.25	-0.16	0.29	-0.03	-0.02	-0.20	-0.37	-0.36	-0.24	-0.22	-0.09	0.21	-0.08	-0.12	-0.34	0.13	-0.12	-0.06	0.26	-0.38	0.06	0.21	-0.04
Estonia	-0.04	-0.25	-0.73	0.06	0.12	0.05	0.44	-0.13	-0.55	-0.11	-0.19	-0.72	-0.11	0.04	-0.28	0.21	0.01	0.04	-0.07	-0.10	-0.32	0.61	0.04
Finland	-0.44	-0.39	-0.95	-0.37	-0.67	-0.43	0.56	0.80	-0.54	0.21	-0.05	-0.18	0.01	-0.12	0.32	0.03	-0.18	0.12	0.20	-0.50	0.08	-0.61	-0.10
France	-0.05	0.62	-0.60	-0.15	-0.38	-0.10	-0.34	-0.19	0.20	-0.37	0.02	0.04	-0.12	-0.17	-0.08	-0.15	-0.20	-0.06	-0.05	-0.06	0.25	-0.51	-0.16
Germany	0.05	-0.06	0.51	0.02	-0.32	-0.27	0.06	0.14	0.40	-0.38	0.12	0.13	0.20	0.18	0.00	0.23	-0.02	0.21	0.39	0.39	0.07	-0.08	0.05
Greece	-0.31	-0.24	0.08	-0.15	-0.31	-0.65	-0.50	-0.68	-0.49	0.25	-0.50	-0.57	-0.25	-0.24	0.17	-0.24	-0.62	-0.35	-0.52	-0.79	-0.69	-0.73	-0.63
Hungary	0.15	0.04	-0.14	-0.18	-0.06	-0.09	0.12	-0.04	-0.83	0.04	-0.09	0.04	0.05	0.15	-0.31	-0.14	0.14	0.15	-0.07	0.41	0.18	0.42	0.05
Ireland	0.28	0.22	0.05	-0.32	-0.61	-0.59	0.06	-0.69	-0.95	-0.49	0.67	0.76	-0.23	-0.29	-0.26	-0.05	0.28	-0.10	0.15	-0.75	-0.46	-0.55	0.55
Italy	-0.13	0.62	-0.98	0.17	0.12	0.27	-0.41	-0.05	-0.04	0.24	-0.22	-0.12	0.24	0.42	-0.06	0.42	-0.41	0.20	0.47	-0.12	0.22	0.64	0.14
Latvia	-0.23	0.31	-0.30	-0.11	-0.07	-0.48	0.79	-0.37	-0.45	-0.50	-0.32	-0.19	-0.30	0.02	-0.04	-0.04	-0.13	-0.24	-0.40	-0.22	-0.30	0.33	-0.35
Lithuania	0.11	-0.15	0.54	-0.11	0.26	-0.22	0.26	-0.15	-0.70	0.75	0.04	-0.39	0.01	-0.15	-0.42	0.05	-0.23	-0.08	-0.12	-0.10	-0.35	0.82	0.04
Luxembourg	-0.29	-0.54	-0.06	0.61	-0.53	-0.32	0.14	-0.07	-0.98	-0.99	-0.46	-0.68	0.27	0.04	0.32	-0.15	-0.31	-0.12	-0.01	-0.48	-0.50	-0.89	-0.47
Malta	-0.60	-0.77	-0.63	0.41	-0.80	-0.73	-0.98	-0.98	-0.54	-0.39	-0.79	0.26	-0.07	-0.72	-0.78	-0.63	0.10	-0.01	-0.46	-0.88	-0.48	-0.91	0.43
Netherlands	0.24	0.15	0.62	0.07	-0.12	-0.05	-0.51	-0.05	-0.30	0.12	0.21	0.08	-0.01	-0.17	-0.03	0.03	0.03	-0.04	0.23	-0.15	0.11	-0.31	0.01
Poland	0.17	-0.09	0.78	-0.30	-0.06	-0.32	0.39	-0.03	-0.30	0.07	-0.24	-0.47	0.07	0.15	-0.05	0.10	-0.16	0.12	-0.24	0.25	0.23	0.75	-0.24
Portugal	-0.35	0.43	0.47	0.06	0.15	0.22	0.39	0.27	-0.11	-0.20	-0.34	-0.54	0.12	0.38	-0.19	0.18	-0.32	-0.04	-0.27	-0.05	-0.15	0.30	-0.48
Romania	-0.40	-0.45	0.68	-0.47	0.53	0.08	0.59	-0.64	-0.14	0.09	-0.38	-0.52	-0.18	-0.47	-0.09	-0.28	-0.19	-0.11	-0.25	0.25	0.57	0.63	-0.27
Slovakia	-0.10	-0.11	-1.00	-0.16	0.02	0.23	0.28	0.16	-0.05	0.40	-0.08	-0.53	0.16	0.11	0.23	0.06	0.12	0.03	0.08	0.32	0.10	0.26	0.01
Slovenia	-0.35	-0.14	-1.00	0.03	-0.36	-0.34	0.17	0.09	-0.63	-0.61	-0.17	0.41	0.15	0.03	-0.12	0.20	-0.24	0.33	0.12	0.05	-0.01	0.33	-0.07
Spain	0.03	0.25	-0.75	-0.05	-0.28	-0.11	-0.02	0.02	-0.42	-0.22	-0.11	-0.11	0.04	0.37	0.13	0.11	-0.57	0.01	-0.07	0.16	0.38	-0.22	-0.38
Sweden	-0.32	-0.13	-0.40	-0.25	-0.41	-0.47	0.51	0.71	-0.62	0.15	-0.13	0.32	-0.07	-0.23	0.13	0.09	-0.01	0.02	0.14	0.11	-0.09	0.09	-0.09
United Kingdom	-0.44	0.14	-0.47	-0.31	-0.57	-0.55	-0.81	-0.47	0.44	0.09	-0.06	0.13	-0.21	-0.27	-0.08	-0.24	-0.24	-0.21	0.01	-0.14	0.16	-0.63	-0.16
EU-27	-0.01	0.24	0.08	-0.03	-0.21	-0.06	0.04	0.06	0.09	-0.05	0.03	0.10	0.05	0.08	0.00	0.10	-0.10	0.07	0.19	0.13	0.14	0.05	-0.02
USA	-0.04	-0.48	-0.18	-0.33	-0.88	-0.82	-0.39	0.04	0.48	0.00	0.13	-0.26	-0.17	-0.25	-0.20	-0.15	-0.26	-0.25	-0.03	-0.30	-0.46	-0.69	-0.19
Japan	-0.87	-0.83	-0.96	-0.18	-0.97	-0.95	-0.98	-0.29	0.38	-0.46	0.15	-0.64	0.35	0.28	0.30	0.18	0.12	0.30	0.63	0.76	0.60	-0.66	-0.26
Brazil	0.78	-0.81	0.91	-0.51	-0.81	0.54	0.82	0.54	-0.29	-0.69	-0.46	-0.59	-0.29	-0.08	0.33	-0.22	-0.85	-0.45	-0.38	-0.22	0.02	0.30	-0.53
China	0.07	-0.43	0.66	0.72	0.95	0.81	0.26	-0.12	0.40	-0.20	-0.22	0.14	0.42	0.61	-0.03	0.62	0.24	0.35	-0.02	-0.15	0.41	0.91	0.73
India	0.32	-0.15	0.83	0.65	0.95	0.65	-0.47	-0.54	-0.31	0.56	-0.30	0.51	0.14	0.03	-0.65	0.15	-0.61	-0.29	-0.44	0.15	0.24	0.03	0.38
Russia	-0.61	-0.81	0.31	-0.89	-0.97	-0.89	0.61	-0.20	-0.89	0.91	0.15	-0.95	-0.75	-0.65	0.49	-0.73	-0.82	-0.82	-0.88	-0.91	-0.51	-0.83	-0.92

Source: Own calculations using COMTRADE data

Figure 6.10. Revealed comparative advantage index in service industries in 2011 - EU countries, US, Japan, Brazil, China, India and Russia.

Country name	Telecom., computer and information	Construction	Finance	Insurance and pension	Other business services	Personal, cultural and recreational	Transport	Travel
Austria	0.56	0.52	0.41	0.81	1.10	0.43	1.17	1.25
Belgium	0.86	1.17	0.70	0.65	1.62	0.69	1.29	0.45
Bulgaria	0.89	0.42	0.20	0.98	0.52	0.74	0.97	2.00
Cyprus	0.13	0.27	2.20	0.28	1.14	0.49	1.23	1.22
Czech Republic	0.90	1.44	0.07	0.64	1.23	0.89	1.08	1.21
Denmark	0.36	0.21	0.21	0.21	0.88	0.72	2.78	0.37
Estonia	0.76	2.28	0.27	0.07	0.78	0.29	1.73	0.81
Finland	2.51	1.17	0.50	0.10	0.78	0.30	0.65	0.54
France	0.47	1.81	0.59	1.32	1.23	1.67	1.00	0.97
Germany	0.78	1.85	1.04	1.17	1.19	0.33	1.08	0.53
Greece	0.23	1.28	0.08	0.72	0.26	0.46	2.26	1.38
Hungary	0.66	0.76	0.16	0.08	1.08	5.64	0.96	0.92
Ireland	4.06	0.00	1.67	5.63	0.93	0.00	0.26	0.16
Italy	0.79	0.05	0.47	1.16	1.29	0.25	0.67	1.52
Latvia	0.53	0.75	1.29	0.28	0.71	0.40	2.26	0.62
Lithuania	0.26	0.87	0.17	-0.01	0.34	0.32	2.56	0.90
Luxembourg	0.45	0.22	11.17	2.30	0.69	3.34	0.24	0.25
Malta	0.28	0.00	1.02	0.35	0.49	35.88	0.39	0.95
Netherlands	1.07	1.01	0.26	0.34	1.66	0.62	1.28	0.50
Poland	0.68	1.70	0.24	0.57	1.28	1.18	1.35	1.06
Portugal	0.43	1.23	0.23	0.30	0.68	1.10	1.30	1.65
Romania	1.35	1.53	0.30	0.56	1.00	0.86	1.20	0.44
Slovak Republic	0.92	1.49	0.10	0.20	0.75	1.09	1.48	1.37
Slovenia	0.74	1.34	0.13	0.88	0.70	0.91	1.29	1.55
Spain	0.61	1.23	0.69	0.51	1.14	1.28	0.77	1.56
Sweden	1.51	0.54	0.44	0.72	1.39	0.75	0.81	0.78
United Kingdom	0.76	0.35	4.16	3.16	1.52	1.14	0.58	0.45
EU27	1.11	0.75	1.28	1.19	1.13	1.10	1.06	0.88
United States	0.44	0.20	2.34	1.33	0.76	0.40	0.61	0.92
Japan	0.13	3.20	0.57	0.62	1.29	0.10	1.29	0.30
Brazil	0.13	0.02	1.33	0.69	2.50	0.12	0.71	0.64
China	0.71	3.19	0.09	0.85	1.23	0.06	0.89	0.98
India	4.33	0.24	0.87	0.98	0.77	4.52	0.59	0.48
Russian Federation	0.51	3.04	0.36	0.30	1.23	0.72	1.38	0.73

Source: Own calculations based on IMF and OECD data

BACKGROUND STUDIES

Chapter 1 "*The competitive performance of EU manufacturing*" was written by Mats Marcusson and Konstantin Pashev.

Chapter 2 "*Structural change*" is based on the background study "Structural change" by Werner Hölzl (WIFO), Andreas Reinstaller (WIFO), Serguei Kaniovski (WIFO), Robert Stehrer (wiiw), Peter Havlik (wiiw), Michael Landesmann (wiiw), Doris Hanzl-Weiss (wiiw), and Mark Knell (NIFU).

Chapter 3 "*Reducing productivity and efficiency gaps : the role of knowledge assets, absorptive capacity and institutions*" is based on the background study "Reducing productivity and efficiency gaps: the role of knowledge assets, absorptive capacity and institutions" by Neil Foster-McGregor (wiiw), Johannes Pöschl (wiiw), Ana Rincon-Aznar (NIESR), Robert Stehrer (wiiw), Michela Vecchi (NIESR), and Francesco Venturini (NIESR).

Chapter 4 "*A 'manufacturing imperative' in the EU: the role of industrial policy*" is based on the background studies "A 'manufacturing imperative' in the EU – Europe's position in global manufacturing and the role of industrial policy" by Roman Stöllinger (wiiw), Michael Landesmann (wiiw), Robert Stehrer (wiiw), Johannes Pöschl (wiiw), Mario Holzner (wiiw), and Neil Foster-McGregor (wiiw), and "Bringing research to the market: policy analysis to speed up the market uptake of research results" by Ruslan Lukach (Idea), Annelies Wastyn (Idea), Pierre Padilla (Idea), Vincent Duchêne (Idea), Andrea Szalavetz (Institute for World Economics), and Marzenna Weresa (World Economy Research Institute).

Chapter 5 "*EU production and trade based on key enabling technologies*" is based on the background study "Production and trade in KETs-based products: the EU position in global value chains and specialization patterns within the EU" by Els Van de Velde (Idea), Pieterjan Debergh (Idea), Arnold Verbeek (Idea), Christian Rammer (ZEW), Katrin Cremers (ZEW), Paula Schliessler (ZEW), and Birgit Gehrke (NIW).

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