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Knowledge Flows

Intra-Triad Knowledge Flows

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List of abbreviations

BERD: Business Expenditure on Research and Development
BoP: Balance of Payments
EC: European Commission
EPO: European Patent Office
FDI: Foreign Direct Investment
FP: The Framework Programs for Research and Technological Development
GDP: Gross Domestic Product
GERD: Gross Expenditure on Research and Development
ICT: Information and Communication Technology
JPO: Japanese Patent Office
HRST: Human Resources in Science and Technology
MNF: Multinational Firm
R&D: Research and Development
S&E: Science and Engineering
S&T: Science and Technology
USPTO: United States Patent and Trademark Office
WIPO: World Intellectual Property Indicator

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1 Introduction

The goal of the Lisbon strategy developed in 2000 was to make the European Union the most competitive and knowledge-based economy in the world. The world's leading economies of innovation and knowledge creation are referred to in the literature as the triad regions. The definition of this concept varies, but is generally known to, and will in this paper, entail Europe, and in particular the European Union, the United States and Japan.[1] The purpose of this paper is to assess the capacity of the European Union to absorb new knowledge created in the other triad regions through different channels of knowledge flows. Furthermore, the position of Europe as a leading knowledge-based economy is analyzed in relation to the United States and Japan. The different channels for international knowledge flows that are of focus for this paper are flows through academic channels, patent related knowledge flows, technology trade, strategic R&D cooperation, trade networks, foreign direct investments (FDIs), and international migration. These flows of knowledge are analysed by means of a literature survey and compilations of recent available data.

The paper is organized as follows: Section 2 gives some background information to the present situation of the knowledge economy. In Section 3 we make a short overview of the knowledge production in the three triad regions using official secondary data. A general introduction to knowledge flows is presented in Section 4. Academic knowledge flows are highlighted in Section 5, while Section 6 investigates the information about knowledge flows that can be found in patent data. Knowledge flows due to technology trade is the subject of Section 7 and knowledge flows due to strategic R&D alliances are discussed in Section 8. One important source of knowledge flows is imports and that is studied in Section 9. Knowledge flows via foreign direct investments along with the importance of intra-firm knowledge flows in multinational enterprises (MNFs) are taken up in Section 10. Much knowledge is embodied in people and thus it is natural to devote one section – Section 11 – to knowledge flows via migration. Section 12 concludes.

2 Background - The era of the knowledge economy

It is quite common to describe the current economic era as the era of the knowledge economy. Never before in history has such large amounts of resources been devoted to the generation of new knowledge and to the diffusion of knowledge by means of education. However, the spatial distribution of these resources over the globe is quite uneven. During most of the twentieth century the dominating share of all investments in knowledge production and knowledge generation were made in the industrialized western economies including Japan. Since around 1990, this picture has started to change substantially with rapidly increasing such investments in particular in the BRIC countries[2] (McCann, 2008). However, from a global perspective one can still claim that these investments still have a very uneven geographical distribution. Disregarding the uneven distribution for a moment, it seems appropriate to stress some fundamental changes in the global economy that has happened in recent decades, which has increased the demand for knowledge and at the same time fundamentally changed the conditions for knowledge production (cf., Archibugi & Coco, 2005):

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[1] Ohmae (1985) refers to this concept in his early work "Triad power" where the triad regions are North America, Western Europe and Southeast Asia.

[2] BRIC = Brazil, Russia, India and China

1. The world economy is globalising and this is true not least for technological activities and research and development (R&D) (Cantwell, 1992). International trade and foreign direct investments (FDIs) are increasing. An increasing number of firms are outsourcing and selling output to abroad.

2. Many firms have become more motivated and more systematic in searching for, protecting and exploiting scientific, technological and/or entrepreneurial knowledge to increase their competitiveness by better products and/or more efficient production processes (Granstrand, 1999; Suarez-Villa, 2000; Karlsson & Johansson, 2006). Firms are changing the way they innovate and are increasingly searching for access to sources of scientific and technological knowledge outside their national boundaries building networks of distributed research and development (R&D) including own R&D facilities in foreign locations (Thursby & Thursby, 2006). Multinational firms (MNFs) global sourcing of science and technology[3] changes the conditions for research and higher education organizations (Veugelers, 2010).

3. The number of knowledge handlers, i.e. people that develop new knowledge or transfer and diffuse knowledge, is rapidly increasing.

4. People with higher education and, in particular, students and researchers have become increasingly more internationally mobile. Thus, firms, research institutes and universities are increasingly competing for talent in the global market (Veuglers, 2010).

5. Innovation has in recent decades been going through a globalisation process involving innovation by MNF' overseas subsidiaries, the sourcing of R&D through alliances and joint ventures with foreign firms or universities, and/or the exploitation of foreign technologies through patents and licences (Archibugi & Michie, 1997; Narula & Zanfei, 2005). Innovation processes are increasingly characterised by (Gerybadze & Reger, 1999): i) multiple centres of knowledge in different locations, ii) a combination of learning through the transfer of knowledge from the parent company and the knowledge created at a given location, and iii) technology transfers, both between different geographical locations and between organizational units. Thus, the trend in the globalization of technological activities is unambiguously rising (Cantwell, 1995).

6. International cooperation has become a significant and increasingly important channel for the transfer and diffusion of knowledge in both the public and the private sector (Archibugi & Coco, 2004). One reason behind this is that an increasing share of the research agenda consists of research questions that have a global dimension, such as climate change, energy, safety, and pandemics (Veuglers, 2010).

7. Rapid improvements in the transfer of information and in the transport of goods and people together with substantial deregulation have made the transfer across the globe of commodities, information, human capital and financial resources much easier (Held & McGrew, 1999; Antonelli, 2001; Freeman & Louca, 2001; Karlsson, Johansson & Stough, 2010). In particular, the revolution in information and communication technologies (ICT) and the Internet has reduced the costs of international communication of information and intensified international exchange and communication in

[3] Technology can be interpreted both in a narrow sense as including production technologies (product and process technologies) and in a broad sense as including production technologies, but also managerial knowledge, marketing skills, and other so-called intangible assets at the firm level (Pavitt, 1999).

R&D and innovation. As a result, the costs of research and scientific activities as well as innovation have decreased drastically (Veuglers, 2010).

8. The number of players in terms of both nations and firms able to enter both old and new playing grounds has increased, which implies that the global economic competition has become more intense (Archibugi, Howells & Michie, 1999, Eds.; Mowery & Nelson, 1999, Eds.; Karlsson, Johansson & Stough, 2010).

9. The knowledge generation process has changed and become more network-dependent (Gibbons, et al., 1994; Meyer-Kramer, 2000). Partnerships and collaboration have become increasingly important. International science and technology cooperation has increasingly also become a focus of policy makers, who have become more and more willing to fund programs that stimulate the internationalisation of higher education and R&D (Veuglers, 2010). Collaboration makes it possible to increase the number of agents benefiting from knowledge and provides expanding learning opportunities (Archibugi & Michie, 1995). It allows partners to use each other's expertise and thus enriches the overall accessible know-how (Hagedoorn, Link & Vonortas, 2000). The dynamic interplay and the increasing simultaneity of knowledge demand and knowledge supply has become obvious. Multi-disciplinarity and heterogeneity of the actors involved in the knowledge generation process has grown. The increased networking character of knowledge creation and diffusion is evident and has many forms including increased co-authorships among scientists, intensified university-industry R&D cooperation and the growing number of strategic R&D alliances between firms. However, the generation of knowledge is not defined by clear rules or governed by settled routines. Instead, it is based on a varying mix of theories and practice, of abstraction and aggregation and of coupling of ideas and data from different sources and origins.

Today, it generally is accepted that knowledge, technology and innovation are major factors contributing to economic growth and development alongside labour and capital (Malecki, 1991; Nelson & Romer, 1996; Lundvall & Foray, 1996; Edquist & McKelvey, 2000) and also increasingly critical for the competitiveness of contemporary firms (Kortum & Lerner, 1999; Jaffe, 2000; Shapiro, 2000; Baumol, 2002; van Zeebroeck, et al., 2008). One of the most important contributions of the new growth and international trade theories in recent decades has been the recognition of the significant role of knowledge flows between economic agents from different spatial units. For example, the long-term development of export market shares is not driven by price competition but by technology and quality competition based upon superior knowledge and technological capability (Soete, 1981 & 1987; Greenhalg, 1990; Greenhalg, Taylor & Wilson, 1994; Maskus & Penubarti, 1995; Wakelin, 1998a; Kleinknecht & Oostendorp, 2002; Legler & Krawczyk, 2006; Madsen, 2008).

Knowledge is acknowledged as a critical factor at the micro level, at the regional level, at the national level and at the supra-regional level for preserving and developing competitiveness. Firms need to accommodate and develop new knowledge to supply the innovations that are needed to meet the demands of sophisticated as well as price sensitive customers both at home and abroad to stay ahead of competitors in the relevant market niches. Thus, the competitiveness of a firm is at least partly the result of its capacity to generate but also to find, absorb and assimilate new scientific, technological and entrepreneurial knowledge developed elsewhere, i.e. its absorptive capacity (Cohen and Levithal, 1990). Major dimensions of this capacity of firms to absorb and to accommodate new knowledge are their stock of human capital and their own investments in scientific and technological research.

At the regional level, competitiveness and thus regional growth, development and welfare increasingly is driven by endogenous or decentralized regional factors and here the regional capacity to absorb knowledge developed elsewhere as well as to develop new knowledge plays a central role. Even if the importance of regions has increased substantially similar factors apply at the national level but here the design of the national innovation systems play a decisive role (Rosenberg, 1982; Nelson, 1984; Nelson, 1993, Ed.). The idea behind the concept of national innovation systems is that nations provide a milieu for their firms to compete in international markets, and, in particular, that the innovative milieu they offer affect the capacity of their firms to generate and develop innovations. It is important to observe that the relationships between internationalisation and innovation are both complex and reciprocal. In other words, internationalisation is not only about commercialising technologies developed in a certain country. Depending on the industry, also other motivations, such as resource access and control, technology development, and the development of shared network assets can be of importance. However, while innovation often stimulates internationalisation, there are also considerable evidences of the opposite effect, i.e. that internationalisation itself stimulates learning and innovation within international firms.

Also at the supra-national level illustrated by the triad North America (US) – Europe (EU) – East Asia (Japan) the capacity to absorb and to develop new knowledge is critical for competitiveness and for economic growth and development (Ohmae, 1995). Even if each of the triad regions makes very substantial investments in R&D, they can never afford to disregard the new knowledge developed in the other two regions, if they in the long run want to preserve their competitiveness in different markets. Thus, it has become a major policy concern within not only governments, firms and trade unions in Europe but also at the EU level how to develop means to promote scientific and technological activities, to absorb knowledge developed elsewhere, to foster innovation within firms and to upgrade the quality of the human capital. Since private R&D is dominated by multinational firms and involves both outward and inward activities, policy-makers at the EU level are confronted with a two-fold policy challenge: i) How to stimulate the internationalisation of European firms, while ensuring the reinforcement of European innovation capabilities?, and ii) How to attract innovative foreign companies that will strengthen European innovation capabilities?

In Europe, the generation of economic benefits from R&D and not least from publically funded research has become a matter of major concerns among policymakers. The awareness has increased that there in Europe exists a very substantial gap between the rather high levels of scientific performance of publicly funded R&D in Europe and the relatively low levels of scientific contributions to Europe's industrial productivity and competitiveness, which been described as the "European paradox" (Verbeek, Debackere & Luwel, 2003). It is in this connection important to stress, that the application in industrial innovation processes of new knowledge generated at universities and public research institutes has been identified as a key mechanism for economic growth (Romer, 1990). This raises different questions (Polt, Rammer, Schartinger, Gassler & Shibany, 2000): Where does this paradox occur? How does this paradox occur?, Why does this paradox occur?, Does the European science system fail to develop and to make the kind of contributions upon which modern industrial economies have become increasingly dependent? Does the European industry lack the ability, the absorptive capacity and/or the levels of R&D necessary to effectively use the knowledge produced in the European science sector and in other parts of the world? Authors like Sapir, et al., (2004) and Aghion & Howitt (2006) argue that it is insufficient knowledge investments in industry, which are the main obstacle competitiveness and growth in Europe. However, other authors stress that it is over-regulated markets in particular in the service sector but also more generally administrative burdens to industry and entry barriers across sectors, which limits competitiveness and economic growth in Europe (cf., e.g., Nicoletti & Scarpetta, 2003; Griffith, Redding & Van Reenen, 2004; Bassanini, Nunziata & Venn, 2009). Actually, this second explanation might partly explain why European industry under-invest in knowledge production. It is of course important to understand the reasons to the unsatisfactory performance of Europe to be able to design actions that can change the current situation.

It is in this connection important to recognize that productivity and competitiveness improving innovations do not merely depend on the level of total R&D inputs but also on the way innovation processes are coordinated within and across organizations and countries as stressed in the literature on national systems of innovation (Freeman, 1987; Lundvall, 1992, Ed.; Nelson, 1993, Ed.). This research field developed from the simple observation that nations had different levels of success in generating innovations measured in terms of the number of patents generated, production of high-technology goods and services, or trade in high-technology goods and services (Patel & Pavitt, 1987; Mowery, 1992; Mowery & Teece, 1993). In particular, was this kind of research stimulated by concerns among US and European policymakers and scholars that the Japanese system of innovation and manufacturing seemed to be leaving the US and Europe behind in the 1980s. Researchers in the field have studied the influence on the success of these national innovation systems of a large number of variables including private R&D spending, public R&D spending, antitrust laws, potential market size, the education systems, the quality of the labour force, and the nature of the patent systems[4]. While the perceptions have changed drastically since the 1980s, the questions asked in this research still have their relevance: Are there better systems for generating a larger national innovative output, i.e. to increase the innovative productivity? If so, what should the components be and how should they be related?

There are, however, a number of phenomena, which partly changes the focus from the quantity and quality of R&D to the organisation of R&D and innovation. One such phenomenon is the shift from ‘closed’ to ‘open’ innovation (Chesbrough, 2003), which has accompanied a broadening of R&D and innovation to include new organizational forms such as outsourcing of R&D, R&D consortia and strategic alliances and the spin-out of firms from incumbents and universities. Furthermore, there seems to be a substantial variation between national innovation systems in terms of productivity and efficiency, not least due to organizational and institutional factors (Lehrer, 2007). European R&D has for example lagged significantly behind that of the two other triad regions in terms of commercial productivity (Andreasen, et al., 1995).

Another important aspect is that knowledge spillovers, in particular from academia to industry but also over national borders, are far from automatic (Audretsch & Feldman, 2004). This is clearly illustrated by, for example, national differences in the capacity to commercialize biotechnology research (Lehrer & Asakawa, 2004; Cooke, 2006). One problem in this connection is the often complex interdependence between basic and applied research.

The European Union (EU) has for many years been concerned with how to strengthen its innovative capability being an increasingly networked node within the global system (Kale & Little, 2007). One example is the development of a European ‘knowledge economy’, which has been at the heart of EU’s economic policy since the launching of the so-called ‘Lisbon strategy’ in March 2000. The strategic goal of the Lisbon strategy was that Europe the coming

[4] A deeper discussion of patents and intellectual property rights is beyond the scope of this report. The economic analysis of patents goes back at least to Plant (1934). There exists since many years a rich literature of “optimal” patent systems and their ability to generate more inventions (quantity) and/or bigger inventions (quality) (Klemperer, 1990; Gilbert & Shapiro, 1990; Scotchmer, 1991).

decade should 'become the most dynamic and competitive knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion, and respect for the environment'. Later at the European Council meeting in Barcelona in March 2002 it was agreed that the 'overall spending on R&D and innovation in the Union should be increased with the aim of approaching 3 percent of GDP by 2010. Two-thirds of this new investment should come from the private sector.'[5] These targets were very ambitious and at the same time the European summits failed to provide the necessary instruments to reach these targets and left a number of critical questions unanswered. How should the private sector be stimulated to increase its R&D investments? How should the growth of R&D investments be distributed between the different member countries and between different industries? How should the responsibilities to reach the targets be distributed between the individual governments and the EU institutions? Furthermore, the Lisbon strategy did not focus enough on the need to increase the flows of knowledge and technology, in particular, from the two other triad regions. Thus, nobody should be surprised that the Lisbon strategy to a large extent failed.

Thus, Europe still lacks an integrated R&D and innovation strategy with proper instruments to achieve the goals. Europe lacks cohesion and central decision-making regarding R&D and innovation comparable to what exists in USA and Japan. The individual member states still have a substantial autonomy when it comes to R&D, innovation and higher education. It is far beyond the scope of this paper to try to design a new R&D and innovation strategy for Europe. Instead, we focus on one critical factor for a successful such strategy and that is the capacity of Europe to rapidly acquire knowledge developed in the two other triad regions. The importance of such a capacity is well understood as soon as we realise that the gross domestic R&D expenditure in current USD (PPP-adjusted) in the US and Japan taken together is about double of that in the EU, and that researchers in the US and Japan produce approximately the same number of scientific and technical articles as the researchers within the EU (Archibugi & Coco, 2005). The underlying reason why such a capacity is so important is the role of diversity or heterogenity of knowledge for new combinations to emerge, i.e., for the creation of new knowledge and (technological) innovations (Schumpeter, 1939; Nelson & Winter, 1982; Nonaka, 1994; Nooteboom, 2004). According to this perspective, new knowledge and new technology is assumed to emerge from the combination of existing knowledge bits.

In line with earlier research, this paper will focus on the triad EU-USA-Japan to make it possible to make comparisons with earlier research. However, we acknowledge that our focus imply a certain limitation due to the surge during the two last decades of i) globalisation of R&D activities (Belitz, Edler & Grenzmann, 2006), ii) international R&D co-operations (Frietsch & Schmoch, 2006; Schmoch & Schubert, 2008; Mattsson, et al., 2008), iii) international investments (UNCTAD, 2005), iv) the number of MNF branches and affiliates. Future analysis must increasingly consider what is going on outside the triad and not least in China and the other BRIC countries. However, even if the triad regions' (USA, Japan and Europe) share of the worldwide exports of, for example R&D-intensive goods, declined from 82 percent in 1993 to 69 percent in 2004, the triad regions are still major players in the global economy (Gehrke, Krawczyk & Legler, 2007).

[5] See http://europa.eu.int/comm/lisbon_strategy/index_en.html

3 Knowledge production in the Triad regions – inputs and outputs

This chapter provides a brief overview of knowledge production in the triad region before digging deeper into each of the different channels for knowledge flows. The purpose of the chapter is to establish Europe's position as an advanced knowledge-based economy among the triad regions. Chapter 5 will then analyse Europe's ability to enhance its position through its absorptive capacity of knowledge flows. The tables and figures refer to different compilations of Europe (EU-15, EU-19, EU-27, Euro area and Western Europe), due to the data availability from the different sources. Complete lists of the countries included in each European region can be found in the Appendix in Table 14.1. The paper makes use of EU-27 for the most part, although it is interesting to compare it with EU-15. As will be noticed, the EU-15 countries are responsible for most of the knowledge creation within the EU.

Concerns that Europe is lagging in terms of knowledge production compared with in particular the United States have been expressed at least since the 1960s (Servan-Schreiber, 1968; Patel & Pavitt, 1987; Archibugi & Pianta, 1992).[6] This is from one perspective very remarkable, since Europe is a major player in the generation of scientific and technological knowledge, which we will highlight below. However, from another perspective it is not very remarkable, since Europe is underperforming when it comes to taking advantage of the new knowledge in terms of new products and entrepreneurship, which also results in underperformance in terms of employment growth and economic growth.

3.1 Research and innovation indicators

Between the years 2004 and 2009, Europe has had the highest average annual growth rate of GDP per capita of the triad regions. EU-15 increased its GDP per capita by 6 percent annually and the GDP per capita in EU-27 increased by 4 percent. Corresponding figures for the US and Japan are 3 percent and 2 percent respectively (see appendix Figure 14.1). The reason for Europe's seemingly superior performance reflects the quite sharp decrease in GDP per capita in the US and Japan in 2008-2009. In Table 3.1, some basic knowledge indicators from the triad regions are displayed; among other things the size of the R&D investments and the size of the R&D output measured in the form of scientific and technological articles. In addition, Table 3.1 shows that although Europe has experienced a stronger GDP per capita growth, the level of GDP per capita in EU-15 is lower than in the US and the level of GDP per capita in EU-27 is lower than both other triad regions in 2009.

The total R&D budget of EU-27 is around 2/3 of that of the US and almost doubles that of Japan. The gap of gross R&D expenditures (GERD) between the triad regions remains almost the same between 2004 and 2009, although the triad R&D budget, in particular the US R&D budget, grows during this period (see appendix Figure 14.2). However, the share of GDP devoted to R&D investments in EU-27 is substantially lower than that of the US and Japan. Figure 14.3 in the appendix shows that the R&D expenditures as a percentage of GDP has been relatively stable over the past five years among the triad regions. In terms of scientific and technological articles the EU-27 is outperforming the two other triad regions. The overall scientific productivity measured in terms of the number of science and technology articles per million USD research investments is substantially higher in EU-27 than in the US and Japan. However, this might indicate that scientific and technological R&D within EU-27 to a high

[6] Interestingly similar concerns have been raised in the US (See, e.g. Kennedy, 1988; Pianta, 1988; Nelson, 1989)

extent is focusing on academic publication, while it might be the case that similar R&D in the US and Japan is more focused on generating an output that is patentable and perhaps, also has a more applied focus.

Table 3.1 Some basic indicators related to R&D investments in the triad regions

Indicator	EU-15	EU-27	USA	Japan
Population (2009)	355,261,920	489,875,200	307,007,000	127,560,000
GDP in million USD (PPP-adjusted) (2009)	13,697,318	15,640,070	14,256,300	4,138,481
GDP per capita current international $ (PPP-adjusted) (2009)	38,556	31,927	46,436	32,443
Gross domestic R&D expenditures in million USD (PPP-adjusted) (2008)	261,852	276,734	398,194	149,213
R&D expenditures as share of GDP (%) (2008)	1.95	1.85	2.77	3.42
Scientific and technological articles (2007)	227,004	245,852	209,695	52,896
Scientific and technological articles per million R&D expenditures	0.91	0.93	0.56	0.36

Sources: OECD (2010a) for gross R&D expenditures; NSF (2010) for scientific and technological articles; World Bank (2010a) for other indicators.

In order to compare the gross expenditure on R&D, Table 3.2 below displays the shares of the world's GERD contributed by the triad regions and the BRIC (Brazil, Russia, India and China) countries. Even though the largest part of R&D investments in the world is attributed to the triad regions, they have each lost percentage shares between 2002 and 2007. This is partly due to the upswing of both China and India, but also the rest of the world. The world total R&D investments increased by 45 percent, from USD 790.3 billion in 2002 to USD 1145.7 billion in 2007 (UNESCO, 2010). Germany, the United Kingdom and France are responsible for the drop in Europe's share of R&D expenditures (UNESCO, 2010).

Table 3.2 Share of the world's gross R&D expenditure of the triad regions and BRIC countries: 2002 and 2007

Triad regions and BRIC countries	2002	2007
EU-27	26.1	23.1
USA	35.1	32.6
Japan	13.7	12.9
Brazil	1.6	1.8
Russia	2.0	2.0
India	1.6	2.2
China	5.0	8.9
Rest of world	14.9	16.5
Total	100	100

Source: UNESCO (2010)

The basic R&D-related indicators can be complemented by some other indicators, which highlight the innovation potential in the triad regions (See Table 3.3). What is most interesting to note in Table 3.3 is the extent to which EU-27 is lagging in terms of higher education compared with the other two triad regions. EU-27 is also lagging somewhat in terms of broadband penetration, but compared with the lack of people with higher education this seems to be less of a problem. Concerning science and engineering graduates, EU-27 is second to Japan but beats the US. Thus, there is no general lack of science and engineering graduates in Europe but a remaining question is of course if they are educated in the right fields and have developed the right competencies.

Table 3.3 Innovation Potential Indicators in the Triad Regions, 2008

Innovation indicator	EU-27	USA	Japan
Graduates in mathematics, science & technology graduates per 1000 population aged 20-29	13.9	10.1	14.3
Population with tertiary education per 100 population aged 25-64	24.0	41.0	43.0
Broadband penetration rate (Fixed (wired) broadband subscriptions per 100 inhabitants) (2010)	24.7	27.1	26.3
Number of internet users per 100 population	64.6	74.1	71.4

Source: Eurostat (2010); OECD (2010); UNESCO (2010)

As mentioned earlier, the Lisbon strategy adopted in 2000 aimed to make EU the most competitive and dynamic knowledge-based economy in the world. In 2002, it was established that each country should devote 3 percent of its GDP on R&D investments by 2010 (UNESCO, 2010). 2/3 of these investments should come from the private sector. Although, statistics is only available until 2008, it is fairly safe to conclude that this target has not been met. In fact, Europe still lags far behind both the US and Japan, as can be seen in Table 3.4. The R&D intensity in the triad regions is further highlighted in Table 3.4 displaying the business investment in R&D (BERD). It is shown that business R&D expenditure as a percentage of GDP is substantially lower in EU-15 and EU-25 than in the US and Japan.

Table 3.4 Gross and Business Expenditure on R&D as a percent of GDP in the triad regions

Triad region	GERD (% of GDP) in 2004	GERD (% of GDP) in 2008	Mean Annual Rate of Growth 2004 to 2008 (%)	BERD (% of GDP) in 2004	BERD (% of GDP) in 2008	Mean Annual Rate of Growth 2004 to 2008 (%)
EU-15	1.85	1.95	1.4	1.18	1.24	1.2
EU-25	1.75	1.85	1.4	1.11	1.16	1.1
USA	2.54	2.77	2.3	1.76	2.01	3.6
Japan	3.17	3.42	2.0	2.38	2.69	3.3

Sources: OECD (2010a); World Bank (2010a)

In Table 3.6, we complement the figures given earlier with the industry financed share of GERD and share of R&D expenditures on medium-high and high-tech industries. Evidently, the regions spend a similar share of R&D expenditures on these industries. However, Japan funds more of its R&D expenditures by the private industry than Europe and the US. A little more than half of the R&D funding in Europe originates from the industry. Evidently, Europe has not met the goal that 2/3 of the R&D investments should come from the industry.

Table 3.5 GERD-to-GDP ratio, industry financed share of GERD and share of medium-high-tech and high-tech R&D*

Triad region	GERD/GDP ratio	Industry financed share of GERD	Share of medium-high-tech and high-tech R&D*
EU-27	1.83	54.5	85.2
USA	2.67	67.0	89.9
Japan	3.67	73.0	86.7

Source: EIS (2008)
*) Chemicals, machine manufacture, office equipment, electric, electronic, telecommunication equipment, automobiles, aeroplanes and other transport.[7]

3.2 Intellectual property rights

Competition in global markets is increasingly based upon intellectual property rights (Andersen, 2004) and it has been shown that there is a strong link between patents and success in international markets, i.e. export performance (Dosi, Pavitt & Soete, 1990; Porter, 1990; Grupp, Münt & Schmoch, 1996; Münt, 1996; Wakelin, 1997 & 1998a & 1998b; Gehrke, Krawczyk & Legler, 2007). Patents explain export streams in industrialised countries, in particular in high-tech sectors, but also in low-tech sectors (Blind & Frietsch, 2006).

Patents reflect inventive and innovative activities that are proprietary in nature and are developed mainly for commercial purposes.[8] However, there are substantial differences between industries and even firms within industries as to what extent patents are used versus other protection measures, such as trade secrets, quick moves, down the learning curve, etc. (Levin, et al., 1987). The propensity to patent can also change over time due to reasons that have little to do with technology, including the support for patentees in the courts (Shapiro, 1990) or the patent office's budget and workload (Griliches, 1989). It is interesting that since the beginning of the 1990s, there has been an extreme increase in the number of patent filings at the major

[7] It is important to stress that definitions of what is counted as high-tech always tend to be pretty subjective.
[8] Patents are popular indicators, since they are so easily available, by definition directly measure technology and generally objective metrics that change slowly over time (Griliches, 1990).

patent offices (USPTO, JPO and EPO) without a similar increase in the R&D expenditures during the same period (Frietsch, Schmoch, van Looy, Walsh, Devroede, Du Plessis, Jung, Y. Meng, Neuhäusler, Peeters, & Schubert, 2010).

Researchers have provided numerous explanations to this divergence including an increase in R&D productivity, a shift to new and more R&D-intensive technologies, an increased internationalisation, changes in the patent systems, and a more frequent strategic use of patent applications by firms (Harabi, 1995; Kortum & Lerner, 1997 & 1999; Hall & Ham, 1999; Cohen, Nelson & Walsh, 2000; Rivette & Kline, 2000; Janz, Licht & Doherr, 2001; Hall & Ziedonis, 2001; Janz, Licht & Doherr, 2001; Cohen, et al., 2002; Arundel & Patel, 2003; Sheehan, Martinez & Guellec, 2004; Blind, et al., 2006).

The patent systems in the triad regions differ, which could be part of the explanation to the vastly differing number of domestic and foreign patent applications to the USPTO, the EPO and the JPO. The US system has a broad, strong protection, with minimal administrative procedures, whereas the Japanese system has narrower, weaker protection and a sometimes difficult administrative system. The European systems are somewhere in between (Erickson, 2008).

In Tables 3.6-3.8 we present information about the total number of patent applications to USPTO, EPO and JPO from the triad regions in 1985 and 2005 as well as the total growth in number of applications between 1985 and 2005 (and for more recent years when possible). The data in Table 3.6a clearly illustrates the increasing importance of intellectual property rights. Between 1985 and 2005, the number of patent applications from the triad regions to USPTO has increased with more than 200 percent. However, Europe has not been able to match the other two regions and has during this period had a decline of its market share from 22.3 percent to 15.8 percent (17.1 percent in 2008). US patents are of particular interest, since the US is the largest market and an innovation of any importance will likely head for the US market and search patent protection there (Glissman & Horn, 1988).

Table 3.6a Number of patent applications to USPTO from triad regions in 1985 and 2005

Triad region	1985	1985 (%)	2005	2005 (%)	2008	2008 (%)	Total growth 1985-2005 (%)
EU-27	24,523	22.3	52.323	15.8	64,599	17.1	113,4
USA	63,874	58.2	207,867	62.6	231,588	61.2	225.4
Japan	21,431	19.5	71,994	21.7	82,396	21.8	235.9
Total	109,828	100.0	332,184	100.1	378,583	100	202.5

Source: NSF (2008); NSF (2010)

When patents are sought for protection in the US, the EU and Japan, substantial resources are required for obtaining and maintaining them, which means that their owners consider them to be valuable. Interestingly, Table 3.6b shows that the share of high-value patent grants by the USPTO is very similar in the triad regions and accounts for a combined 90 percent share of the world total high-value patent grants (NSF, 2010).

Table 3.6b Share of high-value patent grants by the USPTO: 1997 and 2006

Triad Region	1997	2006
EU-27	33.0	28.7
USA	33.5	30.9
Japan	26.8	27.5

Source: NSF (2010)

In Table 3.7 we display the number of patent applications to EPO from triad regions in 1985 and 2005 (and 2007). We see that the number of applications to EPO in 2005 is less than one third of the applications the same year to USPTO and that the growth in the total number of applications is lower for EPO than for USPTO. Once again, we can observe that Europe has lost market shares between 1985 and 2005 (although Europe gained market shares in 2007). The growth of Japanese patent applications to the EPO between 1985 and 2005 is almost identical to the growth of Japanese patent applications to the USPTO during the same time period.

Table 3.7 Number of patent applications to EPO from triad regions in 1985 and 2005

Triad region	1985	1985 (%)	2005	2005 (%)	2007	2007 (%)	Total growth 1985-2005 (%)
EU-27	21,217	53.8	52,255	49.1	46,097	54.5	146.3
USA	11,635	29.5	32,064	30.1	21,471	25.4	175.6
Japan	6,617	16.7	22,123	20.8	17,007	20.1	234.3
Total	39,469	100.0	106,442	100.0	84,575	100	169.7

Source: NSF (2008); 2007 data from Eurostat (2010)

A reform that would result in a European Community patent that can be applied at, and granted by, the EPO and which would be valid throughout the EU is under a prolonged discussion (UNESCO, 2010). The situation for patent applicants today involves enforcements that must be carried out in national courts in individual countries and also different patent rights in different countries. Furthermore, inventors seeking patent protection in specific EU countries do not always seek out the common application at the EPO (Maurseth & Verspagen, 2002). These complications could be part of the reason for the low patent applications to the EPO from the EU and the other triad countries. Another aspect that might distort the patent figures is that more export-oriented countries will be more inclined to seek patent protection across borders.

Between 2002 and 2007, the number of total patent applications to the JPO fell from 412,000 to 396,000, a trend reflecting a change in the patent strategies of Japanese firms (not displayed in table) (UNESCO, 2010). Firms have been focusing on obtaining high-quality patents to develop their core business instead of filing large quantities of patents for defensive purposes. Furthermore, firms have chosen to hide new technology within the firm whenever it implies a competitive edge rather than applying for patent protection (UNESCO, 2010).

Table 3.8 shows the number of patent applications to Japan Patent Office (JPO) from triad regions in 1985 and 2005. Evidently, Europe here has a low market share and even if it increased between 1985 and 2005, it remains low. The total growth of patent applications to the JPO during this time period is much lower than the total growth of patent applications to both the USPTO and the EPO.

Table 3.8 Number of patent applications to JPO from triad regions in 1985 and 2005

Triad region	**1985**	**1985 (%)**	**2005**	**2005 (%)**	**Total growth 1985-2005 (%)**
EU-27	12,253	4.5	25,453	7.3	107.7
USA	34,689	12.7	36,658	10.5	5.7
Japan	226,202	82.8	286,082	82.2	26.5
Total	273,144	100.0	348,193	100.0	27.5

Source: NSF (2008)

Research has shown that Japanese patents tend to be much narrower in scope, consequently the Japanese tend to file numerous patents which could have been covered by one single patent in Europe or the US (Erickson, 2008). Despite this, the much smaller Japanese population balances the patent figures somewhat.

In Table 3.9 we exhibit data for triad patent applications, i.e. patent applications from the triad regions filed to USPTO, EPO and JPO.[9] Even if Europe in 2005 is on par with the two other triad regions, we can observe that Europe's market share for triad patents has decreased from 39.2 percent in 1985 to 33.2 percent in 2005.

Table 3.9 Number of triad patent applications to and from triad regions in 1985 and 2005

Triad region	**1985**	**1985 (%)**	**2005**	**2005 (%)**	**Total growth 1985-2005 (%)**
EU-27	8,463	39.2	14,988	32.2	77.1
USA	7,781	36.1	16,368	35.1	110.4
Japan	5,335	24.7	15,239	32.7	185.6
Total	21,579	100.0	46,595	100.0	115.9

Source: NSF (2008)

Patents granted in the US and applied for in Europe per one million people are illustrated in Table 3.10, which demonstrates a decrease in the number of EU-27 and US patents granted at USPTO per person. It should be observed that EU-27 is not even close to Japan when it comes to getting patents granted by USPTO in the US – the largest market in the world. Not even in its home market is EU-27 matching the activities of Japanese firms and is only slightly above the activities of American firms, although Europe is the only region displaying positive growth numbers here.

[9] Several econometric analyses have shown that patents for which applications have been filed in several countries are of higher economic and in particular technological value than purely national patent applications (Grupp, Münt & Schmoch, 1996; OECD, 2004; Dernis & Kahn, 2004; Frietsch & Schmoch, 2006; Bessen, 2008; Frietsch & Schmoch, 2010).

Table 3.10 Patents Granted at the USPTO and Patents Applied at the EPO by the Triad Regions per million people

Triad region	Mean Annual Granted Patents at USPTO 2000-2001	Mean Annual Granted Patents at USPTO 2007-2008	Mean Annual Rate of Growth 2000-2001 to 2007-2008 (%)	Mean Annual Applied Patents at EPO 2000-2001	Mean Annual Applied Patents at EPO 2006-2007	Mean Annual Rate of Growth 2000-2001 to 2006-2007 (%)
EU-27	56	45	-19.5	106	115	9.0
USA	304	259	-14.9	108	106	-1.8
Japan	254	262	3.4	164	162	-1.1

Source: Patents granted by USPTO from NSF (2010); Applied patents at EPO from Eurostat (2010)

We follow up the information presented in Table 3.10 with information from 2007. Of special interest in Table 3.11 are the so-called triad patents (Grupp, Münt & Schmoch, 1996). The background to the triad patent idea was that the world market in the 1980s and early 1990s was dominated by production and trade within and between the triad regions. Triad patents refer to patents, which are applied for at USPTO as well as JPO and EPO. Triad patents proved to be an appropriate innovation indicator of international competitiveness, since there is a close link between triad patents and foreign trade in technology-intensive goods (Grupp, Münt & Schmoch, 1996). The information in Table 3.11 mirrors that in Table 3.10. EU-27 is underperforming in terms of patenting and the most probable reason is the low business expenditures on R&D within EU-27.

Table 3.11 Intellectual Property Protection in the Triad Regions in 2007

Patenting frequency	EU-27	USA	Japan
EPO patents per million population	128.0	167.6	219.1
USPTO patents per million population	49.2	273.7	274.4
Triad patents per million population*)	19.6	33.9	87.0

Source: EIS (2008)
*) Triad patents involve European, American and Japanese patents.

US has been, and still is, the largest national market for most products, which means that most innovations with any importance will seek protection by a patent at the USPTO. Although the US market receives much more foreign patentees than the other markets, all nations/ regions patent more heavily in their home patent office as the tables above have illustrated (Erickson, 2008). Large differences exist between the patent systems, affecting the number of domestic and foreign patent applications and grants, which must be kept in mind when using patents as a measurement to asses technological output. Another approach to measure technological output is by identifying high-technology industries and assess output, exports and imports (Soete, 1987).

3.3 Knowledge-intensive and high-technology industries

For intellectual property to result in new products and new high-value products in particular, business services and knowledge-intensive services play a critical role. Value added is a measure of industry production; it is the amount contributed by the country, firm, or other entity to the value of the good or service. Value added of knowledge- and technology-intensive industries was almost $16,000 million in 2007, representing 29 percent of world

GDP compared with a 26 percent share 15 years ago (NSF, 2010). These types of industries are growing and have become a major part of the world economy.

The value added created in knowledge-intensive services and high-technology industries in the triad regions is highlighted in Table 3.12-3.14. We can observe in Table 3.12 that Europe, the US and Japan have all increased the value added of these industries relative to their respective GDP between 1995 and 2007. The US has the highest share of value added of knowledge-intensive and high-technology industries as a percentage of GDP.

Table 3.12 Value added of knowledge-intensive and high-technology industries as share of region's GDP: 1995 and 2007

Triad region	1995	2007
EU-27	26.9	29.7
USA	34.0	38.4
Japan	25.5	28.2

Source: NSF (2010)

Europe and the US have both increased their market share of value added in commercial knowledge-intensive services (excludes education and health) at the expense of Japan, according to Table 3.13 below. Remarkably, the growth of the value added of commercial knowledge intensive services in Japan has decreased between 1995 and 2007.

Table 3.13 Value added of commercial knowledge-intensive services in 1995 and 2007 (millions of current USD)

Triad region	1995	1995 (%)	2007	2007 (%)	Total growth 1995-2007 (%)
EU-27	1,345,000	37	2,874,000	42	114
USA	1,464,000	41	3,267,000	47	123
Japan	791,000	22	774,000	11	-2
Total	3,600,000	100	6,915,000	100	92

Note: Knowledge-intensive services include commercial business, financial, and communication services and largely publicly supported education and health services. Commercial knowledge-intensive services exclude education and health.
Source: NSF (2010)

What has then happened with the value added in high-tech manufacturing, since the intellectual property rights and the knowledge-intensive services to a substantial degree is used to develop such manufacturing? Similar to the table above, Europe and the US have increased their market share of value added of high-technology manufacturing industries, while Japan's market share declined to almost half (Table 3.14). Value added of high-tech manufacturing industries has increased with 75.2 percent in Europe between 1995 and 2007.

Table 3.14 Value added of high-technology manufacturing industries: 1995 and 2007 (Millions of current USD)

Triad region	**1995**	**1995 (%)**	**2007**	**2007 (%)**	**Total growth 1995-2007 (%)**
EU-27*	174,500	30.2	305,800	37.8	75.2
USA	209,400	36.3	374,200	46.3	78.7
Japan	193,300	33.5	128,900	15.9	-33.3
Total	577,200	100	808,900	100	40.1

*EU-27 excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.
Source: NSF (2010)

The output of high-technology manufacturing industries as a share of GDP has decreased to a larger extent in Japan between 1995 and 2007, although there was a slight decrease in the other two triad regions as well (Table 3.15). Japan has the highest share relative to GDP of output of ICT industries in 2007, even though the output of ICT industries as a share of GDP is stagnant in Japan between 1995 and 2007, but increases in both the US and Europe.

Table 3.15 Output of high-technology manufacturing and ICT industries as a share of GDP: 1995 and 2007 (percent)

	High-technology manufacturing industries		**ICT industries**	
Triad region	**1995**	**2007**	**1995**	**2007**
EU-27*	1.9	1.8	3.8	4.3
USA	2.8	2.7	4.4	5.1
Japan	3.7	2.9	5.2	5.2

*EU-27 excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.
Source: NSF (2010)

In Table 3.16, we highlight the gross revenues in high-tech sectors in the triad regions. We might observe that the growth of revenues between 1985 and 2005 in Europe has only been half of that in the US. This implies that Europe has lost market shares, although the same is true for Japan.

Table 3.16 High-tech gross revenues in triad regions in 1985 and 2005 (millions of 2000 USD)

Triad region	**1985**	**1985 (%)**	**2005**	**2005 (%)**	**Total growth 1985-2005 (%)**
EU-27	312,348	36.2	650,268	31.2	108.2
USA	262,476	30.4	932,864	44.7	255.4
Japan	289,161	33.5	502,369	24.1	73.7
Total	863,985	100.1	2,085,501	100.0	141.4

Source: NSF (2008)

Many of the products produced in high-tech manufacturing are exported to other countries. A country’s success in exporting its goods to other countries is one measure of its comparative economic advantage. In Table 3.17 we present data for the exports of high-tech products from the triad regions. Here we see that Europe has increased its market shares at the expense of

Japan and to some extent the US between 1995 and 2008. In fact, Europe has surpassed the US in regards to exports of high-tech products in 2008. The total export value of high-tech products from all triad regions during the time period in question have more than doubled.

Table 3.17 Exports of high-tech products from triad regions in 1995 and 2008 (millions of 2000 USD)

Triad region	1995	1995 (%)	2008	2008 (%)	Total growth 1995-2008 (%)
EU-27*	119,631	29.2	398,625	44.5	233
USA	155,622	37.9	312,107	34.8	100
Japan	134,836	32.9	185,661	20.7	38
Total	410,089	100	896,393	100	119

Source: NSF (2010)
*EU exports involves trade only with countries outside of the EU.

Looking at the global export shares for high-tech products we see in Table 3.18 that the European high-tech share of the world market has grown slightly between 1997 and 2008. This can be contrasted with the global high-tech export shares of Japan and the US, which both have decreased substantially during the time period, while the rest of the world has increased its share. The decrease of the global market share of US and Japan is a consequence of a market expansion rather than a decrease in their high-tech export in numbers, as can be seen in Table 3.17.

Table 3.18 Share of global high-tech export for the triad regions, 1997, 2003, 2008

Triad region	1997	2003	2008
EU-27	16.8	17.6	17.4
USA	23.4	16.8	13.6
Japan	14.7	10.6	8.1
Rest of world	45.1	54.9	60.9
Total	100	100	100

Source: NSF (2010)
*EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. EU exports exclude exports among EU member countries.
Note: High-technology products include aerospace, communications and semiconductors, computers and office machinery, scientific instruments and measuring equipment, and pharmaceuticals.

The figure below shows a more dynamic picture of the development of high-technology exports from the triad regions through the use of an index with base year 1995. The trend changes around 2001 when Europe begins to increase its exports quite rapidly and both the US and Japan start to lag behind.

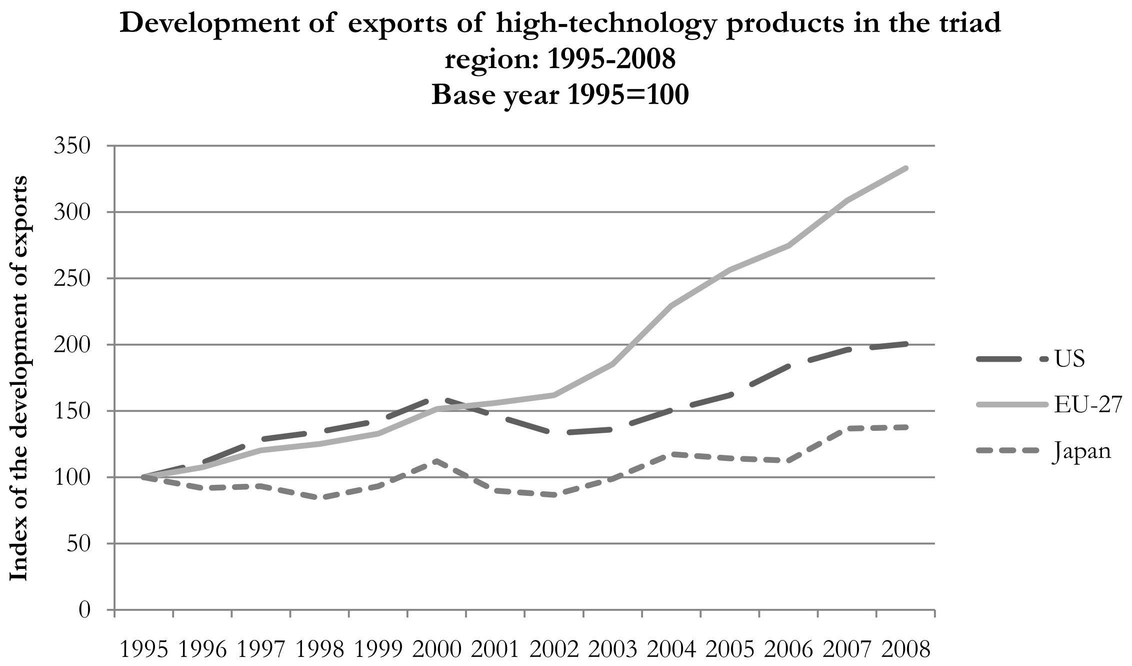


Figure 3.1 Index of the development of high-technology exports: 1995-2008
Source: NSF (2010)
Note: EU exports involves trade only with countries outside of the EU.

The tables and the figure above imply that Japan is lagging behind in terms of output of high-technology products since its growth has been lower than that of the other triad regions. It might however be of interest to study per capita figures since Japan has a much smaller population. Table 3.19 illustrates the triad regions performance in terms of high-technology exports per capita. Clearly, Japan is outperforming the US and especially Europe in this sense. If figures were available for EU-15, the picture might have looked different. However, Europe is catching up with a growth rate of high-tech exports per capita above 100 percent between 2000 and 2008, which is well above the corresponding figures for both the US and Japan.

Table 3.19 High-tech exports per capita from the triad regions: 2000, 2004 and 2008 (US dollars/capita)

Triad region	2000	2004	2008	Growth 2000-2008 (%)
EU-27*	389	577	816	109.9
USA	885	799	1025	15.9
Japan	1192	1240	1454	22.0

Source: NSF (2010)
* EU-27 excludes exports within the region

In Table 3.20 employment in medium-high and high technology manufacturing in 2007 is illustrated. EU-27 is doing well in terms of employment in medium-high and high technology manufacturing, although Japan has a slightly larger percentage of the total workforce.

Table 3.20 Employment in medium-high and high technology manufacturing in the triad regions in 2007

Indicator	EU-27	USA	Japan
Employment in medium-high and high technology manufacturing as a percent of the total workforce	6.63	3.84	7.30

Source: EIS (2008)

One reason for Europe's relatively low share of high-technology exports per capita, could be that entrepreneurship is underdeveloped in Europe, in particular compared to the US. According to Audretsch (2007), entrepreneurship, as a canal for knowledge spillovers, is the missing link in Europe between investments in new knowledge and economic growth. One reason for this might be a lack of venture capital within EU-15 compared with the US. EU-15 spends only 0.017 percent on early stage venture capital[10] of its GDP in 2009. The corresponding figure for the US is 0.045 (Eurostat, 2010). In terms of ICT expenditures as a percentage of GDP EU-27 is doing reasonably well with 2.5 percent compared to Japan's 2.8 percent and the US' 3.3 percent in 2009 (OECD 2010a)

The US has been rather successful in generating high-value innovative products that are compatible in international markets. Europe is increasingly gaining market shares with strong growth for all indicators of its performance in high-technology industries, although, the EU-27 region still lags behind in per capita figures. Japan, with its small population is outperforming the other two regions in terms of high-tech exports per capita, although the growth rates of high-tech industry related indicators have been very low in comparison to Europe and the US in recent years. Another way to compare the innovative and competitive capabilities of the triad regions is through the output and quality of academic research.

3.4 Output and quality of research

In Table 3.21, we look closer upon the output of scientific and technical articles from journals monitored by the Science Citation Index in the triad regions, which gives indications of activities of the three academic communities. Scientific publications are today an important source of industrial competitiveness and have become more and more important for high-technology industries in recent decades (Tijssen, 2001). While EU-27 beats Japan in terms of publication intensity, its publication intensity is almost 30 percent below that of the US. However, the number of European articles published per capita has had the strongest growth rate of the triad countries between 2001-2002 and 2006-2007.

Table 3.21 Scientific and technical articles per million inhabitants in the triad regions

Triad Region	No. of Scientific Publications 2001-2002	No. of Scientific Publications 2006-2007	Mean Annual Rate of Growth 2001-2002 to 2006-2007 (%)
EU-27	470	504	1.45
USA	666	698	0.96
Japan	442	420	-1.00

Source: World Bank (2010a)

[10] Venture capital involves company investments in seed or start-up capital.

The total number of scientific publications in the world did have an annual growth rate between 1995 and 2008 of 3 percent (NSF, 2010). During this period the market share for the triad regions decreased from 68.1 percent to 53.6 percent. This is a dramatic change and highlights mainly the increasing importance of other parts of Asia besides Japan as a source of scientific output. Here we focus on the changes of market shares within the triad regions, which are illustrated in Table 3.22. All triad regions and the US in particular have had a drop in their market share between 1995 and 2008.

Table 3.22 Market shares in percent in world scientific publications of the different triad regions (Science and engineering articles in all fields, ICI publications)

Triad region	1995	2000	2008
EU-27	30.6	41.7	26.1
USA	30.2	36.9	22.2
Japan	7.3	10.7	5.3
Rest of the world	31.9	35.9	46.4
Total	100.3	100.0	100.0

Source: NSF (2010)

Not all publications are equal. Scientific (ICI) journals can be ordered along a quality distribution. The US dominates publications in high quality journals, but the trend is negative (See Table 3.23). The EU share of cited articles in the top 1 percentile is roughly half of that of the US but the trend is positive in this case.

Table 3.23 Trends in scientific publication shares across the quality distribution among the triad regions

Triad region	Share of articles in TOP 1 percentile citations			Share of articles in TOP 10 percentile citations			Share of articles in Bottom 50 percentile citations		
	1995	2000	2005	1995	2000	2005	1995	2000	2005
EU-27	24.7	25.9	29.0	31.8	34.8	34.3	32.7	35.2	34.2
USA	62.3	59.9	54.6	49.7	44.6	41.7	31.6	28.4	25.8
Asia-10	4.9	5.6	7.5	7.4	9.0	12.0	14.0	16.8	20.6

Source: NSF (2008)

Notes: TOP 1 = 99^{th} percentile of citations received (> 21), TOP 10 = 90^{th} percentile (> 6), BOTTOM 50 contains the publications with 0 or 1 citations. 1995 are all 91-93 articles cited by 1995 articles; 2000 are all 96-98 articles cited by 2000 articles; 2005 are all 2001-2003 articles cited by 2005 articles.

No data available for Japan only. Asia-10 includes China (includes Hong Kong), India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand

The capacity to produce high quality research should naturally be a function of the availability of researchers with PhD training. Table 3.24 reports the distribution of PhDs awarded in the triad regions in 2007 together with each regions share of triad scientific publications in 2008. The information in the table is very interesting. EU-27 is dominating in terms of PhD education as well as in terms of the number of scientific publications compared with the other triad regions. However, the US produces more scientific publications per capita as can be seen in Table 3.21. Furthermore, the US has a much larger share of articles in the Top 1 and the Top 10 percentile citations than Europe and Japan. This raises many questions: Is the European PhD education not effective enough to train PhDs for high quality international publication? Is the NSF data underreporting high quality scientific publications in other languages but English? Do European PhDs go into other career tracks than the academic career, perhaps due to the low investments in R&D by European businesses?

Table 3.24 The distribution of PhDs awarded in the triad regions in 2007 together with each regions share of triad scientific publications in 2008 (percent)

Triad region	Share of triad PhD degrees awarded in 2007 (%)	Share of triad scientific publications in 2008 (%)
EU-27	55	48.6
USA	35	41.5
Japan	10	10.0
Total	100	100

Source: PhD degrees from Eurostat (2010); Scientific publications from NSF (2010)

3.5 Summary of chapter

This chapter has summarized Europe's position in a knowledge generating context through its performance of various knowledge-based indicators. The evidence presented above indicate that

- Europe is lagging behind the two other triad regions in terms of investments in science and technology.
- the gap is larger for business-related indicators than for publicly funded R&D
- Europe lags behind the other two regions in terms of performance in science and technology as shown by the patenting statistics
- Europe is increasing its competitiveness on the global market for high-tech exports, whereas both the US and Japan have lost market shares. Even so, Europe still lags behind the US and Japan in per capita figures.
- Europe lags behind the US in terms of high quality scientific publications. Although the quantity of published articles is higher in Europe, the number of publications per capita is lower in Europe.

The next section discusses knowledge flows and the ways a country/region can improve its absorptive capacity of knowledge spillovers. In chapter 5, Europe's ability to absorb knowledge from the other triad regions through different channels of knowledge flows will be analysed.

4 An introduction to knowledge flows and knowledge generation

This section will introduce the reader to the different forms and channels of knowledge flows and how knowledge spillovers are absorbed. Knowledge as an economic good has special properties. It is a non-rival and (partly) non-excludable good (Foray, 2004), which implies that it can be used simultaneous by several economic agents (Romer, 1990) to develop new knowledge, i.e., inventors can normally not fully prevent over firms for using the knowledge embodied in their inventions. These R&D or knowledge spillovers (externalities) may benefit the competitors' R&D by lowering the costs of their own R&D activities with potential positive effects on their productivity and competitiveness.

However, the public good character of knowledge does not imply that it is freely available to all economic agents, that it is easily accessible, or even that all economic agents are aware of the existence of specific pieces of knowledge. The transfer and generation of knowledge are far more expensive processes than the transfer and generation of goods and services for in particular two reasons: i) it involves learning which is time-consuming and often needs proximity and interaction between people, and ii) knowledge is to some extent context-specific, local and tacit. This holds even for the current Internet era, since in particular personal or tacit knowledge is complex to transfer. Much knowledge is tacit due to the fact that cognitive capabilities and abstract concepts are difficult to articulate explicitly and thus to transfer between people (Cowan, David & Foray, 2000; Breschi & Lissoni, 2001b).

Thus, knowledge that contains a large tacit (i.e., non-codified or learning-by-doing) component is non-transferable at arm's length, and hence difficult to imitate (Cantwell, 1991). However, within groups of people that shares the same theoretical framework and has a common vocabulary of concepts tacitness need not be a major hindrance for the transfer of knowledge and technology and thus the generation of new knowledge even if learning the theories and concepts might take substantial time, which increases the costs of transfer to outsiders. At the same time, it is certainly true that the Internet drastically has increased the volume of accessible codified knowledge (David & Foray, 1995).

That knowledge is a non-rival good implies that those economic agents that are willing to pay the costs to adopt it, e.g. in the form of a new technology, can do so without interfering with its other's use of the knowledge. The tacit, local, and context-related characteristics of knowledge require specific channels for interregional and in particular international knowledge flows. There is plenty of empirical evidence that, for example, international technology transfer is associated with substantial costs (Teece, 1977; Mansfield & Romeo, 1980; Ramachandran, 1993). This should not be a surprise, not least since technology can be transferred both in the form of tangible assets such as new products and equipment, and in the form of un-tangible assets such as patents, licences, information and knowledge (Howells, 1998).

Thus, to access knowledge deliberately, economic agents must be prepared to create the necessary knowledge links and pay the associated transaction costs. Knowledge networks like other networks possess key features such as reciprocal exchange relationships among the partners with a potential to stimulate intentional reciprocal explicit and endogenized knowledge flows. However, knowledge and other networks may also stimulate unintentional implicit and exogenous knowledge flows, so called knowledge spillovers without the partners involved being aware of this.[11] Knowledge spillovers occur when knowledge generated by one economic agent is used by another economic agent without the knowledge-generating economic agent getting any compensation or a compensation that is lower than the value of the knowledge (Fischer, 2001). The reason that knowledge can spill over is that it in particular in codified form only is a partially-excludable good (Romer, 1990). However, for codified knowledge to spillover, the code must be known and economic agents might have to do prior investments into absorptive capacity to understand, internalise and use the knowledge developed elsewhere (Cohen & Levinthal, 1990).

Thus, the ability of employees and firms to absorb tacit and codified knowledge depends on their prior investments in R&D and training and the general level of skills, experiences and

[11] Much discussion and analysis of knowledge spillovers has become contaminated because of unclear definitions of the concept of 'spillovers' (see e.g. Gordon & McCann, 2000; Echeverri-Carrol, 2001).

education of the employees. The individual employees and the firms are poorly prepared to engage in interaction and learning-by-doing without such investments (Gertler, 2003). This implies that the magnitude of the knowledge transfer strongly depends on the capability of individuals and that knowledge spillovers in many cases are connected with costs. Actually, in the case of tacit knowledge, knowledge spillovers are the result of deliberate actions of economic agents involved in interactions with other economic agents. This motivates that part of the focus when studying knowledge spillovers must be on individuals and their behaviour since an important part of all knowledge is embodied in individuals as tacit knowledge (Polanyi, 1966).

Karlsson and Johansson (2006) argue that from the perspective of a firm one can make a separation of three groups of knowledge flows, which may generate knowledge spillovers:

- transaction-based knowledge flows,
- transaction-related knowledge flows, and
- pure knowledge spillovers.[12]

The three categories are presented in Table 4.1 together with nine types of knowledge flows.

Table 4.1 Classification of knowledge flows to a firm

Knowledge flow category	**Knowledge flow type**
Transaction-based flows	1. Flows from knowledge providers that sell knowledge that is used as an input to a firm's R&D activities 2. Flows in the form of inventions (innovations) that are sold to a firm (e.g., by licensing a patent) 3. Knowledge flows between firms that cooperate in an R&D project, where costs and benefits are regulated by an explicit or an implicit contract, which may or may not be associated with unintentional knowledge spillovers 4. A firm obtains access to knowledge via a merger or an acquisition
Transaction-related flows	5. A flow of knowledge that is embodied in the delivery of inputs from an input supplier to a firm 6. In the course of supplying inputs to a firm, knowledge from the input supplier spills over unintentionally to the input-buying firm 7. In the course of supplying inputs to a firm, knowledge from the input-buying firm spills over unintentionally to the input-selling firm
Pure spillover flows	8. Unintentionally, knowledge spills over from one firm to a competing firm in the same industry 9. Unintentionally, knowledge spills over between firms belonging to different industries

Source: Karlsson & Johansson (2006)

[12] Griliches (1979) makes a distinction between pure knowledge spillovers and rent spillovers, where the latter arise because new goods and services are purchased at less than their fully quality adjusted prices. Transaction-related knowledge flows here represent rent spillovers.

From a firm's point of view one can make a distinction between upstream, downstream and horizontal knowledge and technology flows. Upstream knowledge flows are helpful in generating access to suppliers' knowledge and technology often embedded in inputs bought by a firm. Downstream knowledge flows include the sale of knowledge and technology to customers either as licenses or embedded in products. Horizontal knowledge flows include intended and unintended knowledge and technology flows between firms in the same industry.

Knowledge flows, intentional as well as unintentional, are generally assumed to enable technological progress, to increase competitiveness and to support long-term economic growth and development in many different and complex ways (Cassiman & Veuglers, 2002). New knowledge is created on basis of the existing knowledge stock (Griliches, 1990) and to a high extent by combining existing knowledge pieces, i.e. novelty by combination (Schumpeter, 1934). Thus, knowledge – codified knowledge as well as tacit knowledge embodied in human beings – is the most important input in the knowledge production process. New knowledge and new technologies are certainly not created in some anonymous production process (Fischer, 2001). Instead, they are the result of interaction between often identifiable individuals who previously have accumulated a substantial stock of knowledge in their specific fields of expertise but who also more or less constantly are keeping themselves updated through various knowledge channels to be aware of new knowledge created elsewhere. New knowledge and new technologies are created when these individuals share their knowledge within a larger group of people, e.g. at a university department or in a research institute or a firm's research department (Nanoka & Takeuchi, 1995).

Thus, in order to be able to generate new knowledge combinations, it is critical to have the capacity to absorb existing knowledge through various knowledge channels. Highly-skilled labour educated at universities is necessary for the successful transfer, absorption, and adaptation of knowledge in new contexts (Cohen & Levinthal, 1990). Breschi & Lissoni (2001a) argue that it is important to improve the understanding of the transmission mechanisms of knowledge in addition to measure knowledge spillovers by a rather limited set of indicators. There exist several mechanisms, which support and facilitate the transfer and diffusion of tacit as well as codified knowledge (Cf., Arrow, 1994) and technology:

- through education,
- through communication channels that are interactive and have a high bandwidth (e.g., E-mail, the Internet, etc.),
- through deliberate policy (e.g., organisations setting up scouting and knowledge intelligence units),
- research collaboration,
- through special activities of people in order to obtain and disseminate knowledge (e.g., gatekeepers, cf., Allen, 1977),
- mobility of people with the relevant knowledge and skills,
- international trade in goods, services and technologies,
- foreign direct investments,
- intra-firm knowledge management, and
- through imitation and reverse engineering (cf., Verspagen,1994).

It is important to observe that even if each of these channels or mechanisms can be seen as partly independent, they are often linked to each other in different ways. It is in this connection important to observe that international collaborations are a significant and increasingly important channel for transfer of knowledge and technology in both the private and the public sector (Archibugi & Coco, 2004). An increasing number of partnerships among firms, universities and public research centres as well as between individual researchers and inventors is a clear indication of the growing importance of collaboration (NSF, 2002). Collaboration permits the partners to share and acquire the expertise of each other, thus enriching the overall know-how. It can function as a positive sum game, where the advantages outweigh the disadvantages even if the advantages are not always equally shared among partners (Archibugi & Lundvall, 2001, Eds.). The total number and type of collaborations can be taken as a measure on the one hand of the vitality of the regional, national and international knowledge systems and on the other hand as an indicator of the extent and types of knowledge and technology transfers. The attractiveness of the knowledge base of economic agents will determine the extent to which they are invited to participate in collaborative ventures. This implies that the extent to which economic agents of different kinds in Europe is collaborating with economic agents in the two other triad regions is an indication of the attractiveness of the European knowledge base.

The extent of knowledge flows and knowledge spillovers is generally measured by the patterns of patent and publication citations, technology licencing or the degree of co-patenting and co-publication activities of researchers at universities and research institutes and in industry (Jaffe, Trajtenberg & Henderson, 1993; Audretsch & Feldman, 1996; Crespi, Geuna & Nesta, 2006; Ponds, van Oort & K. Franken, 2007).[13] In this paper, we broaden the scope and concentrate on channels for international knowledge flows and we identify the following channels for international knowledge flows:

1. Academic channels
2. Patent studies
3. Technology trade (including international consulting)
4. Strategic R&D cooperation
5. Trade networks
6. Foreign direct investments (FDIs)
7. International migration

These seven channels for knowledge flows, and Europe's potential to absorb knowledge from these, will be analyzed with reference to the triad regions, in the following chapters.

5 Intra-triad academic knowledge flows

The purpose of this chapter is to highlight how both codified and uncodified, or tacit, knowledge related to academia can spill over across space. Cooperation at both the individual level and the organisational level offers a potential for knowledge flows and knowledge exchange. Furthermore, knowledge is transferred when researchers and scientists study the publications of other researchers and scientists. Such knowledge flows are normally documented by citations of earlier contributions in the field. In addition, the mobility of students and researchers provides knowledge flows to both the home country and the host country. The performance of Europe in this context and its ability to take advantage of these

[13] It is interesting to note that research on other types of linkages between universities and industry other than those related to patents and publications are rare, despite that other channels for knowledge flows and knowledge spillovers, such as consulting, contract research and training programs probably are more frequently used in practice (D'Este & Patel, 2007; Link, Siegel & Bozeman, 2007).

knowledge flows in comparison to the other triad regions is put into focus in the following sections of this paper.

5.1 Knowledge flows through academic co-authorships

Researchers and scientists at different universities, research institutes and even firms, often located in different countries, are increasingly involved in various types of cooperation, such as joint research projects, temporary visits, co-authorships and networking at workshops, symposia and conferences. Cooperation also exists at the organisational level involving joint research centres, joint research programmes, agreements concerning the exchange of students and academic staff, sharing of scientific information, etc. The scope, complexity and cost of certain scientific problems induce research departments, centres and laboratories to start to collaborate with similar units in other countries.

One way to get an indication of the extent of international academic knowledge flows is to analyse to what extent scientific journal articles are internationally co-authored, the trends in international co-authorships and the location of the cooperating scientists. Such co-authorships have increased dramatically in recent decades both absolutely and relatively and so has the number of authors per paper (Adams, et al., 2005).[14] According to Adams, et al., (2005) the number of international collaborations increased five-fold between 1981 and 1999. Obviously, the advantages of collaboration outweigh the increased costs that sometimes might follow with, in particular, international collaboration.

What factors than drive individual scientists to collaborate? The following list gives some important motivations (Mattsson, et al., 2008; Katz & Martin, 1997):

- *financial reasons*, including better access to funding and sharing of core-facilities and databases that individual researchers cannot purchase, which reduces the costs for research in general and for experiments in particular (Andersson & Persson, 1993),
- *social factors*, such as acknowledgement from the scientific community, networking effects (learning to know more people in the scientific community), and/or a preference to work in teams rather than in solitude,
- *knowledge collaborations*, including supervision of students and in particular PhD students and the potential to improve one's technical, analytical, theoretical and methodological knowledge as well as of finding exactly the right research partner(s) (Georghiou, 1998) and taking advantage of the potentials of synergy of ideas (Andersson & Persson, 1993) that follows with idea/theory driven collaborations (Wagner, 2005),
- *political factors*, including the European Framework programmes and other policy-based initiatives supporting scientific collaboration, and
- *increased impact*, including increased productivity and a higher citation frequency for in particular internationally co-authored publications (Lewison & Cunningham, 1991; Glänzel & Schubert, 2001; Persson, Glänzel & Danell, 2004; Rigby & Edler, 2005).

The increase in co-authorships is probably also due to the development of E-mailing, the Internet and to the improvements in international air travelling, which have made it easier and less costly for scientists to meet face-to-face but also the increase in international funding programs (Luukkonen, et al., 1993). Adams, et al., (2005) explain the increase in collabora-

[14] This trend was probably first documented by Smith (1958).

tions with the rise of public R&D investments, the private control of universities, and the increased mobility of PhDs.

Some authors assume that the increases in co-authorships also have increased the quality of scientific publications (Luukkonen, Persson & Sivertsen, 1992; Georghiou, 1998; Glänzel, 2001). The probability that researchers will collaborate internationally is among other things a function of geographical proximity, cultural and language similarities and the supply of funding for international collaborations (Zitt, Bassecoulard & Okubo, 2000).

Table 5.1 gives overall information about the share of co-authored scientific papers in the triad regions. In 2007, half of all the scientific papers in EU-27 were published in cooperation with an author from another country (including another member state). The share of co-authored papers has increased for the triad regions between 2001 and 2007. The table below does not provide information of to what extent European scientists co-author articles with scientists from the two other triad regions. However, such information is provided in Table 5.2 and Table 5.3.

Table 5.1 Percentage of internationally co-authored scientific papers in the triad regions of all scientific papers

Triad Region	**Percentage Internationally Co-authored**			**Annual Growth Rate (%)**	
	1994	*2001*	*2007*	*1994-2001*	*2001-2007*
EU-27	32.1	42.8	49.9	3.0	2.8
USA	15.8	23.2	28.7	5.6	4.0
Japan	13.7	19.7	24.6	5.3	4.1

Source: NSF (2010)

The table above shows that international co-authorships are quite common in Europe.[15] It is interesting to observe in the table below that in 1995-1997 that of the US internationally co-authored papers 60.3 percent involved at least one partner in EU-15 and that the figure has increased since the period 1986-1988. On the other hand, the share of EU-US collaborations of all papers are decreasing between the two periods from 31.9 to 29.0 percent. This is in line with the results reported in Mattsson, et al. (2008); the trend is an Europeanization of co-authorships rather than an internationalisation. It is unclear to what extent this is due to EU's FP[16] programs or to other factors. Even if it from one point of view is positive that researchers within EU cooperate more, it is from the point of view of knowledge transfers negative that European scientists do not cooperate more in terms of co-authored publications with researchers in the US.

[15] It is important to stress that the data is partly misleading. If a Swede publishes an article together with a Dane, then it is counted as an international co-authorship. However, if someone from Boston publishes an article with someone from San Fransisco, then it is counted as a national co-authorship.

[16] The Framework Programs for Research and Technological Development also called Framework Programs are programs funded by the EU to support research. See the European Commission for Research and Innovation; http://ec.europa.eu/research/index.cfm

Table 5.2 Distribution of internationally co-authored papers across the triad regions (share of all papers)

Triad Region	**1986-1988**			**1995-1997**		
	EU-15	*USA*	*Japan*	*EU-15*	*USA*	*Japan*
EU-15	56.6	31.9	3.1	69.4	29.0	4.5
USA	54.9		8.2	60.3	9.6	
Japan	33.3	54.0		39.4	45.6	

Source: NSF (2000)
Notes: Rows report the percentage of the total number of international co-authorships of the region. Columns indicate the relative prominence of a region in the portfolio of internationally co-authored articles in every region. Row percentages may add to more than 100 because articles are counted in each contributing region and some may have authors from more than 2 regions. As regards EU-15, internationally co-authored articles also include those between member countries.

In accordance with Table 5.1, the table below shows that European scientists co-author a considerable quantity of papers with authors from other countries in the world in comparison to the US and to Japan. Furthermore, the number of co-authored papers of authors from Europe and the US and from Europe and Japan roughly doubled between 1998 and 2008. Japanese scientists cooperate with more scientists from Europe than from the US.

Table 5.3 International co-authored papers between the triad regions: 1998 and 2008

Triad Region	**1998**			**2008**		
	EU-19[1]	USA	Japan	EU-19*	USA	Japan
EU-19[1]	-	28,714	4,622	-	53,406	8,243
USA	28,714	-	4,520	53,406	-	6,201
Japan	4,622	4,520	-	8,243	6,201	-
World	102,438	43,254	10,000	184,394	78,348	16,038

[1]EU-19 excludes Luxembourg and Slovakia and does not include articles between member countries
[2]The world also includes countries within the EU-19.
Source: NSF (2010)

The number of co-authored articles should also be discussed in relation to the size of the population of the triad regions. Europe produces almost twice as many articles per capita than the US in international collaboration and about three times as many articles than Japan in the same category (Table 5.4). Europe's share of internationally co-authored articles in relation to total articles published in Europe is 29 percent in 2008, whereas Europe's share of internationally co-authored articles out of the world's internationally co-authored articles is 61 percent the same year (Table 5.5). The share of internationally co-authored articles compared to the regions total articles are roughly the same for the US and Europe and the proportions have not changed much between 1998 and 2008. However, international collaboration on science and engineering articles has increased in all three economies in relation to total science and engineering article output in each region.

Table 5.4 Scientific publications in international collaboration, 2008

Region	**Number of articles, 2008**	**Number of articles per million people, 2008**
EU-27	209,251	429
USA	83,854	275
Japan	18,162	142

Source: UNESCO (2010)

Table 5.5 International collaboration on science and engineering articles: 1998 and 2008 (% of regions total article output and % of world's internationally co-authored articles)

	Share of region's total article output		**Share of world's internationally co-authored articles**	
	1998	**2008**	**1998**	**2008**
EU-27	21	29	66	61
USA	20	30	57	55
Japan	17	26	13	11

Source: NSF (2010)
*Interregionally coauthored articles have at least one collaborating institution from indicated region/country and an institution from outside that region/country.
Detail adds to more than 100% because articles may have authors from more than two countries/economies

5.2 Knowledge flows via citations of scientific contributions

Citation measures have increasingly been used as research performance indicators. A basic underlying assumption is that the number of citations can be regarded as a measure of scientific quality and scientific impact. However, citations can also be used as an indicator of knowledge flows, and, in particular, of flows of codified knowledge, since they are mirror images of the references in scientific publications. The underlying assumption here is of course that scientists cite those works they find useful and helpful in their own research. According to a traditional account of science, the norms of science oblige researchers to cite the works upon which they draw, and in this way acknowledge or credit contributions by others (Merton, 1979). These norms are preserved through informal interaction in scientific communities and through peer review of in particular manuscripts submitted to scientific journals.[17] Furthermore, infringements to these norms might lead to potentially severe sanctions (Davenport & Cronin, 2000). Thus, the use of citations is justified when it comes to finding linkages between scientific publications.

By studying the citation patterns of researchers and not least when scientists start to cite important scientific break-troughs it is possible to get clear evidence of the flows of codified knowledge both within and between countries. In Table 5.6, the world shares of cited papers published in the US, Europe and Japan by citation percentile are presented. The US is clearly outperforming the other two regions with 51.6 percent of the world's articles in the top 1 percentile. Japan is far behind that of both Europe and the US. Table 3.1 showed that Europe produces the largest share of the world's science and engineering articles, a surprising fact considering the citation statistics. Whether this is an indication of that European articles are of lower quality than articles published in the US remains a topic of discussion.

[17] It is important to observe that other incentives may prevail, such as the importance of creating visibility of one's work, and being selective in referencing to create a distance between oneself and others.

Table 5.6 Share of cited papers in the triad region, by citation percentile: 1998 and 2008

Citation Percentile	No. of citations	EU-27		USA		Japan	
		1998	2008	1998	2008	1998	2008
99	≥21	25.1	29.6	62.0	51.6	4.3	4.5
95	9–20	30.7	32.5	52.9	44.1	5.5	5.2
90	6–8	33.9	33.6	46.2	39.2	6.8	6.1
75	3–5	36.0	34.7	40.2	34.7	7.9	6.7
50	2	36.4	34.4	35.9	30.2	8.9	7.6
<50	0–1	34.3	32.4	30.0	24.8	8.9	8.5

Source: NSF (2010)

The US outperforms both Europe and Japan when it comes to highly cited articles in all science and engineering categories as can be seen in Table 5.7. However, the gap between Europe and the US is contracting in all categories except engineering between 1998 and 2008. The index will be higher if the region's share of world articles is lower.

Table 5.7 Index* of highly cited articles in triad region: 1998 and 2008

Field	EU-27		USA		Japan	
	1998	2008	1998	2008	1998	2008
All science & engineering	0.73	0.89	1.83	1.78	0.50	0.58
Engineering	0.97	0.88	1.61	1.84	0.73	0.57
Chemistry	0.77	1.02	2.40	2.13	0.67	0.73
Physics	0.88	1.04	2.00	2.00	0.68	0.62

Source: NSF (2010)
*Index of highly cited articles is country's share of world's top 1% cited articles divided by its share of world articles for the cited year window.

Although Europe lags behind the US in their share of highly cited articles, it was discovered in section 5.1 that European researchers engage in international cooperation to a larger extent. Again, Table 5.8 shows that a much larger percentage of European articles has at least one foreign co-author than what is the case for the US and Japan. Even so, average number of citations per article is substantially higher in the US (3.4) than in Europe (2.3) and Japan (2.0).

Table 5.8 Scientific and engineering articles with foreign co-authorship and average number of citations per science and engineering (S&E) article: 2005

	Western Europe	USA	Japan
S&E articles with foreign co-authorship (% of total number of S&E articles)	55.6	26.6	23.0
Average number of citations per S&E article	2.3	3.4	2.0

Source: World Bank (2010b)

5.3 Knowledge flows through temporary and permanent mobility of academic researchers and scientists

All academic researchers and scientists that temporarily or permanently move between the triad regions bring their embodied knowledge with them and create opportunities for knowledge spillovers and temporary movers may of course bring new knowledge back to their home region. In particular, it seems as if some key researchers, so-called star scientists are important knowledge spillover agents when it comes to the transfer of new scientific knowledge into new technologies, since they are carriers of unique knowledge resources. This claim is supported by Zucker & Darby (2006). Star scientists as well as other highly educated workers are in general more spatially mobile than average workers. The increased globalization of the labour markets for highly educated people in recent decades has increased the potential for spatial mobility for this group of workers.

There is no generally accepted definition of the concept ‘star scientist’. However, they are carriers of a significant amount of up-to-date knowledge and furthermore, their reputation is related to their superior visibility and central relevance to their field of study due to an outstanding research performance. Their overall importance is unclear for the generation of new knowledge and for the transfer of new knowledge to industrial applications but it seems as if they might play a critical role in some fields. Thus, it would be of interest to get information about the mobility of star scientists between the triad regions, since they might represent an especially important mechanism for international knowledge transfers.

As Table 5.9 shows, the share of foreign advanced researchers in relation to all advanced researchers is almost twice as high in the US as it is in Europe. Even Japan has a higher share of international advanced researchers compared to Europe.

Table 5.9 International researchers enrolled as a percentage of all researchers (international plus domestic), 2008

Region	Advanced research programs
EU19 average	14.9
USA	28.1
Japan	16.2

Source: OECD (2010b)

Table 5.10 indicates that a quite large percentage of the European and Japanese PhD students in the US intend to stay in the country after the completion of their studies.

Table 5.10 Temporary visa holder doctorate recipients intending to stay in the United States after doctorate receipt, by country of citizenship, 2007

Place of origin	Number	% staying
Europe	11997	69
Japan	1690	51

Source: OECD (2010b)

The US seems to attract more foreigners to advanced research programs than Europe. This might again be an indication that the quality of advanced research is (or is believed to be) greater in the US. Furthermore, the attractiveness of the US for international researchers might highlight the existence for career opportunities for junior researchers. The ability of the

US to attract and keep a large share of PhD students from abroad is a great advantage for its innovation capacity and competitiveness. According to previous research, doctoral students contribute to the advancement of research during their studies and afterwards (OECD, 2010b).

Language plays a large part in the location decision of international students and is a great advantage for English-speaking countries and for Spain (Latin American students). Other factors, like geographical proximity, cultural and historical links, etc are also important. Most foreign PhD students in the US are from Asia, whereas foreign PhD students in Europe are mainly from other European countries (OECD, 2010b).

5.4 Knowledge flows through student exchange and degree seeking students

The temporary mobility of students creates knowledge flows between the host country and the country of origin. This mobility allows for the build up of international personal and professional networks, which can function as channels for future knowledge transfers. The number of international students in tertiary education enrolled outside their country of residence in 2007 amounted to 2.5 million, an increase of 59.3 percent since 2000 (OECD, 2010b).

Table 5.11 shows that Europe has a larger percentage of foreign students enrolled in tertiary education compared to all students than both the US and Japan in 2008. As the index of change in the number of foreign students in tertiary education indicates, the increase of foreign students between 2000 and 2008 in tertiary education has been much larger in Europe than in the other triad regions.

Table 5.11 Student mobility - International students enrolled as a percentage of all students (international plus domestic), 2008

Triad region	**Total tertiary**	Tertiary-type B programs[2]	Tertiary-type A programs[1]	Index of change in the number of foreign students, total tertiary (base year: 2000 = 100)
EU-19 average	5.9	2.7	6.2	220
USA	3.4	1	3.4	131
Japan	2.9	2.9	2.6	190

[1]Tertiary-type A programs (ISCED 5A) are largely theory-based and are designed to provide sufficient qualifications for entry to advanced research programs and professions with high skill requirements, such as medicine, dentistry or architecture.
[2]Tertiary-type B programs (ISCED 5B) are typically shorter than those of tertiary-type A and focus on practical, technical or occupational skills for direct entry into the labour market, although some theoretical foundations may be covered in the respective programs.
Source: OECD (2010b)

The data in the table above is somewhat misleading since for example a student from France enrolled in Great Britain will count as a foreign student, whereas a student from California, enrolled in Pennsylvania will not.

The evidence above has showed that European countries co-authors articles with researchers from abroad to a larger extent than the other triad regions. This is positive since it increases Europe's potential to take advantage of knowledge flows from external sources. Europe lags behind the US, however, in terms of the quality of published articles. The US also receives more advanced researchers from aborad which might contribute to a stronger performance in the production of qualitative research. Europe receives a larger share of exchange students, which could generate knowledge flows. However since these figures include students moving between EU countries, they are rather misleading. The next chapter will discuss how knowledge can flow through patents.

6 Intra-triad knowledge flows via patents

Patents are one of the most important invention indicators to assess the technological profile and productivity of innovation systems (supra-national, national, regional or sectoral), since it is a well-defined output measure of R&D processes (Freeman, 1982; Grupp, 1998; Frietsch & Schmoch, 2006). They offer important advantages for analyzing technological activities: i) general availability and international comparability, ii) exhaustive coverage across countries and technology fields, iii) most significant inventions are patented, iv) readily access due to official publication, and v) long time series. Patents offer a rather complete description of i) the invention, ii) the technology field concerned, iii) the inventor(s), iv) the applicant, and v) citations to previous patents and scientific articles to which this invention is related.

Patents may generate spillover benefits, which may extend over local, regional and national borders (Jaffe, 1986; Griliches, 1992). A key measure of knowledge spillovers from patents is the distribution of (backward) patent citations across spatial (or/and technological) boundaries, since the patent citations indicate knowledge flows because citations provide information about the state-of-the-art technological background of the invention and thus codify the passage of ideas (Jaffe, Trajtenberg & Henderson, 1993; Jaffe, Fogarty & Banks, 1998; Jaffe, Trajtenberg & Fogarty, 2000).

The purpose of this section is to illustrate how citations of earlier patents in patent applications, citations in scientific publications in patent applications and international collaboration in patent applications can contribute to knowledge flows between the triad regions. These channels are analyzed in order to get an impression of to what extent and how effectively European inventors use these knowledge sources.

6.1 Knowledge flows via patent citations

Jaffe et al. (1993) interprets patent citations in the following manner; a reference to a previous patent indicates that the knowledge in that patent was in some way useful for developing the new knowledge described in the citing patent. Like most indicators, patent citations are not a perfect indicator for various reasons. One major issue concerns the assumption that all subsequent inventions actually build directly upon the knowledge contained in a cited patent. Since patent citations are not only generated by inventors but also by patent attorneys and/or patent examiners, it is natural that they are a noisy indicator of knowledge flows from cited inventions to citing inventors (Jaffe, Trajtenberg & Fogarty, 2000; Alcacer & Gittelmann, 2004).

There are also other problems connected to patent citations. Depending on the rules of the different patent systems, the list of citations may be a redundant or an incomplete list of prior arts (Michel & Bettels, 2001; Lemley & Tangri, 2003). Backward citations reflect the scope of the patent and a patent examiner may have to include more references if the scope of the patent is large. However, a higher number of backward citations causes the content of the patent to be more restricted and therefore limits its possible value (Harhoff, Scherer & Vopel, 2003).

An inventor applying for a patent at the USPTO is legally required to include a full list of prior art known, or believed, to be relevant. The examiner will then remove or add to the list. Patent applications to the EPO, on the other hand, need not to include such a list with citations to prior art. Most citations are added by the EPO examiner in this case. Applicants to the USPTO might provide more references than necessary and the USPTO examiner may not have time to check them all. This difference in the application procedure could partly explain the fact that the average number of citations in USPTO patents is much greater than those found in EPO patents (Michel and Bettels, 2001). Thus, there is a risk that patent citations may both under- and over-represent knowledge flows from prior arts (Nelson, 2009), which implies that we have to interpret the results from patent citation analyses with care.

Regardless of these complications, patent citations can be considered as indicators of technological relevance. Table 6.1 and 6.2 show EU citations to EPO and USPTO patents. Europe’s share of the total number of patent citations is much larger for EPO patents than for USPTO patents.

Unsurprisingly, the share of European patent citations of the total number of citations is larger at the EPO than at the USPTO. The number of European patent citations referring to non-EU patent publications are much greater at the USPTO than at the EPO for all years. The importance of the US market is underlined through this observation. The number of European patent citations referring to European patent publications is about twice as high at the USPTO as at the EPO in 2000. However in 2004, the number of European patent citations referring to European patent publications is higher at the EPO than at the USPTO. This observation indicates that patent citations at the EPO are becoming more important for European inventors. The number of European patent citations to both EU publications and non-EU patent publications has decreased rather drastically both at the EPO and at the USPTO during the time period. This reason for this is that the EPO and USPTO are trying to make the research process more efficient (Frietsch et al., 2010). Unfortunately, we do not have corresponding figures for US and Japanese patent citations.

Table 6.1 EU-27 patent citations at the EPO

	2000	**2001**	**2002**	**2003**	**2004**	**2005**
Share of EU-27 in the total number of patent citations	0.38	0.41	0.39	0.4	0.42	0.43
Number of EU-27 patent citations referring to non-EU patent publications	3,636	2,871	2,400	2,017	1,466	894
Number of EU-27 patent citations referring to EU patent publications	5,445	5,008	4,205	3,794	3,186	2,286

Source: Eurostat (2010)

Table 6.2 EU-27 patent citations at the USPTO

	2000	**2001**	**2002**	**2003**	**2004**
Share of EU-27 in the total number of patent citations	0.13	0.12	0.1	0.09	0.07
Number of EU-27 patent citations referring to non-EU patent publications	34,034	27,515	19,282	11,750	6,325
Number of EU-27 patent citations referring to EU patent publications	11,576	8,958	6,241	4,226	2,404

Source: Eurostat (2010)

Criscuolo and Verspagen (2008) mention that EPO citations might be broader in scope than for example USPTO citations since the patent examiners do not limit their search to prior art written in English or to patents issued by one particular patent office. 90 percent of citations in USPTO are to other USPTO patents according to Michel and Bettels (2001) findings. In contrast, they find that only 23.3 percent of citations in EPO are to other EPO patents, which is a little lower than the figures in Table 6.1 (38-43 percent), although these figures are for later years. Furthermore, Michel and Bettels (2001) found that 30.9 percent of citations in EPO are to USPTO patents, 16.3 percent to WIPO patents, 13.1 percent to German patents, 6.2 to Brittish patents, 5.2 to Japanese patents, and 5 percent to other patents. These data illustrate the bias for domestic patents in the USPTO. In addition, Sampat (2005) suggests that patents granted by USPTO might be of lower quality if they cover technological fields where most prior art is not contained in US patents.

Hagedoorn and Cloodt (2003) showed that the number of patents filed by a firm and the average citations received by those patents are positively correlated with the development of new products. Frietsch et al. (2010) assert that patents are a means to increase absorptive capacity within a firm; both trough stock measures (number of patents) and quality measures (counts of citations received). Self citations have been used as a indicator of the value of patents as enhancing the absorptive capacity within a firm, since they suggest that a firm has a strong competitive position in a specific technology (Frietsch et al., 2010).

Mancusi (2008) uses self citations as a function to measure a country’s past experience in research in order to capture the country’s ability to understand and exploit external knowledge. She argues that positive externalities generated by international technology flows will crucially depend on such ability. Self citation is used as proxy for absorptive capacity since it indicates that the applicant has now generated a new idea building upon his/her own previous research in the same or a related technology field. Mancusi (2008) shows in her paper that absorptive capacity increases the elasticity of a laggard country's innovation to international spillovers, while its marginal effect is negligible for countries at the technological frontier. The objection to using self citation as a proxy for absorptive capacity is that it might be seen as an indicator of deepening of internal technological capability along a specific technological trajectory, which limits a country’s absorptive capacity.

Table 6.3 shows the share of citations to the inventors previous own patented work (self), to other national patents or to international patents for selected European countries as well as the US and Japan. Japan has the largest share of self citations followed by Belgium and the US. Moreover, Japan and the US have much smaller shares of international citations compared to the European countries. This could either imply that Japan and the US have a stronger absorptive capacity or that the European countries are more inclined to build their work on previous research from abroad, and therefore take better advantage of international knowledge flows. The evidence suggests that there are no significant barriers against knowledge flows between the European countries.

Table 6.3 Percentage share of citations by type (patent applications at the EPO): 1991–1999

Country*	Self	National	International	Total
Belgium	23.6	5.4	71.0	100
Germany	17.3	24.2	58.4	100
Spain	12.2	5.5	82.3	100
Finland	11.5	14.8	73.7	100
France	15.7	14.2	70.1	100
UK	18.7	15.7	65.6	100
Italy	17.2	15.1	67.8	100
Netherlands	20.3	7.4	72.3	100
Sweden	14.3	10.4	75.4	100
USA	21.5	38.7	39.8	100
Japan	26.6	32.6	40.7	100

*Country refers to the citing patent.
Source: Mancusi (2008)

In Table 6.4 the direction of international citations are displayed for selected European countries, the US and Japan. Most citations are to patents from the US, followed by Japan and Germany. European countries cite patents from the US to almost the same extent as patents from other European countries.

Table 6.4 Percentage distribution of international citations by country (patent applications at the EPO):1991–1999

	Cited country											
Citing country	**BE**	**DE**	**ES**	**FI**	**FR**	**GB**	**IT**	**NL**	**SE**	**Sum EU***	**US**	**JP**
Belgium	–	14.0	0.5	0.9	6.8	9.8	3.5	4.4	1.5	41.4	36.2	19.7
Germany	1.6	–	0.4	1.8	9.7	9.7	5.2	3.9	2.9	35.2	36.7	25.7
Spain	1.1	18.6	–	1.7	9.8	9.3	8.8	3.1	2.4	54.8	28.0	15.0
Finland	1.1	12.9	0.4	–	4.9	9.4	2.4	3.0	9.8	43.9	35.3	17.2
France	1.3	18.1	0.5	1.5	–	9.2	4.6	3.3	2.4	40.9	36.2	20.4
UK	1.5	14.5	0.4	1.5	7.1	–	3.1	3.6	2.4	34.1	44.3	18.7
Italy	1.5	20.7	0.7	1.0	10.2	7.9	–	3.4	2.3	47.7	30.0	19.9
Netherlands	1.9	14.3	0.4	1.6	6.3	8.1	3.2	–	2.2	38	35.5	23.7
Sweden	1.2	14.4	0.3	5.6	5.2	8.8	3.6	3.2	–	42.3	37.3	17.2
USA	2.1	18.4	0.4	1.7	9.2	14.3	4.1	4.5	3.2	57.9	–	37.5
Japan	1.5	17.4	0.3	1.4	7.0	9.1	3.3	4.5	1.9	46.4	50.6	–

*Sum of the selected European countries
Note: the percentages in the table refer to the share of citations from the citing country directed towards the cited countries (row sums are equal to not equal to 1 since a few countries have been excluded).
Source: Mancusi (2008)

The statistics above indicate that Europe is better at taking advantage of knowledge from abroad in their use of previous patents when creating new knowledge.

6.2 Knowledge flows via science cited in patents

The capacity to create and to absorb new knowledge from the research frontier is of crucial importance for developing and maintaining leading technological positions in science based industries. This prevails in particular in newly emerging fields (Verbeek, Debackere & Luwel (2003), where firms rely increasingly on external sources of scientific knowledge (Meyer, Debackere & Glänzel, 2010). The science-dependence of technology can be analyzed by an alternative form of "patent citation analysis" pioneered and further developed by Narin and his colleagues (Narin & Noma, 1985; Narin, Hamilton & Olivastro, 1995 & 1997). Citations to science literature in successful patents indicate the extent of use of past research in practical advances. The literature linkage data in patents emphasize patterns of the impact of academic science research on potential technological development (NSF, 2010).

In Tables 6.5 and 6.6, we illustrate the geographical distribution of citation flows to published literature present in triad USPTO and EPO patents, respectively. The results for Europe are interesting in several respects. Firstly, Europe is less outward-looking than either US or Japan with a domination of citations from European publications. Secondly, Europe is making fewer references to US publications than the US make to European publications. Thus, American inventors seem to be much more interested in the European science-base than the European inventors are interested in the American science-base. Is the European absorptive capacity for new knowledge produced in the US lower than the American absorptive capacity for new knowledge produced in the US? Or could it be the case that there is a mismatch between the science-base and the industrial-base in Europe?

Table 6.5 Geographic distribution of citation flows to published literature present in triad USPTO patents (percent)

Triad relation	1987-1991	1992-1996
US to US	51	47
US to EU-15	32	36
US to Japan	8	6
EU-15 to EU-15	54	54
EU-15 to US	28	30
EU-15 to Japan	8	6
Japan to Japan	29	26
Japan to US	36	32
Japan to EU-15	28	33

Source: Verbeek, Debackere & Luwel (2003)

Table 6.6 Geographic distribution of citation flows to published literature present in triad EPO patents (percent)

Triad relation	1987-1991	1992-1996
US to US	41	35
US to EU-15	34	45
US to Japan	8	7
EU-15 to EU-15	57	59
EU-15 to US	24	23
EU-15 to Japan	9	6
Japan to Japan	30	25
Japan to US	28	26
Japan to EU-15	34	38

Source: Verbeek, Debackere & Luwel (2003)

Table 6.7 illustrates the geographic distribution of citation flows to published literature in biotechnology patents 1992-1996 within the triad regions. What is in particular interesting is that US inventors seem to use European literature to a much higher extent that European inventors use US literature. The question is why. We also see that European inventors cite European publications much more frequently than US inventors cite US publications.

Table 6.7 Geographic distribution of citation flows to published literature in biotechnology patents 1992-1996 within the triad regions (percent)

Triad relation	USPTO patents	EPO patents
US to US	48	34
US to EU-15	47	39
US to Japan	7	4
EU-15 to EU-15	60	59
EU-15 to US	30	22
EU-15 to Japan	5	4
Japan to Japan	26	22
Japan to US	23	32
Japan to EU-15	40	38

Source: Verbeek, Debackere & Luwel (2003)

In the case of information technology (Table 6.8), European inventors are more likely to make citations of US publications than US inventors of European publications. EU inventors also cite European publications to a much lesser extent that US inventors cite US publications. However, we do not know the reasons to these patterns.

Table 6.8 Geographic distribution of citation flows to published literature in information technology patents 1992-1996 within the triad regions (percent)

Triad relation	**USPTO patents**	**EPO patents**
US to US	51	43
US to EU-15	30	34
US to Japan	6	6
EU-15 to EU-15	35	29
EU-15 to US	45	38
EU-15 to Japan	10	21
Japan to Japan	22	18
Japan to US	51	43
Japan to EU-15	28	29

Source: Verbeek, Debackere & Luwel (2003)

What Tables 6.7-6.8 tell us is that the knowledge flows obviously differ between different knowledge fields. But why is this? Do inventors in different fields in a given region behave differently, i.e. is it a question of inventor culture? Or could it simply be that European biotechnology research is much larger and has a higher quality than European research in information technology?

6.3 Cross-border patenting

Cross-border inventions as a share of all inventions measured by patents are increasing, re-flection the globalisation of firms, R&D and technology. Cross-border patents (corresponding to MNFs inventions abroad)[18] accounted for more than 17 percent of all patents in 2003. However, there is a substantial variability across regions and countries in terms of the motives, the characteristics and the effects of cross-border R&D regarding knowledge flows (Guellec & Zuniga, 2008). A central question here is the size of the knowledge flows to Europe generated by these cross-border flows between the triad regions and the knowledge benefits related to these knowledge flows?

Guellec & Zuniga (2008) define cross-border patents as patents corresponding to "cross-border" inventions made by foreign MNF affiliates, where the applicant (the owner) and the inventor reside in two different countries. In those cases where two or more inventors are involved, co-inventors might come from other countries including the home country of the actual MNF, which implies that knowledge flows might go in both directions. The assumption made here is that such a cross-border patent is coming out of R&D performed at an MNF affiliate located in another country than the home country of the MNF. Based upon the information contained in these patents it is possible to compute two indicators of cross-border ownership of patents at the country level[19] (Guellec & van Pottelsberghe, 2001:

- Foreign ownership of domestic inventions, which refers to patents, which are applied by a firm from abroad and which have at least one domestic inventor. The number of such patents can also be divided by the total number of domestic inventors. This indicator reflects to what extent foreign firms control domestic inventions.

[18] Cross-border patenting may of course also occur without the involvement of MNFs due to inventor networks involving inventors in different countries that are not affiliated to MNFs but we disregard such patents here since they with high probability are less common and less important.
[19] The same indicators can be used for the triad regions.

- Domestic ownership of inventions made abroad, which refers to patents, which are granted to a firm in a given country but whose inventions have been made abroad with at least one foreign inventor. The number of such patents can then be divided by the total number of patents owned by firms in this country regardless of the country of residence of the inventors. This indicator reflects to what extent domestic firms in a country control inventions made abroad involving inventors from foreign countries.

Table 6.9 and Table 6.10 show the extent of international cooperation in patents of the triad regions. When it comes to the number of patent applications to the EPO, European researchers seem to engage in more international cooperation than the US and Japan. However, a larger share of the US patents applied at the EPO has been performed in cooperation with abroad. The US and Europe cooperate with each other to a much larger extent than with Japan.

Table 6.9 International cooperation in patents - Patent applications to the EPO, 2007

Region	Total Patents	Patents with foreign co-inventor(s)				% of patents with foreign co-inventor(s)			
		Total co-operation with abroad	EU-27	USA	Japan	Total co-operation with abroad	EU-27	USA	Japan
EU-27	59 623	5 251	..	2 696	294	8.8	..	4.5	0.5
USA	31 950	4 447	2 696	..	238	13.9	8.4	..	0.7
Japan	20 830	620	294	238	..	3.0	1.4	1.1	..
Rest of World	125 472	10 118	7 996	4 447	620	8.1	6.4	3.5	0.5

Source: OECD (2010a)

The number of patents granted by the USPTO that are performed in international cooperation is actually lower than the number of patents applied at the EPO that are performed in international cooperation. The European share of patents with foreign co-inventors is much larger than for the other two regions. Again, Europe and the US cooperate to a much larger extent with each other than with Japan. However, the share of US patents with European co-inventors is fairly low. In fact, Europe co-invents 21.2 percent of its patents granted at the USPTO with inventors from the US (Table 6.10). The US co-invents only 8.4 percent of its patents applied at the EPO with inventors from Europe (Table 6.9). This observation, could indicate that the US market is more attractive for patent applications, but also that Europe engage in more international cooperation with abroad, which is positive in the sense of knowledge transfer.

Table 6.10 International cooperation in patents – Patents granted at the USPTO, 2007

Region	Total Patents	Patents with foreign co-inventor(s)				% of patents with foreign co-inventor(s)			
		Total co-operation with abroad	EU-27	USA	Japan	Total co-operation with abroad	EU-27	USA	Japan
EU-27	2 818	748	..	595	28	26.5	..	21.1	1.0
USA	26 647	1 706	595	..	157	6.4	2.2	..	0.6
Japan	5 034	215	28	157	..	4.3	0.6	3.1	..
Rest of World	41 382	2 229	853	1 706	215	5.4	2.1	4.1	0.5

Source: OECD (2010a)

Europe seems to build new knowledge on previous knowledge from abroad to a greater extent than the other triad regions as evident by patent citations. Inventors from the US and Japan cite their own work and national work much more than European inventors do. In terms of knowledge flows via science cited in patents, the direction of knowledge flows seems to differ depending on the specific field. European inventors also engage in cross-border patenting in relation to total patents to a larger extent than the other triad regions. In the next chapter, knowledge flows via technology trade will be analyzed.

7 Intra-triad knowledge flows via technology trade

Firms seeking to derive value from their innovation strategies and their intellectual assets can use technology licensing as a powerful tool (Brousseau & Coeurderoy, 2005). Licenses give firms an opportunity to increase their market share rapidly and at low costs. Transborder licensing is an alternative to exports and/or production abroad to commercialise knowledge at foreign markets and represents flows of codified knowledge. This chapter underlines how import and export of technology trade contribute to knowledge transfers between different regions. Data on royalty and license payments (import) and receipts (export) of the triad regions will illustrate Europe's position in technology trade in comparison to the US and Japan.

Fast changing and technology-intensive firms often consider licensing as an efficient governance mode (Oxley & Sampson, 2004). However, licensing firms risk exposing valuable knowledge that might be appropriated by their licensing partners (Oxley, 1999; Teece, 2000). The reason is that the transfer of knowledge between firms is a complex process and subject to many hazards since the licensor has great difficulties *ex post* to control how the transferred intangible intellectual property is used and at the same time, the licensee might have learnt enough to successfully compete with the licensor (Caves, Crookel & Killing, 1983). It must be observed that not only firms but also universities, research institutes and independent institutes can license their intellectual property rights to derive value from their inventions.

Licenses are an attractive measure of knowledge flows, since a licensee typically has to pay i) an upfront fee, and/or ii) an annual fee and/or a percentage of annual revenues of the products produced using the license. Compared to patent citations, licensing indicators should be able to reflect a more explicit relationship between the licensee and his/her licensed patent.

International technology trade is registered in the technology balance of payments that measures intellectual property right transactions between firms and sectors in different countries, i.e. technology transfers with a commercial objective. An advantage with the technology balance of payments is that it provides data in terms of different currencies and thus gives an indication of the economic relevance of each individual technology transfer (Archibuigi, 1988). On the other hand, we must acknowledge that all those technology transfers that are not object to commercial transactions are excluded.

One question that arises is how we shall interpret the technology balance of payments of various regions and countries. If a country in relation to its size has high inflows of license and royalty payments (receipts), we might interpret that as if the country is very successful in getting value from its intellectual property rights. However, there is also another possible interpretation. High inflows might signal that the country in relative terms is very successful in generating innovations but that the rights to use these innovations are sold abroad instead of being developed at home. This might have to do with the institutional framework in the country (North, 1990), lack of entrepreneurs, lack of venture capital, etc. If a country instead in relative terms has high outflows of license payments, there are also two possible interpretations. A first possible interpretation is that such a country is taking advantage of knowledge and technologies developed in other countries. A second possible interpretation is that such a country is not investing enough in R&D and is forced to buy knowledge and technology abroad instead. However, whatever the interpretation we can look upon the relative outflows of license and royalty payments as an indication of the extent to which a region or a country benefits from knowledge and technology flows from other regions and countries.

Europe imports much more royalty and license fees than the US and Japan together, a trend that has been rising rapidly between 2002 and 2008 (Figure 7.1). This is an indication suggesting that either Europe does not invest enough in R&D or that the region is successfully taking advantage of other countries' knowledge and technology.

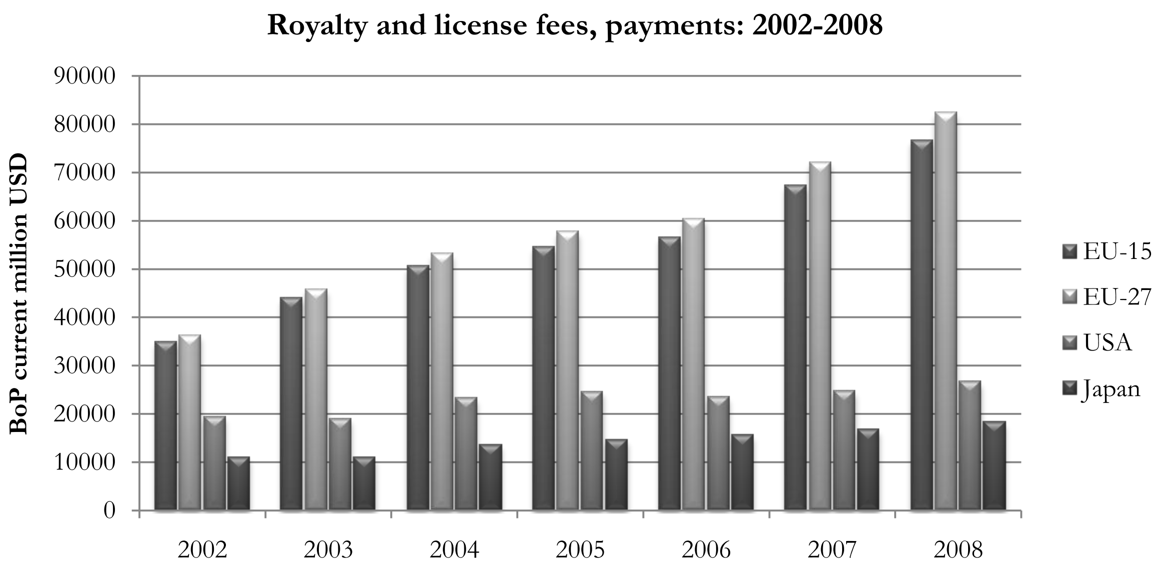


Figure 7.1 Royalty and license fees, payments BoP, current million USD (See appendix, Table 14.3 for exact data)
Source: World Bank (2010a)

Figure 7.2 shows that both EU-15 and EU-27 receive lower royalty and license fees payments than the US, although higher than Japan. In effect, the US obtains more value from its intellectual property rights. All regions are increasing their exports of royalties and licenses during the time period.

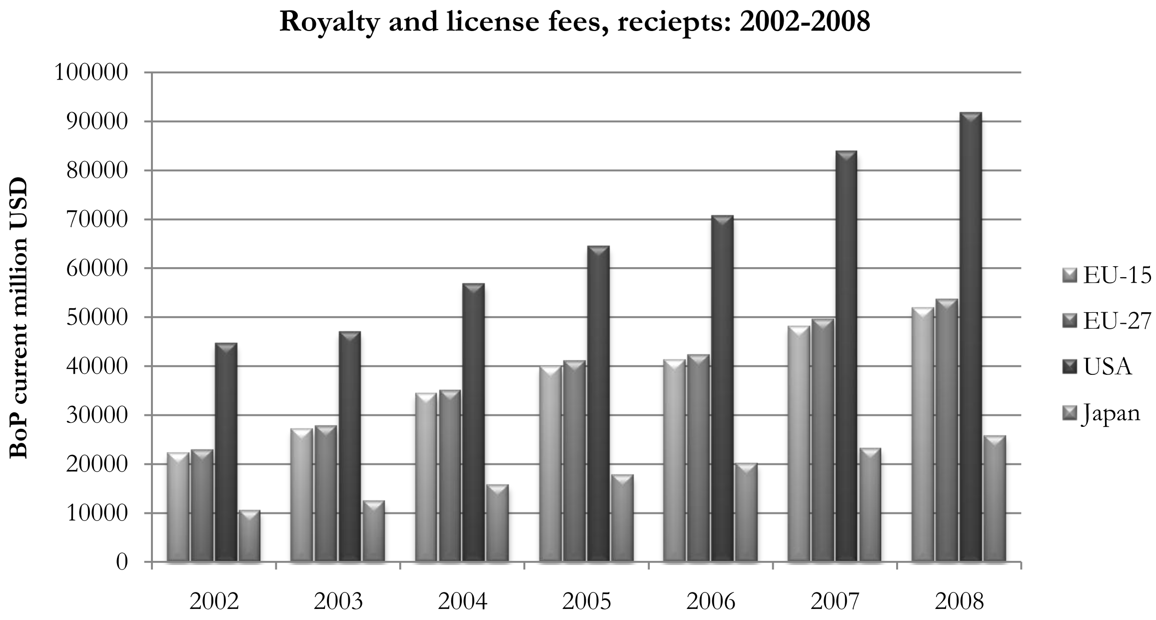


Figure 7.2 Royalty and license fees, receipts (BoP, current million US$) (See appendix, Table 14.2 for exact data)
Source: World Bank (2010a)

As can be seen in Figure 7.3 Europe pays increasingly more for royalty and license fees than the region receives in payments. The net export of the US however, has been positive since 2002 and almost tripled between 2002 and 2008, where it amounts to USD 64,985 million (see appendix Table 14.4 for exact data).

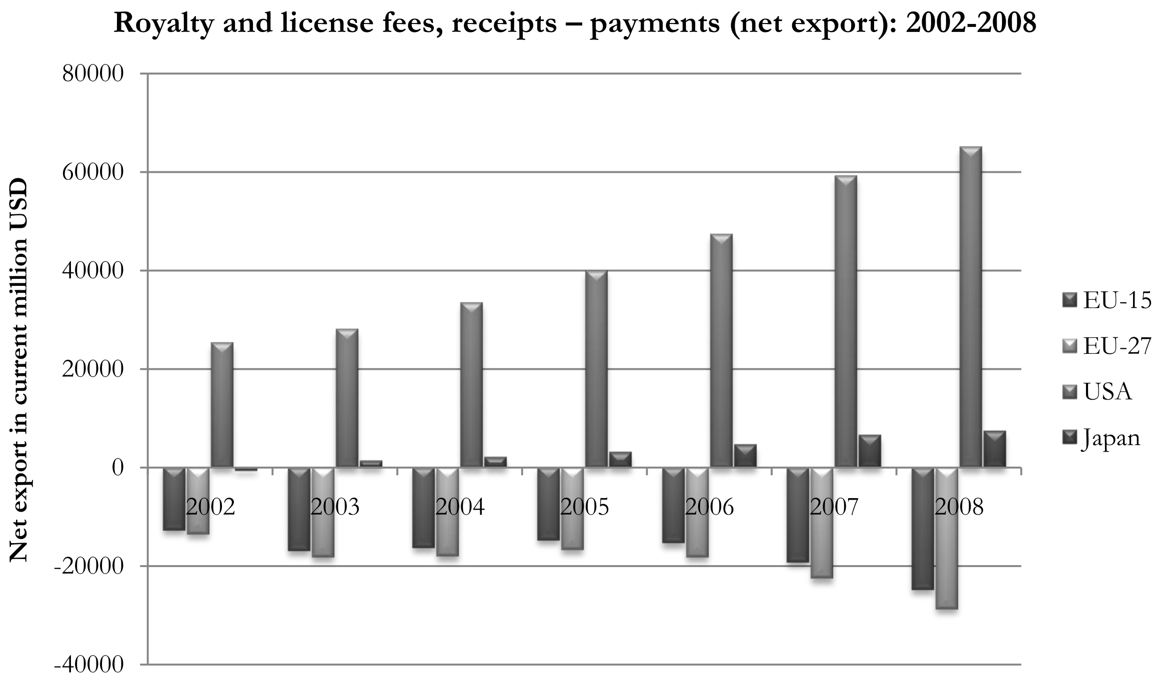


Figure 7.3 Royalty and license fees, receipts – payments (net export in USD million) (See appendix Table 14.4 for exact data)
Source: World Bank (2010a)

It might be more interesting to relate the figures above to the size of the regions and their population. Western Europe (see appendix Table 14.1 for countries included) and Japan receive about the same value of royalty and license fees from other countries per capita in 2007. The US exports the most in form of royalty and license fees also per capita. Western Europe has a deficit of net exports of royalty and license fees per capita, in contrast to the other regions which both have a surplus.

Table 7.1 Royalty and licence fees figures per capita, 2007

	Western Europe	USA	Japan
Royalty and License Fees Receipts (US$/pop.)	187	237	182
Royalty and License Fees Payments (US$/pop.)	601	93	131
Royalty and License Fees Receipts – Payments (US$/pop.) (exports - imports)	-414	144	51

Source: World Bank (2010b)

The information given above indicates that Europe pays a high price per capita in order to buy technology in comparison to the US and Japan. In this context, Europe has the possible to take advantage of knowledge flows through high levels imports of licenses and royalty fees. However, the tables above also highlight the concern that Europe does not invest enough in R&D in order to develop enough of its own knowledge and technology. The following chapter will outline the extent of strategic R&D cooperation across borders in the triad regions.

8 Intra-triad knowledge flows via strategic R&D cooperation

One source of knowledge that has become increasingly important in recent decades is technological cooperation between firms in the form of strategic R&D alliances or partnerships (Hagedoorn, 1996; Archibugi & Coco, 2005), which is a substitute to both the licensing of knowledge and mergers and acquisitions as well as joint ventures[20]. It seems as if alliances are the preferred means when firms want to access complementary assets (Lundan & Hagedoorn, 2001). R&D alliances stand for the specific set of different modes of inter-firm collaboration where two or more firms, that remain independent economic agents share and coordinate some of their R&D activities to achieve a common goal. R&D cooperation between firms is a flexible mode of cooperation and can have three major forms[21]: i) upstream cooperation, where a firm develops new technology in cooperation with one or several supplier(s), ii) downstream cooperation, where a firm develops new technology in cooperation with one or several customer(s), and iii) horizontal cooperation, where a firm cooperates with one or several competitor(s) to create mutually beneficial shared resources, such as new technological standards.

This chapter aims to introduce the reader to the concept of knowledge transfers through cross-border cooperation in R&D investments. Reasons behind strategic R&D alliances are explained along with some background information on the specifics of this type of cooperation agreement. Recent trends are highlighted through data on R&D alliances between the triad regions at the end of this chapter.

Empirical evidence shows that agreements to do cooperative R&D have been increasing since the 1980s in the OECD countries (Busom & Fernández-Ribas, 2008). The percentage of patent co-applications in triad patent families has almost doubled since 1980, and the number of strategic R&D alliances has, on average, almost tripled (Hagedoorn, 2002; OECD, 2002).

Different hypotheses have been launched to explain the incentives of firms to have research cooperation with other (competing) firms and with public research organisations ((Lundan & Hagedoorn, 2001; Caloghirou, Ioannides & Vonortas, 2003; Sena, 2004):

- In order to develop innovations and to shorten the innovation cycles firms needs to search for and take advantage of expertise and competence in other firms in the same or related fields to access complementary intangible assets, mainly tacit knowledge and know-how, which cannot be easily contracted and monitored through market-based transactions and to minimize these problems firms enter cooperative arrangements (Winter, 1987; Sinha & Cusumano, 1991; Katsoulakos & Ulph, 1998). By bringing together a variety of knowledge sources, skills and experiences, the potential for generating new combinations increases (Inkpen, 2000: Hagedoorn & Duysters, 2002; Grant & Baden-Fuller, 2004; White, 2005).
- Strategic R&D alliances can be motivated by a need to share the costs and decrease the risks of R&D projects but also to exploit economies of scale and scope in R&D. Cost and risk sharing are in particular important in emerging industries and in technology fields with a rapidly changing technology.

[20] Joint ventures are not discussed in this report since strategic R&D alliances in the form of joint ventures have become relatively rare (Hagedoorn, 2002).
[21] Firms can also have R&D co-operation with universities, R&D institutes, etc., but such co-operations are beyond the scope of this report.

- A third hypothesis concerns the role of incoming and outgoing knowledge spillovers, where incoming knowledge spillovers relate to the advantages for firms to absorb and exploit knowledge generated by others including improved learning efficiency (Sakakibara, 2003). Outgoing knowledge spillovers occur when knowledge generated in one firm leaks out and is absorbed and used by other firms. If a firm's appropriability mechanisms are weak, its incentives to carry out R&D are reduced. R&D partnerships may under such circumstances provide a mechanism for internalising knowledge spillovers (Katz, 1986).
- R&D cooperation may enable partners to increase market power in product markets (Martin, 1994).
- Strategic R&D alliances may reduce unnecessary duplicated work, resource waste and the risks of patent races (Reinganum, 1989).
- Strategic R&D alliances allow firms to tap into competitors' competencies when the acquisition of such knowledge would be prohibitively expensive through acquisition of of full or partial ownership.

Given these basic reasons for strategic R&D alliances one might ask why the number of such alliances has increased in recent decades. One obvious reason is the increase in the R&D costs of firms due to the fact that firms need to speed up the innovation process in a world with an intensified competition as a result of the globalisation trend and an increasing complexity of modern technology. Strategic alliances are in particular prevalent in high-tech sectors, which might be explained by i) the need for organizational learning, ii) the importance of learning and the speed of technological change is such sectors (Ciborra, 1991; Oster, 1992; Yu & Tang, 1992; Hagedoorn & Sadowski, 1999).
These strategic R&D alliances involve a two-way relationship where knowledge is a crucial component, and tend in most cases to be based on contracts that cover technology and R&D sharing between two or more firms in combination with joint research or joint development projects. These contracts specify where and by whom the specific research is to be carried out. Even if these contracts have a limited time-horizon, due to their project-based organization, each partnership as such appears to ask for a relatively strong commitment of the firms making up the partnership and a solid inter-organizational interdependence during the joint project, which creates a foundation for knowledge transfers between the firms involved.

The R&D cooperation contracts are relational and they differ from traditional contractual outsourcing in the sense that the exact characteristics of the research output are not known beforehand. R&D alliances are strategic in the sense that they represent a long-term planned activity (Mowery, 1992a; Mytelka, 2001). The strategic intent of R&D alliances is apparent in those cases where firms jointly perform R&D in new, high-risk fields, which future importance for their technological capabilities remains unclear for a considerable period of time (Hagedoorn, 2002). R&D alliances will certainly influence both the extent and the location of innovative activities, in terms of the share of MNF R&D conducted abroad and the share of R&D funded by MNF affiliates (Dunning & Lundan, 2009).

Strategic R&D alliances are a source of knowledge and signal where firms seek expertise (Narula & Hagedoorn, 1999). We may assume that a firm's choice of type and number of partners will be influenced by the relative importance of the above hypotheses, which importance differs between different industries, the nature of the R&D project and the costs of establishing the necessary contacts and contracts. When firm search for complementary knowledge assets and skills the probability is high that they will form asymmetric partnerships, where partners are heterogeneous in terms of firm size, knowledge assets, market scope and location, product range, etc. When the ambition is to internalise outgoing knowledge spill-overs or to increase market power firms are more likely to establish symmetric partnerships involving horizontal cooperation with actual or potential competitors (Röller, Siebert & Tombak, 2007).

International alliances are generally considered an important element in the international strategies of a growing number of firms (Yoshino & Rangan, 1995). Firms among other things build international inter-firm partnerships for international sourcing of R&D. Increased international competition has induced many firms to follow a strategy including international R&D alliances despite problems such as i) limited control in long-distance collaboration, ii) limited trust between firms from different countries, iii) information asymmetries, which may stimulate opportunistic behaviour, and iv) the high asset specificity of R&D (cf., Williamson, 1996). This implies that the expected benefits from international R&D cooperation often are substantial.

It is against this background interesting that, the total number of strategic R&D alliances doubled from the early 1980s to the late 1990s but the share of international alliances of all new alliances declined from 70 to 50 percent (Hagedoorn & Lundan, 2001). In Table 8.1, we present information about the distribution of strategic R&D alliances between firms in the triad regions. It is obvious that it is strategic R&D alliances between Europe and the US that are dominating and that the trend is increasing. During the 20-year period, the number of strategic R&D alliances increased with 260 percent.

Table 8.1 The Distribution of strategic R&D alliances between firms in the triad regions

Triad Region Relation	**1980-82**		**1989-91**		**1998-2000**	
	No.	%	No.	%	No.	%
EU-27-Japan	16	15.0	25	13.7	19	8.3
EU-27-USA	48	44.9	101	55.2	173	75.2
Japan-USA	43	40.2	57	31.1	38	16.5
Total	107	100	183	100	230	100

Source: NSF (2002)

One reason why European firms are attracted to form strategic R&D alliances with firms in the US might be that the total amount of resources devoted to science and technology R&D is much greater in US firms. Thus, the larger number of alliances between European and US firms might be the result of the amount of resources invested in R&D by US firms. This is tested in Table 8.2 where the number of European alliances is divided by the total amount of US and Japanese business R&D expenditures, respectively. The greater propensity of European firms to cooperate with US firms is confirmed. While, the European academic community seems to have a decreasing propensity to cooperate with scientists in the US, the European business community shows an increasing propensity.

Table 8.2 Propensities for strategic R&D alliances, 1980-2000. Number of agreements involving European firms by BERD of the region in billion constant USD (PPP-adjusted)

Period	**USA**	**Japan**
1980-1982	0.61	0.71
1989-1991	0.86	0.50
1998-2000	1.07	0.32

Source: NSF (2002); OECD (2010)

More recent data on strategic R&D alliances between US firms, US and European firms, and US and Japanese firms confirms the upward trend towards more international cooperation. Interestingly, the number of alliances between USA and Europe is approaching the number of alliances between US firms only. Again, strategic alliances between Europe and the US are dominating even in recent years.

Table 8.3 U.S. industrial technology alliances with U.S. and foreign-owned companies, worldwide: 1990–2006 (annual counts of **new** alliances)

Year	**USA only**	**USA-EU-27**	**USA-Japan**	**Total**
1990	139	86	35	260
1995	259	173	47	479
2000	167	149	27	343
2001	210	151	34	395
2002	135	127	34	296
2003	220	147	41	408
2004	246	158	51	455
2005	259	185	47	491
2006	249	207	54	510

Source: NSF (2010)

The knowledge flows that potentially emerge when organisations engage in R&D cooperation might be indicated by using the co-patent measure. When two or more organisations have a project-oriented collaboration, the benefits are usually not only confined to the collaborative project but knowledge may flow and/or spillover in a manner that influences and changes the innovation strategies, processes and activities of the organisations involved (Feldman & Kelley, 2006). The co-patent measure in the last decade has become a frequently used variable measuring R&D collaboration (Hicks & Narin, 2001; Guellec & van Pottelsberghe de la Potterie, 2001; Hagedoorn, van Kranenburg & Osborn, 2003). However, it seldom is treated as an indicator of knowledge flows.

In terms of absorption capabilities of knowledge flows, the increasing trend of strategic R&D alliances of European firms with firms from the US is a positive sign. The next chapter emphasizes the importance of imports of goods as a channel for knowledge transfers.

9 Intra-triad knowledge flows via trade networks

The critique of the assumption of the Heckscher-Ohlin model that the production technology is the same across countries and its ability to explain the effects of innovation and technological change on international trade stimulated the development of the product cycle model of international trade (Posner, 1961; Vernon, 1966 & 1979; Krugman, 1979; Dosi & Soete, 1983 & 1991). This model is based upon some fundamental assumptions, including i) a dynamic change of production technology, ii) different abilities in different countries to exploit new technologies, and iii) the existence of an imitation lag, i.e., it takes time for follower countries to absorb new technologies developed in leader countries and to apply them in the manufacturing sector. Products based upon new superior technologies under these circumstances will be sold under conditions of monopolistic or oligopolistic markets, at least temporarily, before the followers catch up. Firms located in technology advanced countries, like the countries making up the triad, will develop and compete with new or improved products integrating new knowledge and new technology.

In this section, we argue that under these circumstances effective links for the import of new knowledge, new technology and new products are vital for the long-term ability for regions to keep or to improve their competitiveness. The basis for this statement is the following observation: The R&D activities in each triad region only make up a share of the total volume of R&D investments in the world economy. Thus, the frequency of innovation in different triad regions is not only or even mainly dependent upon their own investments in R&D but in particular upon their exposure to a diverse set of imports of new knowledge, new technology and new products.

It is in the literature often assumed that trade between countries acts as a conduit for the dissemination of knowledge between countries (Dollar, Wolff & Baumol, 1988; Grossman and Helpman, 1991 a & b; Grossman and Helpman, 1994; Marin, 1995) and as a complement to domestic R&D. In a study of 22 industries in 10 OECD countries, Fagerberg (1996) with a number of control variables regressed exports in 1985 on three R&D measures: i) direct R&D investment, ii) indirect R&D investment in the form of purchases of capital and intermediate goods, and iii) foreign share of indirect R&D. He found that the effect of indirect R&D overall was double that of direct R&D, with a larger impact from indirect R&D on exports from sectors with a low R&D-intensity and a larger impact of direct R&D on exports from high-tech sectors. Imported new products also generate strong incentives for imitations and other innovative reactions to the import flow, since these products have passed two types of tests:

- It has been proved that there exist technical solutions for the new product that works.
- The import flow verifies that there exist customers, i.e. there is a market for the product.

This type of information is of great importance in the innovation process, since innovation generally is associated with a high degree of risk and uncertainty (Kleinknecht and Poot, 1992).

Knowledge can flow between different spatial units in different channels but it is a widely held view that imports of goods and services is one important channel for knowledge imports[22], which can contribute to faster technological progress and higher rates of productivity growth (Helpman, 1997). However, imports may influence growth in different ways. Keller (2000) presents a model suggesting that the pattern of a country's intermediate goods imports affects its level of productivity because it primarily imports such goods from technological leaders in the world. He finds in a study of eight OECD countries that differences in technology inflows related to the patterns of imports explain about 20 percent

[22] The importance of imports in this respect has been stressed among others by Hirschman (1958) and Jacobs (1969) and (1984).

of the total variation in productivity growth. An alternative approach stresses that trade enhances growth through the import and creation of new varieties (Broda, Greenfield & Weinstein, 2006): i) trade increases productivity levels because producers gain access to new imported varieties, and ii) increases in the number of varieties drives down the cost of innovation and results in ever more variety creation. The authors find that in the typical country of the world, new imported varieties account for 15 percent of its productivity growth.

These new analyses of the relationship between trade, technological progress and growth in open economies have been stimulated by the development of theories of endogenous growth (Romer, 1990; Aghion & Howitt, 1992), which has been extended also to include open economies (Grossman & Helpman, 1991 a; Rivera-Batiz & Romer, 1991). By integrating the endogenous growth theories in general equilibrium models, it becomes possible to analyse how trade in both intermediate and final goods affects long-term economic growth. According to Grossman & Helpman (1991a), growth rates are higher when new technology easily flows across international borders. In this framework, knowledge is embodied in intermediate products and thus new technologies are diffused as these products are bought by other firms. There are two main versions, since R&D can produce new intermediate products that are i) different compared to incumbent products – the horizontally differentiated inputs model, or ii) better than incumbent products – the quality ladder model. When such products are imported to a country, its productivity will increase as a result of knowledge creation among its trading partners.

Despite numerous studies of the effects of trade on growth, it has turned out to be difficult to establish robust empirical links between trade and growth. Hallak & Levinsohn (2004) describe three types of "basic methodological shortcomings" in cross-country studies: i) typically trade policy or openness is represented by a one-dimensional index with a weak theoretical basis, ii) important variables are omitted, which leads to biased and non-robust results (Sala-i-Martin, 1997; Rodriguez & Rodrik, 2001; Noguer & Siscart, 2005 & 2006), and iii) the heterogeneity in economic conditions across countries is so large that it is unrealistic to believe that the effects of trade on growth follow the same patterns in all countries. Broda, Greenfield & Weinstein (2006) present estimates that preserve the cross-country and cross-industry richness of the global economy by breaking world trade down into 6-digit bilateral import flows, and estimating hundreds of structural parameters per country.

9.1 Intra-triad knowledge flows via imports of goods

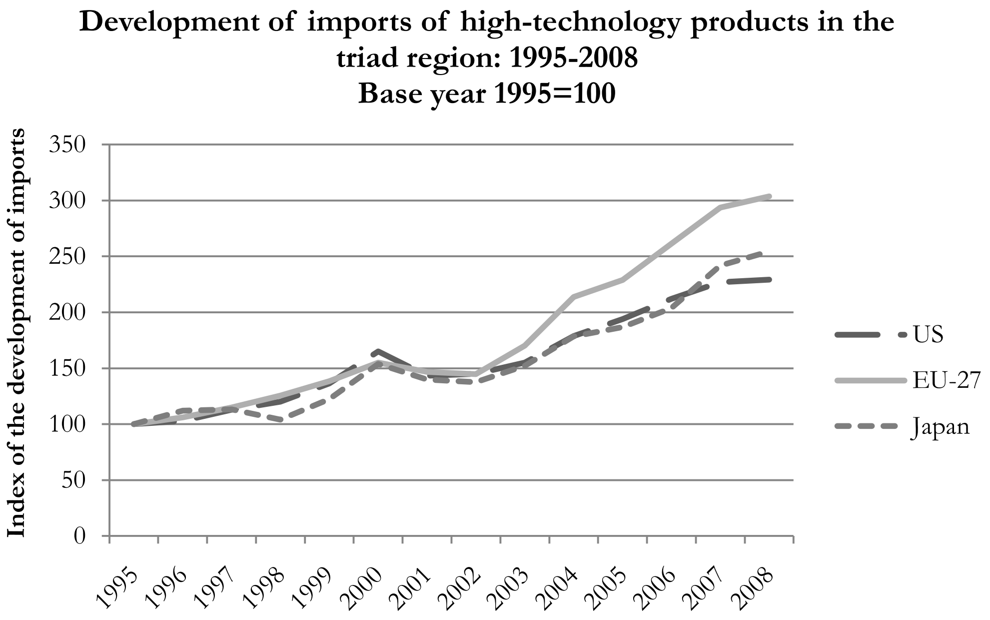
In Table 9.1 we illustrate the imports of high-tech products in triad regions in 1995 and 2008. We see that more than 40 percent of the total imports of high-tech products in the triad go to Europe.

Table 9.1 Imports of high-tech products in triad regions in 1995 and 2008 (millions of USD)

Triad region	1995	1995 (%)	2008	2008 (%)	Total growth 1995-2008 (%)
EU-27*	141,886	38.7	430,835	44.9	203.6
USA	170,852	46.6	391,737	40.8	129.3
Japan	53,757	14.7	136,816	14.3	154.5
Total	366,495	100	959,388	100	161.8

Source: NSF (2010)
*EU imports involves trade only with countries outside of the EU.

In order to get a more dynamic picture of high-technology imports, the figure below shows an index of these imports to EU-27, the US and Japan between 1995 and 2008. The growth of high-technology imports has been the highest in Europe since 2002-2003 and this trend continues until the most recent year of data available.



Source: NSF (2010)

It is of value to complement the information in Table 9.1 and Figure 9.1 with the information in Table 9.2. In the latter table we acknowledge that the European economy is larger than both the US and Japanese economies. The picture that emerges is very interesting. The imports per capita of high-tech products in Europe are lower than that in Japan and substantially lower than that in the US. If we assume that high-tech imports are an important channel for knowledge and technology inflows for a any geographical unit, we might reach the conclusion that one reason why Europe underperforms in terms of economic growth is low imports of high-tech products per capita.

Table 9.2 Imports of high-tech products per capita in the triad regions (Euros/capita)

Triad region	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
EU-25	400	536	507	458	437	474	499
USA	658	932	811	749	645	666	719
Japan	439	644	563	520	486	516	543

Source: EC (2007)

On the world market, Europe’s shares of high-tech imports as well as high-tech exports are higher than the shares of the US and of Japan as can be seen in Table 9.3.

Table 9.3 World market share of high-tech trade (intra EU-trade excluded): 2006 and 2007

Region	Import 2007	Import 2008	Export 2007	Export 2008
EU-27	18.0	19.2	16.6	17.8
USA	16.6	17.0	14.4	15.0
Japan	5.5	5.4	7.8	7.7

Source: Eurostat (2010)

The table below shows that Europe and the US import almost the same value of information and communication technology (ICT) products. The largest share of the imports comes from Asia in 2008. This is a significant change compared to 1995, when the US contributed to more than 25 percent of the ICT imports to Europe and Japan. The table reflects the rise of China as the world's largest assembler and exporter of electronic goods.

Table 9.4 United States', EU's, and Japan's imports of ICT goods, by selected economy of origin: 1995 and 2008 (millions of current USD)

Importing region	Region of origin	1995	1995 share of imports from all countries (%)	2008	2008 share of imports from all countries (%)
EU-27	World excluding intra-EU	93,324		257,120	
	US	23,899	25.6	22,746	8.8
	Japan	20,206	21.7	27,512	10.7
	Asia-9*	31,462	33.7	70,159	27.3
	China and Hong Kong	7,571	8.1	105,032	40.8
USA	World	137,804		256,638	
	EU	10,248	7.4	11,847	4.6
	Japan	38,451	27.9	20,124	7.8
	Asia-9*	60,508	43.9	71,701	27.9
	China and Hong Kong	9,593	7.0	103,950	40.5
Japan	World	35,978		95,324	
	US	10,497	29.2	5,311	5.6
	EU	3,241	9.0	2,988	3.1
	Asia-9*	18,203	50.6	37,601	39.4
	China and Hong Kong	3,580	10.0	48,126	50.5

Source: NSF (2010)
*Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand and Vietnam.

9.2 Intra-triad knowledge flows via imports of services

Trade in services is less important than trade in goods measured both in absolute values and as shares of GDP. The major reason is of course that services have a lower tradability than goods. Still we cannot neglect that trade in services is a potentially important knowledge source. If we exclude intra-EU service imports, EU-27's service import share of GDP in 2007 was 3.5 percent (8.3 percent if we include intra-EU service trade), which can be compared with 3.4 percent for Japan and 2.7 percent for the US (Havlik, Stollinger, Pindyuk & Hunya, 2009). In Table 9.5 we present the sectoral structure of the service imports in the triad regions in 2007. In terms of potential knowledge flows, we can observe that the import share for royalties and license fees for EU-27 is significantly lower than for the US and in particular Japan. The import share for other business services, which most probably contain a high share of knowledge-intensive business services, on the other hand, is higher for EU-27 than for Japan and substantially higher than for the US.

Table 9.5 Sectoral structure of the service imports in the triad regions in 2007 (percent of GDP)

Service sector	**EU-27**	**USA**	**Japan**
205 Transportation	23.4	25.3	30.9
236 Travel	25.4	21.4	21.9
245 Communication services	2.4	2.1	0.6
249 Construction	1.7	0.5	5.0
253 Insurance	1.9	11.3	2.6
260 Financial services	4.1	5.0	2.3
262 Computer and information services	2.7	3.9	2.3
266 Royalties and license fees	4.6	6.6	10.5
268 Other business services	23.9	13.8	22.0
287 Personal, cultural and recreational services	1.2	0.4	0.8
291 Government services	1.2	9.6	1.1
Other	7.4	0.0	0.0
Total	100	100	100

Source: Havlik, et al., (2009)

9.3 Measuring the quality of imports of goods through unit values

The unit value of imports is the quotient of the import value divided by the weight in kilograms. Some products for which their nominal quantity measure is not reported in kilograms have been excluded from the calculations that will follow below. In some industries, the unit value is a good indicator of price competitiveness, whereas it can be a good measure of quality competitiveness in other industries (Aiginger, 1997). On the one hand, in homogenous markets where techniques available throughout the world is used; price competition is important, margins are zero and unit values will reflect average costs. On the other hand, a higher unit value in markets where quality, product innovation, and the adaptation of the product to specialized needs are important, will reflect the ability to set prices and face inelastic markets. A higher unit value will reflect technological superiority of the product in this latter case.

The unit value of imported high-technology products is much higher for the US than for the other two triad regions as can be seen in Table 6.9 (the other industries are included for comparison). This can either imply that the US imports more high-quality, sophisticated high-technological products than the other two regions, or that the US pays more for identical products due to successful marketing campaigns in the US.

Table 9.6 Unit value of imports of products in different sectors during the last decade (2000-2009)

Classification according to OECD	EU-27	USA	Japan
Capital-intensive	0.74	0.74	0.98
Labour-intensive	5.44	5.42	6.78
Scale-intensive	1.30	1.44	1.83
Differentiated products	12.41	11.93	11.39
High-technology	**23.29**	**36.45**	**25.41**

Source: Own compilation of UN Comtrade (2010) statistics

Table 9.7 emphasizes the difference of the unit values of imports. The unit value of import of high-technological goods to Europe is only 64 percent compared to the unit value of high-technology imports to the US. The figures for Europe and Japan are more similar. Even though Table 9.1 showed that Europe imports more high-technology products, the US imports high-technology products of more advanced quality.

Table 9.7 Relative unit values of imports of high-tech goods to Europe and the US or Japan (unit value of imports to EU-27 / unit value of imports to USA or Japan).

	Quotient of unit value of imports of high-tech goods
EU-27 --> US	0.64
EU-27 --> Japan	0.92

Source: Own compilation of UN Comtrade (2010) statistics

Japan, and especially the US, import more high-technology products per capita and the imports of high-technology products have a higher unit value, indicating a more sophisticated quality. Europe has, however had a stronger growth rate in recent years of high-technology imports, which indicates that the region is catching up with the other triad nations. This is a positive trend since high-technology imports is an essential channel of potential knowledge flows to Europe. In chapter 10, the impact of multinational firms and foreign direct investments in Europe and by European firms in the triad regions are discussed.

10 Intra-triad knowledge flows via FDIs

Globalization and the associated improvements in transportation and communication technologies in recent decades have made it possible for multinational firms (MNFs) to spread their value-creating activities at a global scale. The geography of the innovative activities of MNFs has evolved in a parallel process, i.e. the knowledge-creating and knowledge-sourcing activities of MNFs have gradually become more and more international. Even if the internationalisation of the innovative activities of MNFs has lagged behind the internationalisation of their productive activities (Dunning & Lundan, 2009), MNFs today play a critical role for the transfer of knowledge between different parts of the world (Breznitz, 2007; Taylor, 2009).

The purpose of this section is to get a better understanding of knowledge flows via MNFs based on intra-firm networks and foreign direct investment flows. A theoretical approach is mainly attempted in order to establish Europe's position and ability to absorb knowledge through intra-MNF networks. However, data on FDI is presented and discussed in a knowledge-based context.

10.1 Intra-triad knowledge flows via intra-MNF networks

One reason is that foreign affiliates today play a much more central role in the knowledge-creating activities of the MNF as a whole by linking the internal innovation network with the regional and national innovation systems in which they are embedded. Another reason is the rapidly increasing number of MNFs from a wider range of home countries has made the innovative activities of MNFs much more geographically dispersed. However, the patterns of internationalisation of R&D show a tendency for 'triadisation' rather than globalisation in the sense that the international R&D effort to a high extent is concentrated to the triad regions (Meyer-Krahmer & Reger, 1999; Kuemmerle, 1999b; von Zedtwitz & Gassman, 2002). Most active in internationalising R&D is European firms undertaking 58 percent, US firms undertaking 33 percent and Japanese firms undertaking 10 percent of all internationalised R&D (Patel & Vega, 1999). Furthermore, within the triad, R&D is concentrated within existing agglomerations (Rozenblat & Pumain, 1993; Cantwell & Iammarino, 2000).

The overall effect of these developments is that the international flow of knowledge and technology within MNFs has increased substantially as their subsidiaries have come to play increasingly important roles as centers of learning and R&D (Ghoshal & Bartlett, 1988; Gupta & Govindarajan, 1991; Asakawa, 2001; Iwasa & Odagiri, 2004). This argument applies mainly to MNFs located in developed countries (Dunning, 1998) and in particular to those located in the triad regions (Asakawa, 2001). From a European perspective, it is against this background motivated to ask how Europe is affected by the current trends: To what extent does Europe derive benefits from the presence in Europe of MNFs from the two other triad regions? To what extent do the innovation activities in European MNFs benefit from the presence of their subsidiaries in the two other triad regions? There exist no official data on the knowledge and technology flows within MNFs. To get idea about the extent of these knowledge flows we are directed to theoretical analyses and empirical studies using various indirect measures.

From an innovation point of view, MNFs can be seen as mechanisms for international knowledge and technology transfers and as knowledge and technology generators. By means of asset- or knowledge-exploiting investments, which might be conducted for various reasons, such as market-, resource- or efficiency-seeking, MNFs transfer knowledge and technology from the home base to host countries in particular by means of new products and new processes. Despite the increase in the R&D that MNFs do abroad, these new products and processes is to a high extent the result of R&D investments in the home country (Hennart, 2007). MNFs want to internalise such transactions due to imperfections in the markets for knowledge and technology (Buckley & Casson, 1976 & 1985). MNFs as knowledge and technology generators perform asset- of knowledge-seeking/augmenting investments to expand their knowledge-base and to keep themselves up-to-date with the innovative activities of competitors.

Actually, Bresnman, Birkinshaw & Nobel (1999) claim that MNFs maximize their innovative output when they renew their innovative capabilities by transferring, sourcing, combining and integrating innovative knowledge using various strategically advantageous international locations.[23] An underlying motivation for this claim is that due to the cumulativeness and path-

[23] In earlier research on MNFs' innovative activities it was often claimed that innovation is an activity with limited knowledge flows across borders that is and should be a centralized activity at the parent firm location (Vernon, 1966; Dunning, 1980; Cantwell, 1989; Patel & Pavitt, 1991) due to the need for physical co-location of

dependence of innovation an international strategy focusing on knowledge diversity is necessary to avoid the risks of ‘lock-in’ into technological and institutional cul-de-sacs (Michie, 1998; Redding, 2002). Knowledge diversity increases the pool of know-how a firm can access and combine, which stimulates the innovation process, since innovation to a high extent is based upon the principle novelty by combination (Leonard-Barton, 1995; Glassman, 2001). Furthermore, new innovation strategies unfolds when firms have to deal with diverse uncertainties and complexities in their economic milieu (Simon, 1985; Kaufman, 1995; Patel, Kaufman & Madger, 1996; Andriani, 2001).

To better understand the role of MNFs for international knowledge and technology flows and the effects of these flows, we need to analyse

- the intra-MNF knowledge transfers between regions and countries,
- the extent and the effects of knowledge transfers for the receiving economy when MNFs perform asset- or knowledge-exploiting investments, and
- the extent and the effects of knowledge transfers for both host and home country when MNFs perform knowledge-seeking investments.

Concerning the impact of MNF’s R&D abroad, it is in particular interesting to analyze the impacts of intra-MNF knowledge flows in terms of effects on:

- the home country’s technology base (“hollowing out” versus expansion of national capacity), and
- the host country’s technology base (“knowledge drain” versus local knowledge development).

Data on R&D investments performed by MNFs in Europe and the US sheds some light on the extent of potential knowledge transfers through intra-MNF networks. US MNFs performed a total of 28,484 millions USD on R&D investments in the world in 2006 (NSF, 2010). 18,628 million USD (65 percent) of these were spent in affiliates in EU-27 and 1,739 million USD (6 percent) were spent in affiliates in Japan. In total, foreign affiliates in the US spent 34,257 million USD on R&D investments (NSF, 2010). Out of this, European multinationals USD 25,803 million USD on R&D in the US in 2006. Japanese owned affiliates in the US USD 3,995 million USD on R&D investments the same year. Europe receives most of the investments in R&D by MNFs from the US and most of R&D performed by foreign MNFs in the US are performed by European MNFs.

The research on international knowledge and technology transfer processes within MNFs is at a relatively early stage (Buckley & Carter, 1999; Iwasa & Ogadiri, 2004; Kotabe, Dunlap-Hinkler, Parente, & Mishra, 2007). However, we might assume that staff mobility is an important means to transfer and exchange knowledge within MNFs (Havlik, et al., 2009). In Table 10.1, it is evident that the US is the principal recipient of intra-company transfers. The stock of intra-company transferees working in the United States in 2006 was 320,000. The United Kingdom also receives a large number of intra-company transferees: the stock in 2006 exceeded 43,000 (Chaloff & Lemaître, 2009). Unfortunately, data for additional European countries is not available at this stage.

R&D (Cohen, 1998), the importance of the home market, and the importance of home country competitiveness (Porter, 1990; Sakakibara & Porter, 2001).

Table 10.1 Flows of intra-company transfers in Austria, Germany, USA and Japan: 2000-2006

Country	2000	2001	2002	2003	2004	2005	2006
Austria	163	-	-	168	172	96	196
Germany	1,296	2,023	1,903	2,131	2,322	2,530	2,757
USA	54,963	59,384	57,721	57,245	62,700	65,458	72,613
Japan	3,876	3,463	2,900	3,421	3,550	4,184	5,564

Source: Chaloff & Lemaître (2009).
Note : Flows for European countries do not include movements of EU citizens

10.2 Knowledge flows due to inward investments

Existing economic theory identifies a range of possible spillover channels by which foreign direct investments (FDIs), i.e. multinational firms (MNFs), may generate benefits to the receiving economies including benefits for exiting domestic firms, not least in the form of knowledge spillovers. Such knowledge spillovers, for example, may lead to higher productivity levels and/or productivity growth in domestic firms. Many governments in developed as well as developing and transition countries also strive to attract MNFs to invest in their countries with the belief that knowledge brought by MNFs will spill over to domestic firms and increase their productivity and thus their competitiveness. The literature in the field has identified three potential spillover channels (Saggi, 2002):

- *Demonstration effects*. MNFs introduce new technologies, which are adopted by local firms through imitation or reverse engineering.
- *Labour mobility*. Labour trained by MNFs may bring information, skills and knowledge with them if they become employed by local firms, or if they become entrepreneurs and start their own firms.
- *Vertical linkages*. MNFs may transfer new technologies and knowledge to local firms that are either suppliers or customers to the MNFs.

Researchers have done a substantial number of studies of the productivity effects in host countries of the presence of MNFs in both developed and less developed economies. Interestingly these studies have produced very mixed results. This should be no surprise, given the difficulties associated with disentangling the various effects of FDIs as well the problems of getting the necessary data. Generally, the literature seems to have failed to find evidences for positive intra-industry spillovers from FDIs. There are some evidence that spillovers from FDIs may take place through contacts between foreign affiliates and their local suppliers in upstream sectors (Smarzynska Javorcik, 2004). Görg & Strobl (2001) present results from a meta-analysis of the literature on MNFs and productivity spillovers, which indicate that how the presence of MNFs is defined and whether cross-section or panel analysis is employed may have an effect of the results. They also find some evidence for a publication bias in the sense that there is a higher probability that studies with significant results will be published.

Productivity spillovers from MNFs take place when the entry or presence of MNFs increases the productivity of domestic firms in the host economy and the MNFs do not fully internalize the value of these benefits. The belief of such spillovers from MNFs is based on the expectation that these firms must have firm-specific productivity advantages based upon technological and knowledge assets, which make it possible for them to get compensation for the higher costs due to unfamiliar demand and supply conditions they must cover when they make FDIs in foreign markets compared with exporting their products to these markets (Hymer, 1976; Dunning, 1993).[24] There is also substantial evidence that MNFs have a productivity advantage compared to domestic firms (Girma, Greenway & Wakelin, 2001; Griffith & Simpson, 2002).

The productivity spillovers may be either intra-industry, i.e. horizontal or inter-industry, i.e. vertical, spillovers. The presence of MNFs may induce productivity increases in firms in the host region through different knowledge 'spillover' channels (see e.g. Blomström & Kokko, 1998; Smarzynska Javorcik, 2004):

- Skilled employees may leave MNFs and take employment in domestic firms in the region and bring knowledge with them that that can be applied by their new employer to rise the productivity.
- Skilled employees may leave MNFs and start new firms in the region with a superior productivity than incumbent domestic firms, which may force incumbents to leave the market.
- There may exist "demonstration effects" in the sense that domestic firms may learn superior production technologies from MNFs when there are arm's-length relationships between MNFs and domestic firms.
- Domestic firms may learn how to improve productivity from MNFs via backward and forward linkages.
- Knowledge may spill over from MNFs to domestic firms via joint research projects.
- Domestic firms may be forced by rival MNFs to up-date their production technologies and products and thus become more productive – a competition effect.[25]
- The presence of MNFs may induce the entry of international trade brokers, accounting firms, consultancy firms, and other professional service firms, whose services also may become available to domestic firms.
- Local ownership participation in FDI projects (Beamish, 1988; Blomström & Sjöholm, 1999; Smarzynska Javorcik & Spatareanu, 2008).

What is important to observe is that knowledge flows from MNFs can be both intentional and unintentional. MNFs like any other firm are of course eager to try to prevent knowledge to leak to competitors so that they can improve their performance. On the other hand, many MNFs provide inputs or capital equipment to their customers and in those cases, knowledge is so to say part of the deal. MNFs are also customers in the host economy and as qualified and demanding customers with high quality requirements, they may transfer knowledge to their suppliers to increase the quality of the inputs they buy from them. This implies that the nature and extent of productivity spillovers from MNFs partly depend upon the motivation of MNFs for undertaking them (Cantwell & Narula, 2001; Driffield & Love, 2002). Inefficient political institutions and/or mechanisms of corporate governance may act as barriers in some economies preventing domestic firms to benefit from knowledge spillovers (Prescott, 1998; Parente & Prescott, 2000).

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[24] It is important to remember that FDIs are undertaken for different purposes and not only as a substitute for exports. One motivation is, for example, to decrease production costs by locating in low cost regions. Another motivation is the acquisition of technological knowledge or technology sourcing from the host region (Fosfuri & Motta, 1999; Kogut & Chang, 1991; Neven & Siotis, 1996; Cantwell & Janne, 1999). Driffield & Love (2002) using industry-aggregated FDI flows for the UK conclude that technology-sourcing FDI has detrimental effects on the domestic sector's productivity trajectory.

[25] Competition from MNFs may also reduce productivity in domestic firms if MNFs are able to attract demand away from them (Aitken & Harrison, 1999).

It is important to stress that the spatial range of the different types of knowledge flows differ since the geographical transaction costs differ with the type of knowledge flow (Johansson & Karlsson, 2001; Döring & Schnellenbach, 2006). Generally speaking, one could argue that the higher the degree of tacitness of the actual knowledge, the higher the geographical transaction costs and thus the shorter the distance over which the knowledge is communicated between independent economic agents.[26]

Summarizing the arguments, there are reasons to expect that vertical knowledge flows from MNFs might be more important to improve productivity in domestic firms than horizontal knowledge flows but as pointed out by Blomström, Kokko & Zejan (2000) rather few empirical studies analyze vertical productivity spillovers. Of course, the stress of vertical productivity spillovers does not imply that the effects of horizontal knowledge flows should be negligible. Horizontal knowledge flows might be stimulated by technological proximity, i.e. the extent to which domestic firms have expertise and experience in the same or related technological field as the actual MNFs. More generally, the literature in the field of knowledge flows stress the importance of that the receiving firms have the necessary absorptive capacity to absorb and apply the new knowledge, which becomes available through the different knowledge channels (Cohen & Levinthal, 1989; Mariani, 2000; Verspagen & Schoenemakers, 2000; Maurseth & Verspagen, 2002). The underlying reason is that knowledge is acquired in a cumulative learning process, which implies that new knowledge can only be evaluated, absorbed and applied if the necessary complementary knowledge is already in place. Thus, the more similar the historical learning paths of firms, the higher the probability of productivity improving knowledge flows, which would increase the scope for horizontal knowledge flows.

It should also be observed that there are reasons to believe that the importance of knowledge flows varies between sectors and that they, in particular, are important in ‘young’ industries and sectors, where new knowledge can be assumed to be of special importance (cf. Glaeser, et al., 1992; Feldman & Audretsch, 1996). This implies that the sectoral composition of the MNFs in the host region as well as the sectoral composition of the domestic firms in the host region can be assumed to have a significant influence on the extent to which the MNFs generate productivity improving knowledge flows. Domestic firms active in relatively young sectors with a low share of routinized activities can be expected to be more open and exhibit a greater demand for new knowledge and a greater willingness to adopt new knowledge coming from MNFs. Normally, young firms have not have time and resources to build up their own R&D departments, and, therefore rely on external sources of knowledge to a high extent.

From this short overview, it is obvious that the various types of knowledge flows, which might influence productivity are difficult to trace and to measure. As a result, much of the literature actually mainly avoids the question of how different knowledge flows from MNFs actually influence productivity in domestic firms. Instead, most studies try to test whether the presence of MNFs affects the productivity in domestic firms. The most common method has econometric analyses where it is tested whether the presence of MNFs has a significant effect on labour productivity or total factor productivity in domestic firms when controlling for relevant background factors. If the parameter estimate for the MNF presence is positive and statistically significant, it is assumed that there is evidence of knowledge spillovers from MNFs to domestic firms.

[26] Knowledge communication within economic agents normally has lower geographical transaction costs. One may even argue that one reason why MNFs is that they can economize on the geographical transaction costs of transferring knowledge between different geographical locations.

The literature in the field contains a rather large number of industry- and firm-level studies from various counties. Most of these studies show a positive correlation between the presence of MNFs and the average labour productivity in different industries (Caves, 1974; Globerman, 1979; Blomström & Persson, 1983; Blomström 1986; Blomström & Wolff, 1994; Kokko, 1994; Kokko, 1996, Liu, et al., 2000; Driffield & Munday, 2000; Driffield, 2001) or firms (Kokko, Tansini & Zejan, 1996; Blomström & Sjöholm, 1999; Chuang & Lin, 1999; Sjöholm, 1999 a & b). However, most of them rely on cross-sectional data, which implies that they are unable to establish the direction of causality.[27] It may, for example, be the case that MNFs tend to invest in industries with high labour productivity, when they invest in a country. It is also possible that MNFs out-compete domestic firms in the industries they invest in or that they by taking a large market share increase the average productivity in their industry.

Another type of studies in the literature is based upon firm-level panel data. Here the research question concerns whether the productivity of domestic firms increases with the presence of MNFs. Here the results go in two directions. Studies of developing and transition countries seem to generate either no significant effects or significant negative horizontal spillovers (Haddad & Harrison, 1993; Aitken & Harrison, 1999; Djankov & Hoekman, 2000; Kathuria, 2000; Konings, 2001), while studies of developed countries seem to tend to generate evidence of significant positive productivity spillovers from MNFs (Haskel, Pereira & Slaughter, 2000; Keller & Yeaple, 2003).[28] Thus, the presence of MNFs in developing countries seems to have a negative effect on the productivity of domestic firms active in the same sector. The reason might be that domestic firms lose market shares to MNFs, and thus must distribute their fixed costs over a smaller production volume (Aitken & Harrison, 1999).

A rather small number of studies tests for productivity spillovers from MNFs taking place through backward and forward linkages, and some find evidence for the presence of productivity spillovers taking place through backward linkages from foreign affiliates to their domestic suppliers (Blalock, 2001; Smarzynska Javorcik, 2004; Blalock & Gertler, 2008).[29] The literature also contains studies, which give evidence that vertical spillovers are associated with shared domestic and foreign ownership but not fully owned foreign subsidiaries (Smarzynska Javorcik & Spatareanu, 2008).

Table 10.2 shows the FDI inflows between 2002 and 2009, whereas Figure 10.1 shows the positions at year end as a percentage of GDP. Negative values of the FDI flows indicates disinvestment in assets or discharges of liabilities.[30] The difference and relation between FDI flows and positions are summarized as follows:

Position at the end of the period = Position at the beginning of the period + FDI flows + price changes + exchange rate changes + other adjustments. (Duce, 2003)

[27] It should be observed that Blomström (1986) and Blomström & Wolff (1994) studied changes taking place between two points in time and Liu, et al., (2000) used panel data.

[28] The study of UK by Girma, Greenaway & Wakelin (2001) did generate insignificant results.

[29] Schoors & van der Tol (2001) provide evidence of positive spillovers from MNFs through backward linkages using cross-sectional firm-level data from Hungary.

[30] FDI includes the three following components: equity capital, reinvested earnings and intra-company loans. Data on FDI flows are presented on net bases (capital transactions' credits less debits between direct investors and their foreign affiliates). Net decreases in assets or net increases in liabilities are recorded as credits, while net increases in assets or net decreases in liabilities are recorded as debits. Hence, FDI flows with a negative sign indicate that at least one of the three components of FDI is negative and not offset by positive amounts of the remaining components. These are called reverse investment or disinvestment. (UNCTAD, 2010)

Evidently, Europe receives a much larger inflow of FDI investments than both the US and Japan for all year in table 10.2 below. In 2007, the inflows of FDI to Europe peaked at USD 1,195 billion. The inflows of FDI were fairly low in the latest year to all three regions. The inward stocks of FDI per GDP dollar are more than twice that of the US (Figure 10.1). Caution must be taken in interpreting the data since FDI inflows to the EU includes flows between the member states, which results in inflated figures. It would be desirable to obtain data on European FDI flows to and from extra-EU countries only; however these statistics are not available at the moment.

Table 10.2 FDI Inflows (billion USD)

Triad Region	2002	2003	2004	2005	2006	2007	2008	2009
EU*	397	345	287	664	669	1,195	678	459
USA	84	64	146	113	243	271	328	135
Japan	9	3	8	3	-7	23	24	12

Source: OECD (2010d)
*EU15 until end 2003, EU25 in 2004-2006, EU27 as from 2007. Includes intra-EU flows.

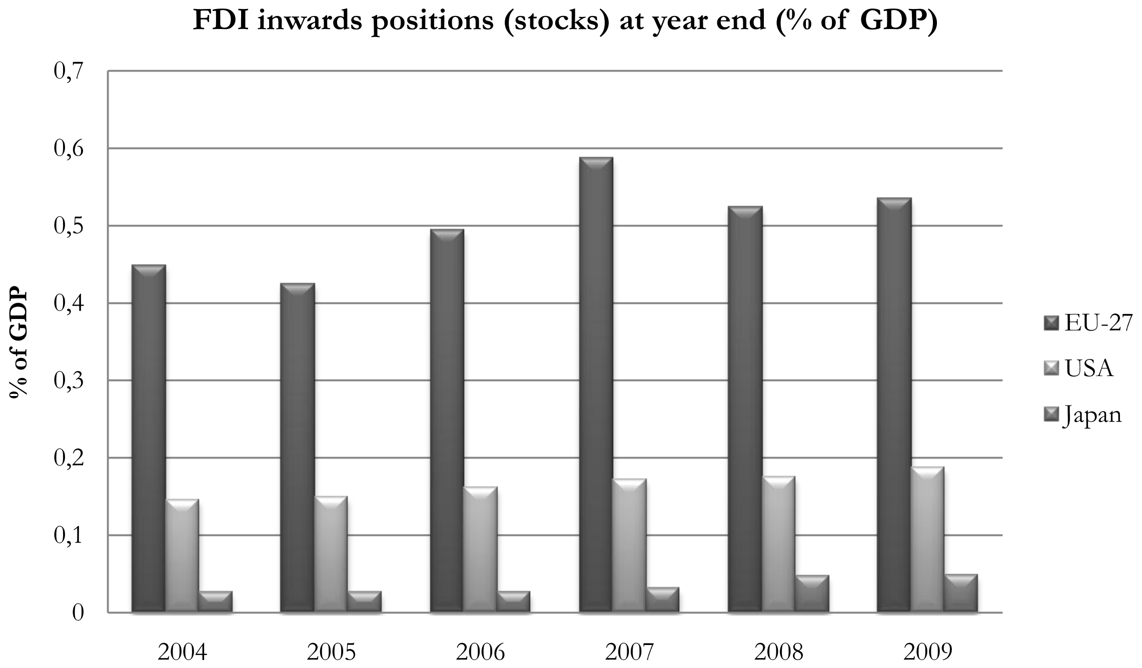

Figure 10.1 FDI inward position (stocks) (% of GDP), 2004-2009
Source: OECD (2010d)
Note. Data from EU-27 includes intra-EU flows. See Appendix Table 14.5 for outward positions for each triad region in USD million

In 2002, about 80 billion USD of a total of 154 billion USD of FDI outflows went from the US to Europe (Table 10.3 and Table 14.6 in appendix). In 2005, the picture had changed drastically since the outflows of FDI from the US to Europe were negative. This is reflected in the total outflows of FDI from the US, which only amounted to 36 billion USD in 2005 (Table 10.4 in section 10.3). From studying the percentage share of FDI outflows from the US to Europe in Table 10.3 one can easily detect that almost half of the FDI outward stocks from the US are invested in European countries (e.g. in 2005, a value of 1,203 billion USD were invested in Europe out of a total of FDI outward stocks of 2,652 billion USD from the US).

The share of total FDI outflows from Japan that are invested in Europe decreases slightly during the time period as can be seen in Table 10.3. However, Europe has received a rather stable share of Japanese outward FDI stocks.

Table 10.3 Outflows and outward positions from USA and Japan to EU-27 (billion USD)

Type of FDI	2002	2003	2004	2005	2006	2007	2008	2009
USA: outflows to the EU-27	80	87	137	-29	-	-	-	-
% of total outflows from USA to EU-27	20.9	22.1	30.0	-				
USA: outward positions to the EU-27	853	970	1173	1203	-	-	-	-
% of total outward positions from USA to EU-27	45.7	47.2	47.0	45.4				
Japan: outflows to the EU-27	14	12	13	8	18	21	23	18
% of total outflows from Japan to EU-27	43.8	41.4	41.9	17.4	36.0	28.4	18.0	24.0
Japan: outward positions to the EU-27	72	87	103	94	121	148	165	179
% of total outward positions from Japan to EU-27	23.7	25.9	27.8	24.3	26.9	27.3	24.3	24.2

Source: OECD (2010d)

10.3 Knowledge flows due to outward investments

European firms are increasingly conducting innovative activities in R&D centers in the two other triad regions with a strong bias to R&D centers in the US. This behavior cannot be fully explained by a hypothesis a la Vernon (1966) that European firms are doing this R&D to serve product demand or manufacturing operations the other triad markets. It is obvious that the technological- and human capital-endowments of some regions in the US and Japan are a strong attractor of R&D in European MNFs (cf. Kuemmerle, 1997 & 1999a; Cantwell & Janne, 1999; Frost, 2001; Le Bas & Sierra, 2002; Chung & Alcacer, 2002). Hedge & Hicks (2008) highlight three different strategic perspectives of R&D performed by MNFs foreign subsidiaries:

1. *Foreign R&D as customization and modifications*. Foreign R&D is here understood as support to product development and production management in foreign markets along the lines of Vernon (1966 & 1979). The general conclusion here seems to be that early stage innovation is best served by being close to headquarters, while later less significant innovations to support overseas markets might be performed locally (Teece, 1977; Lall, 1979; Caves, 1996).

2. *Foreign R&D as including listening posts*. MNF overseas subsidiaries R&D encompass according to Dunning (1994, 75-76) the following activities: i) product, material or process applications or improvements, ii) basic materials or product research – on immobile subjects, such as tea plants, oil refineries, bauxite mines or agriculture, iii) rationalized research, i.e. all research on a particular topic conducted in one location, and iv) research to acquire or gain an insight into foreign innovation activities, i.e. learning and building firm research capability. The last type is “listening post” R&D and it recognizes the existence of high-level R&D capability in other countries and the need for MNFs to absorb foreign know-how in particular from other triad countries.

3. *Foreign R&D as a source of innovation*. In the last two decades it has become more and more obvious that more and more MNFs are adopting a global approach not only in terms of applying their total knowledge base in foreign operations but also to more generally improve their overall innovation capabilities (Bartlett & Ghoshal, 1989; Florida, 1997; Cantwell & Janne, 1999; Zanfei, 2000; Chung & Alacer, 2002; Almeida & Phene, 2004). In the literature a distinction has been made between "home-base exploiting" or "asset exploiting" or "production-based" and "home-base augmenting" or "strategic asset augmenting" or "learning-based" investments (Kuemmerle, 1997 and Dunning & Narula, 1995, respectively.[31] In the latter case, R&D is established abroad to access knowledge from local firms and universities. One motivation for such a strategy might be that the home country resources in the form of R&D capabilities are not adequate to meet the firm's requirements. The knowledge absorbed from the local community can be transferred to other R&D units within the MNF and/or for local creation of new knowledge. There are evidences that the flow of knowledge between overseas subsidiaries and MNF headquarters is growing and that MNFs may gain more knowledge from their foreign locations than they contribute themselves to these locations (Singh, 2004).

Location of R&D to other countries might bring a variety of benefits to MNFs. It gives them an opportunity

- to get advantages form different national systems of innovation (Robinson, 1988; Cantwell, 1992),
- to become acquainted to new lines of technological diversification as reflected in local markets (Cantwell, 1992; Cantwell & Kotecha, 1997; Iwasa & Odagiri, 2004),
- to be exposed to more varied flows of ideas, products, processes and technologies (Håkanson & Nobel, 2001),
- to increase speed and effectiveness of communication and thus reduce development costs (Chiesa, 1996),
- to benefit from location-specific advantages through an international division of labour between foreign R&D locations (Lorenz, 1983),
- to be more responsive to local needs, in terms of both time and relevance through the access to local supply of goods and services (Caves, 1982; Robinson, 1988; Dunning, 1993; Chiesa, 1996) and to closeness to customers (Casson, Pearce & Singh, 1992), and/or
- to take advantage of what different national innovation systems offer in terms of positive regulatory environments and favorable government incentives (Caves, 1992; Dunning, 1993).

Similar to the inflows of FDI, Table 10.4 shows that Europe dominates the market of outflows of FDI. However, since the figures for Europe include FDI flows between the member states, they are rather misguiding.

[31] According to Patel & Vega (1999), 75% of MNFs' technological innovations abroad are being made in fields where MNFs have a home advantage.

Table 10.4 FDI Outflows, billion USD

Region	2002	2003	2004	2005	2006	2007	2008	2009
EU*	383	393	457	787	803	1,480	1,101	590
US	154	150	316	36	245	414	351	269
Japan	32	29	31	46	50	74	128	75

Source: OECD (2010d)
*EU15 until end 2003, EU25 in 2004-2006, EU27 as from 2007. Includes intra-EU flows.

The data of outward positions, or stocks, of FDI as a percentage of GDP also shows that Europe invests abroad to a greater extent than the US and Japan do relative to each regions GDP (Figure 10.2). European MNFs have a greater potential to acquire knowledge and strategic advantages from foreign countries.

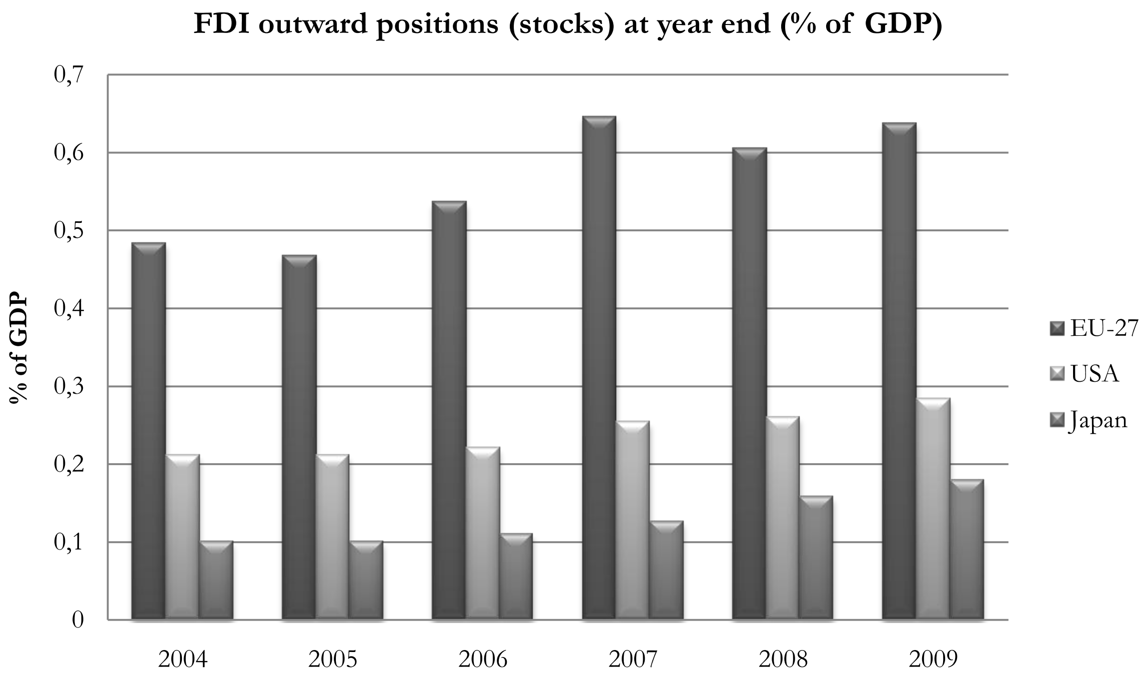

Figure 10.2 Outward position (stocks) at year end (% of GDP)
Source: OECD (2010d)
Note. Data from EU-27 includes intra-EU flows. See Appendix Table 14.6 for outward positions for each triad region in USD million

From Table 10.5, one can recognize that Europe contributes to more than half of the FDI inflows and stocks to the US for most of the years displayed in the table. Furthermore, Europe is a major partner for FDI investments in Japan as can be seen both by the inflows and the stocks. European FDI in the US and Japan has increased gradually during the available years in the table below.

Table 10.5 Inflows and inward positions to USA and Japan from EU-27 (billion USD)

Type of FDI	2002	2003	2004	2005	2006	2007	2008	2009
USA: inflows from the EU-27	45	23	81	78	183	-	-	-
% from the EU-27 of total inflows to USA	56.3	35.9	55.5	69.0	75.3			
USA: inward positions from the EU-27	958	1001	1079	1154	-	-	-	-
% of total inward positions to USA from EU-27	63.9	63.5	62.5	61.6				
Japan: inflows from the EU-27	6	6	7	1	-4	5	5	8
% from the EU-27 of total inflows to Japan	66.7	-	87.5	33.3	-	21.7	20.8	66.7
Japan: inward positions from the EU-27	33	39	42	38	42	62	87	84
% of total inward positions to Japan from EU-27	42.3	43.3	43.3	37.6	38.9	46.6	42.9	42.0

Source: OECD (2010d)

Almost half of the outward stocks of US FDIs are invested in Europe. This trend has remained stable during recent years. About ¼ of the Japanese FDI stocks are invested in Europe, also a trend that has not changed in the past years. Out of all of the FDI stocks in the US, European MNFs account for above 60 percent of the investments. Europe account for around 40 percent of the FDI stocks in Japan. Moreover, Europe invests about the same amount of FDI in the US as the US invests in Europe. Japanese FDI in Europe exceeds that of European investments in Japan.

10.4 Intra-triad knowledge flows via mergers and acquisitions

Firms, in particular in mature industries, use cross-border mergers and acquisitions to promote and advance their competitive advantages (Scherer & Ross, 1990; UNCTAD, 2000; Lundan & Hagedoorn, 2001). Not least the liberalization of international markets and the consequent convergence of production capabilities within the triad has made it possible and motivated MNFs to exploit or leverage their resources and knowledge-based capabilities by getting access to new markets or by getting rid of competitors, as well as to explore, build and extend their knowledge capabilities across geographical space by means of mergers and acquisitions. One of the most significant driving forces behind international mergers and acquisitions is technological change (Ahammad & Glaister, 2008). In a globalised world characterized by increasingly rapid technological change and increasing costs for risky R&D projects many firms are induced to engage in mergers and acquisitions to reduce innovation costs and to access new R&D and technological assets to increase their innovative capacity (UNCTAD, 2000). Another important driving force in recent years have been the international reduction of trade barriers and the liberalization of international capital movements (Child, Falkner & Pitketly, 2001). A third driving force is economic growth in both home and potential host countries (Kang & Johansson, 2000). Also, the growth of common customer needs, the emergence of worldwide customers, the development of international distribution channels and the development of common international market approaches stimulate international mergers and acquisitions (Child, Falkner & Pitketly, 2000).

Mergers and acquisitions is a means for firms to get access to knowledge and technologies protected by intellectual property rights not yet held by the firms as well as to other types of resources. By combining these assets with existing assets MNFs may achieve non-trivial operational, R&D, marketing and /or managerial synergies, which upgrade their capabilities. Cross-border mergers and acquisitions allow MNFs to access locally bound knowledge, which is not easily accessible otherwise or which would need considerable time and resources to develop within the firms (Barkema & Vermeulen, 1998). Hennert (1988) noted that licensing might be a more appropriate mode for the transfer of explicit, i.e. codified, knowledge. However, imperfections in the market for knowledge in the form of evaluation uncertainties, inefficiencies in the system for protection of proprietary knowledge resources (e.g. patents), and the tacitness of many forms of knowledge may lead MNFs to choose mergers or acquisitions or strategic alliances rather than licensing to access knowledge held by other firms. Mergers and acquisitions as well as strategic alliances also give access to knowledge production capacity. However, mergers and acquisitions are not without their problems. Depending on the balance of bargaining power between the foreign and the domestic firm as well as host country government, the buying firm might have to take over assets of limited value attached to the acquisition target, which creates an "indigestibility" problem and higher costs.

The research on mergers and acquisitions has to a large extent focused on financial performance before and after the event as well as on the stock market reaction to the announcement of such events. Research done in the 1990s indicates that mergers and acquisitions are disproportionally concentrated in sectors other than high-tech, where strategic alliances dominate (Lundan & Hagedoorn, 2001). This points in the direction that mergers and acquisitions often are made due to other motives than getting access to unique knowledge and/or knowledge production capacity. However, mergers and acquisitions seem frequently preferred to alliances in the context of strategic asset-seeking investments related to the firm's core activities (Hagedoorn & Duysters, 2002).

An important precondition for mergers and acquisitions within the triad might be the underlying convergence of productive capabilities within the triad. If this is correct, we shall expect high levels of mergers and acquisitions within the triad, both international and domestic, and few mergers with and acquisitions of firms outside the triad. The propensity to engage in mergers and acquisitions certainly vary over industries with a concentration to a few sectors, such as petroleum, automobiles, finance and telecommunications (Kang & Johansson, 2000).

At the moment, we cannot display data on the extent of mergers and acquisitions in the triad region. The next chapter will focus on high skilled migration as an important channel of knowledge flows.

11 Intra-triad knowledge flows via high-skilled migration

Knowledge flows increase the efficiency of the innovation process and the spillovers generated from knowledge creation are the central determinant of economic growth (Romer, 1990). Prior research has shown that some forms of knowledge flows stay geographically localized since it does not flow uniformly across geographic space or freely across the marketplace, and it flows faster locally (Oettl & Agrawal, 2007). Knowledge includes codified and non-codified components; of which both are important in order for inventors to access and apply knowledge. Published articles and patents are examples of codified knowledge and can flow quickly through geographical space. Oettl and Agrawal (2007) assert that the non-codified components of knowledge, however, often require direct interaction with the inventor for effective transfer and therefore contribute to geographical stickiness of knowledge. For this reason knowledge often flows locally, unless geographic migration of inventors and highly skilled persons takes place. This chapter will study the extent of highly skilled migration flows to Europe, the US and Japan.

Oettl & Agrawal (2007) find that the inventor's new country gains from the arrival of the inventor above and beyond any additional knowledge flows to the firm receiving the inventor, i.e. knowledge spillover outside of the firm takes place. Furthermore, the firm that lost the inventor can also gain in the form of increased knowledge flows from the individual's new country and firm. These externalities appear since social relationships facilitate knowledge flows and the person will create new relationships outside of the new firm as well as maintain the relationships in the home country. If the individual moves from one country to a another but within the same firm, the backward knowledge flow is expected to be stronger than if the individual changes firm. The notion that there is a larger possibility for an inventor's knowledge to flow back to the inventor's prior location than if the inventor had never lived there, has positive implications for the countries losing high-skilled workers.

Most developed countries have implemented policies to facilitate the recruitment of highly skilled workers in recent years as a shortage of these workers are expected in the future. The triad countries have different experiences and policies regarding this matter. Highly skilled workers can be defined either by level of education or occupation. Most commonly, persons with a tertiary education qualify as highly skilled. Occupational data of highly skilled workers may include health professionals and high-tech personnel (math, computer, and natural scientists, engineers, and other technicians (Smith & Favell, 2006). In order to streamline the definition of highly skilled workers across nations, the Canberra Manuel definition of Human Resources in Science and Technology (HRST) has been constructed by the OECD and European Commission (EC)/Eurostat. This measure is based on two dimensions: qualification (tertiary level or better education) and occupation (training/employment in a science and technology occupation). An individual belongs to the HRST classification if he/she satisfies one of the two requirements:

1. Successfully completed education at the third level in a Science and Technology (S&T) field of study;
2. Not formally qualified as above, but employed in a S&T occupation where the above qualifications are normally required.

In addition to the definitions given above, Chaloff and Lemaitre (2009) mention that wages paid can be used to distinguish highly skilled workers, where individuals earning above a certain threshold belong to the highly skilled.

11.1 Reasons for migration

There are two reasons for skilled migration to occur; the employment motive and the consumption motive. The employment motive must first be satisfied in order for the consumption motive to gain importance. The consumption motive involves factors that contribute to a higher standard of living. These factors are explained more thoroughly by the push-pull model.

The push-pull model is one of the most fundamental theoretical concepts explaining reasons for migration (EC, 2000). The theory describes a number a push factors causing migrants to leave their country, whereas a number of pull factors attract migrants to a new country. The push factors include economic, social and political elements in poorer countries, while the pull factors are related to comparative advantages in richer countries.

Bouge (1969) mention several pull factors relevant to recent skilled migration patterns of the triad countries. These pull factors include better work opportunities, opportunity to a higher income, potential to increase ones competence, higher standard of living, superior environment and nature, as well as a change of environment. Push factors causing migration from one high-income country to another might include the social climate, congestion, criminality, and high land rents.

An investigation of inter-regional migration in Australia performed by Wamsley, Epps and Duncan (1998) shows that the perceived picture of the quality of life in another place is important as many inter-regional migrants had never visited the place they moved to before. Therefore Wamsley et al. argues that pull factors are much stronger than push factors, where the physical milieu of a place, the climate and a relaxed lifestyle dominates these pull factors. In accordance, Mai (2004) showed in an article describing the impact of television on migration from Albania to Italy that the perceived attractiveness of a place is of importance. Pull factors are in general believed to be more important when it comes to high-skilled migration.

11.2 The demand for skilled migration

Demographic changes such as the current aging population in Europe, the United States and Japan underlines the need for migration of highly skilled personnel. Table 11.1 shows the anticipated sizes in relative terms of the younger cohorts replacing the retiring cohorts, assuming zero net migration and no deaths. Already in 2005, the 15-19 cohort was only 78 percent of the 60-64 cohort in Japan. The EU-15 countries are on average expected to have a 15-19 cohort that is 78 percent of the 60-64 cohort in 2020, a considerable decrease from 2005. The changing age structure is even more considerable in the United States, where the size of the 15-19 cohort relative to that of the 60-64 cohort is expected to decrease from 166 percent in 2005 to 91 percent in 2020.

Table 11.1 Size of the 15-19 cohort relative to that of the 60-64 cohort, based on the current age structure of the resident population (%)

	2005	**2010**	**2015**	**2020**
EU-15 average	116	93	85	78
US	166	125	100	91
Japan	78	58	69	74

Source: Chaloff, & Lemaître (2009)

The figure below illustrates the projected growth of the population of working-age (20-64) at current projected migration levels, the growth of population of not working-age (0-19 & 65+) and their relation through the dependency ratio.

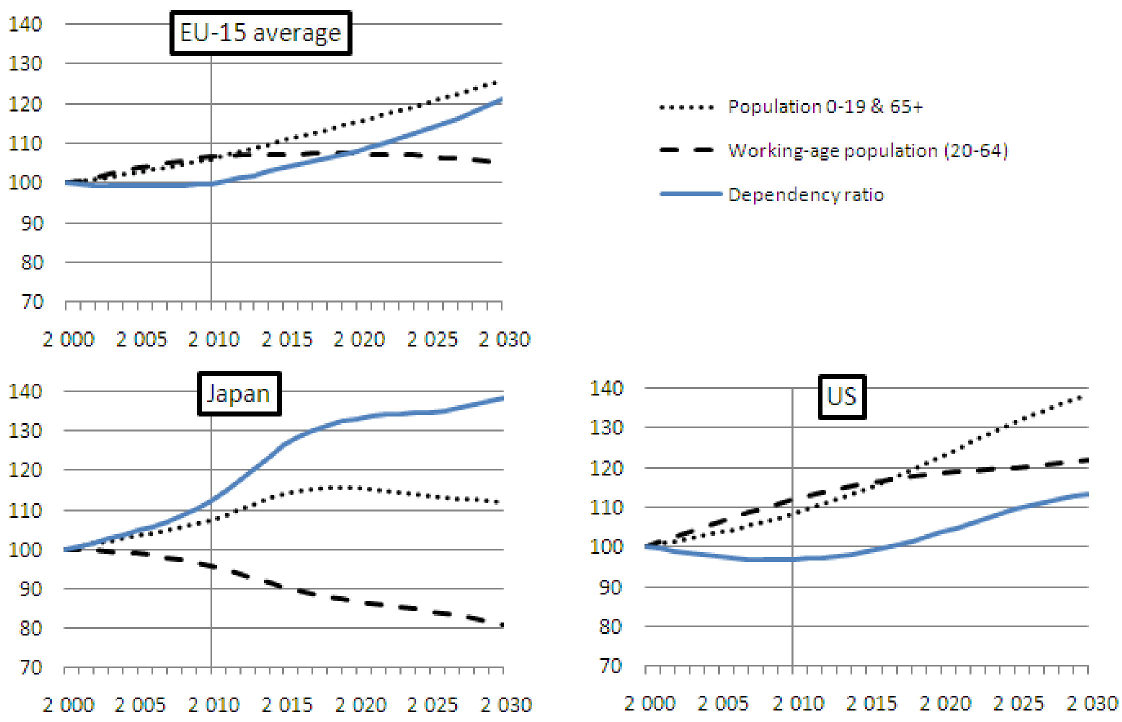

Figure 11.1 Evolution of dependency ratios over the period 2000-2030, Year 2000 = 100
Source: OECD (2010c)

The dependency ratio of Japan has been increasing since 2000 and is anticipated to accelerate in the next decade due to a shrinking working-age population. The result of this pattern is much higher educational and social expenditures per person in the working-age population. The average EU-15 country is anticipated to face similar problems as Japan in the long term. Also the United States is projected to experience a an increasing dependency ratio as their population of not working-age continue to grow at a faster pace than the working-age population. Attracting immigrants, which usually are of working age, is one solution to the aging population.

The anticipated figures in Table 1 and Figure 1 suggest that countries will have to compete for skilled migrants in the decades to come in order to satisfy the labour market demand for high skilled workers. According to Chiswick (2005) one can think of an economy as consisting of three factors of production; low skilled workers, high skilled workers and capital. Since these are complements in production, increasing one of them will increase the productivity of the other two. Additional high-skilled professionals will increase the productivity, hence demand, of low-skilled workers as well as the productivity of capital. More foreign high skilled workers lowers the marginal product, and hence wages, of native high-skilled workers while raising the productivity of low skilled workers and capital.

The effect of this is reduced income inequalities and reduced extent of government transfers from the taxpayers to welfare recipients. Moreover, the increased return to capital may encourage both foreigners and natives to invest in the domestic economy (Chiswick, 2005). Furthermore, high skilled workers have a direct influence on innovation and invention. Chellaraj, Maskus, and Mattoo (2005) find in their study that a decline of the migration, permanent or temporary, of foreign students and professionals to the United States will have sharply negative implications for innovation capacity and competitiveness. In this way, skilled migration contributes to an outward push of the production possibility frontier. In contrast, low skilled immigration tends to lower the wages of all low-skilled workers as well as increase the tax burden. Economies are enhanced far more by high skilled immigration than low skilled immigration (Chiswick, 2005).

Significant growth is expected in US occupations in science and engineering in the next decade (Delanghe et al., 2009). According to Delanghe et al. an increase of around 53 percent is expected in occupations of network systems and data communication analysts, which means an additional 140,000 employment openings. EU countries have to compete with the triad countries for scarce human resource supplies of science and technology. When the growing need for human resource in science and technology (HRST) cannot be met by domestic supplies, the ability to attract HRST from abroad becomes a key factor for the region's future competitiveness. A highly skilled and innovative human resource in science and technology, which initiate R&D advances and knowledge-based product development, will be a decisive factor in order for Europe to remain a competitive knowledge-based economy (Delanghe, Muldur, Soete, 2009). With the internationalization of labour mobility, Europe must have a strategy ensuring an adequate supply of R&D and HRST.

Successful countries in attracting highly skilled labour from Europe include US, Canada, Australia and UK. At the same time, most European countries have struggled in their attempts to attract and retain high-skilled researchers from outside of the EU. In 2006, non-nationals accounted for 6 percent of the human resources in science and technology in the EU-27 countries. Half of these belonged to a nationality outside of the EU-27 countries. (Eurostat publication, 2007)

Immigration of highly skilled workers can provide high returns for the host country. EU lags behind in attracting these types of workers in comparison to the US for example, where innovation has been driven by immigrants workers to a large extent. Many countries are turning more proactive in their attempts to attract highly skilled workers through fast-track admissions and eased up restrictions. The demand of highly skilled workers will continue to grow on a global scale emphasizing the need for Europe to increase its competitiveness as an attractive place for HRST to locate.

The recruitment of highly skilled workers is either demand-driven (through employer requests) or supply-driven (selecting candidates who have applied on the basis of certain characteristics). Recruiting highly skilled personnel from abroad ensures a steady supply of additional labour resources above those available from domestic resources. Moreover, positive externalities beyond satisfying local labour demands is an additional consequence of attracting and facilitating highly skilled labour migration.

The immigration policies differ extensively between the triad regions. The United States places limits on the total inflows of workers rather than aiming for a target. For this reason, employers are prevented from hiring as many foreign high skilled workers as they would like. In order to qualify as a high-skilled immigrant to Japan a college education or ten years experience for a professional or technical worker is required, as well as certain salary levels. The EU countries all have different immigration policies, where some are more open or selective than others. The table below summarizes a selected number of countries' strategies for high skilled migration and their outcomes.

Table 11.2 Policy priorities and strategies for high-skilled migration: United States, Japan and selected European countries

	Policy background	Strategy	Outcome and issue to monitor
United States	• Protect native workers while meeting employer needs • Prevent low-skilled immigration and limit immigration in general	• Quotas for most high-skilled categories • Job offer essential • Large temporary program • Little facilitation for international students	• Programs oversubscribed, with long waiting lists • Recourse to alternative visas (exchange, IC Transfers, etc.)
Japan	• Accept high-skilled migration while maintaining limit on low-skilled immigration	• Strict definition of skilled positions • Allow foreign students to seek work	• Little high-skilled migration despite openness • Some students remain for employment
United Kingdom	• Rely on free movement as much as possible • Allow highest skilled to enter while limiting immigration of less skilled	• Points-system for migration by highest skilled; no quota • Shortage list for high skilled employees sought • Access for international students to above	• New system yet to be evaluated
France	• Protect native workers while meeting employer needs • Increase "economic migration"	• Strict labour market test and occupation list	• Limited immigration
Netherlands	• Reduce immigration by people with few skills and little Dutch language	• Exemptions from strict language and labour market test for high skill, high salary	• Satisfactory use of "high skilled" permit, meets expectations • Some employers still use standard work permit
Germany	• Limit immigration while allowing high skilled to enter • Compete with other destinations for the highest skilled	• Permanent residence for very high skill and high-paid foreigners • Strict conditions for others • Some possibility for former students	• Limited immigration, mostly change of status of students, others. • Flows fall short of expectations

Source: Chaloff & Lemaître (2009)

Many European countries have had a reluctant labour immigration policy in recent decades unless the candidate has a job offer. Apart from to Ireland and the United Kingdom, high-skilled migration has been limited to most EU countries as well as to Japan. In order to address the growing need for HRST, the 'Researchers in Europe 2005' initiative was instigated to increase Europe's attractiveness as a place to pursue a career in research (Delanghe et al., 2009). This initiative facilitates the admission procedures for researchers and makes it easier for them to stay in the country. Japan has also eased immigration restrictions in order to attract HRST.

11.3 Europe's position and capacity of attracting skilled labourers

Table 11.3 below shows recent trends in highly qualified immigration for the EU-15 countries and the United States. There is 5.5 more immigrants with a tertiary education in 2006 relative to 1995 in the EU-15 countries. The increase to the EU-15 region is substantially higher compared to the United States, where there are 1.4 more immigrants with a tertiary education in 2006 relative to 1995. However, these figures signify an increase of immigrants in total rather than an increase of the share of highly skilled immigration. In fact, the percentage of immigrants with tertiary education relative to all immigrants increased only slightly in both the United States and Europe during the ten year time period.

Table 11.3 Trends in highly qualified immigration in the US and EU-15 countries, 1995 to 2006

	Employed immigrants with tertiary education having arrived in previous ten years				Employed immigrants working as managers*, professionals and associate professionals having arrived in previous ten years			
	Quantity in 2006 relative to quantity in 1995	As a percentage of all employed immigrants having arrived in previous ten years			Quantity in 2006 relative to quantity in 1995	As a percentage of all employed immigrants having arrived in previous ten years		
		1995	**2006**	**06/95**		**1995**	**2006**	**06/95**
EU-15 average	5.5	31.1	31.4	1.01	3.9	29.2	26.8	0.92
USA	1.4	29.6	31.2	1.05	0.9	21.9	14.6	0.67

*excluding small enterprises
Source: Chaloff & Lemaître (2009)

At the same time, the percentage of immigrants working in high skilled professions relative to all immigrants having arrived in the prior ten years decreased substantially in the US and to some extent in Europe between 1995 and 2006. However, the total number of immigrants employed in high skilled professions is 3.9 times higher on average in the EU-15 countries in the corresponding years. In the US, the total number of immigrants in a high skilled profession decreased slightly from 1995 to 2006. These figures illustrate that low skilled immigration has been as common, or even more common, to the EU-15 countries and to the United States. While the share of immigrants with a tertiary education has increased slightly in the United States, the share of immigrants working in high skilled professions has decreased considerably. This observation might indicate a mismatch of skills and jobs.

The table below displays the share of recent immigrants in highly skilled occupations.

Table 11.4 Contribution of recent immigrants to employment in highly skilled occupations, 2006

	Persons in employment		**Persons in high-skill[2] jobs**		**Professionals**	
	Employed immigrants as a percentage of total employment	Employed immigrants having arrived during 1995-2006 as new entrants[1] as a percentage of total employment	Immigrants in high-skill jobs as a percentage of all persons in high-skill jobs	Immigrants in high-skill jobs having arrived during 1995-2006 as a percentage of new entrants[1] in high-skill jobs	Immigrant professionals[3] as a percentage of all professionals in employment	Immigrant professionals[3] having arrived during 1995-2006 as a percentage of new entrant[1] professionals
EU-15 average	12.3	16.2	10.2	11.5	11.5	13.3
USA	15.8	22.8	12.5	14.5	18	23.5

[1]New entrants consist of immigrants having arrived in the previous ten years plus native-born persons having completed their education over the last ten years, proxied by native-born persons aged 30-39.
[2]Persons in high-skill jobs include managers (except managers of small enterprises), professionals and technicians and associate professionals, ISCO code 1, 2 and 3.
[3] Professional occupations refer to ISCO code 2.
Source: Chaloff & Lemaître (2009)

Recent immigrants to the United States and Europe are represented to a larger extent in the employment population than are all immigrants, which demonstrates the growth of employment migration in recent decades. In addition, recent immigrants are more strongly represented in high-skill jobs overall and in professional occupations in particular, than are all immigrants. The share of immigrants with a high skill job or a professional occupation compared to the native population is higher in the United States than it is in the EU15 countries on average. However, these figures vary substantially across the European countries. The UK, Switzerland, Ireland and Luxemburg have a much higher share of recent immigrants with a professional occupation than the EU-15 average.

The presence of immigrants in high skill jobs (11.5%) and professional occupations (13.3%) is lower than their presence in employment as a whole (16.2%) in the EU-15 on average. Nevertheless, recent immigrants are more strongly represented in the population with a professional occupation (23.5%) than in the employment population as a whole (22.8%) in the US. On the other hand, recent immigrant representation in high skill jobs (14.5%) is lower than recent immigrant representation in employment as a whole in the US. These observations might reflect the fact that migration to Europe in particular is of lower skilled nature to a larger extent and that qualifications are not easily transferred. Furthermore, the English language facilitates immigration to countries like the United States and the United Kingdom.

In 1989, a revision of Japanese immigration laws facilitated entry into Japan of highly skilled workers with temporary visas for an undefined time period. As Figure 11.2 shows, the increase of the total amount of selected classes of highly skilled workers rose sharply, from 30,000 in 1990 to 201,164 in 2007. The amount of highly skilled entrants into the country in 2007 roughly equals half the number of Japanese university graduates entering the labour force each year and is more than the number entering the United States in similar categories (NSF, 2010).

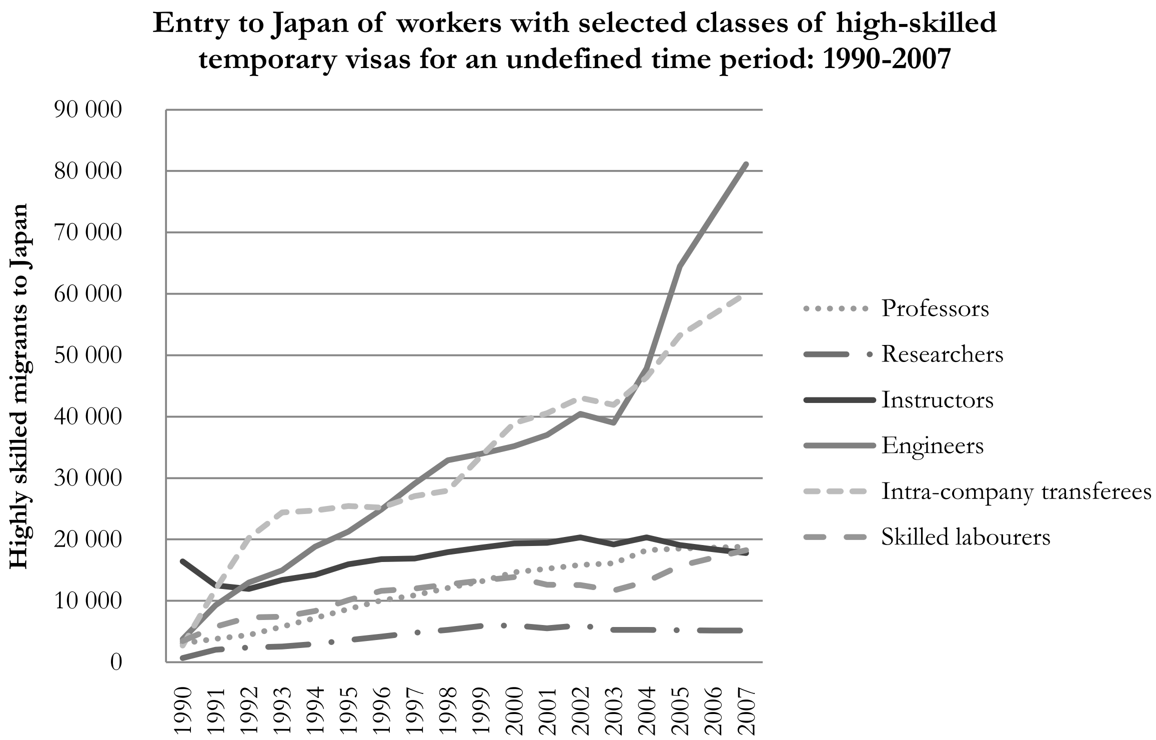

Figure 11.2 Entry to Japan of workers with selected classes of high-skilled temporary visas for an undefined time period: 1990-2007.

Note: data for 2005 and 2006 are estimated averages since data was not available

Source: Japanese Statistics Bureau (2010)

The share of workers with selected classes of high-skilled[32] temporary visas compared to all registered foreigners in Japan increased from 3 percent in 1990 to 9 percent in 2007 (Japanese Statistics Bureau, 2010). As can be seen in the figure below, labour migrants only accounts for a small part of total permanent migration in the US and the average EU-15 country. In Japan, however, labour migration is approximately one fourth of total migration, although it is lower than the labour migration to the average EU-15 country relative to its total population.

[32] High-skilled workers are professors, researchers, instructors, engineers, intra-company transferees and skilled laborers.

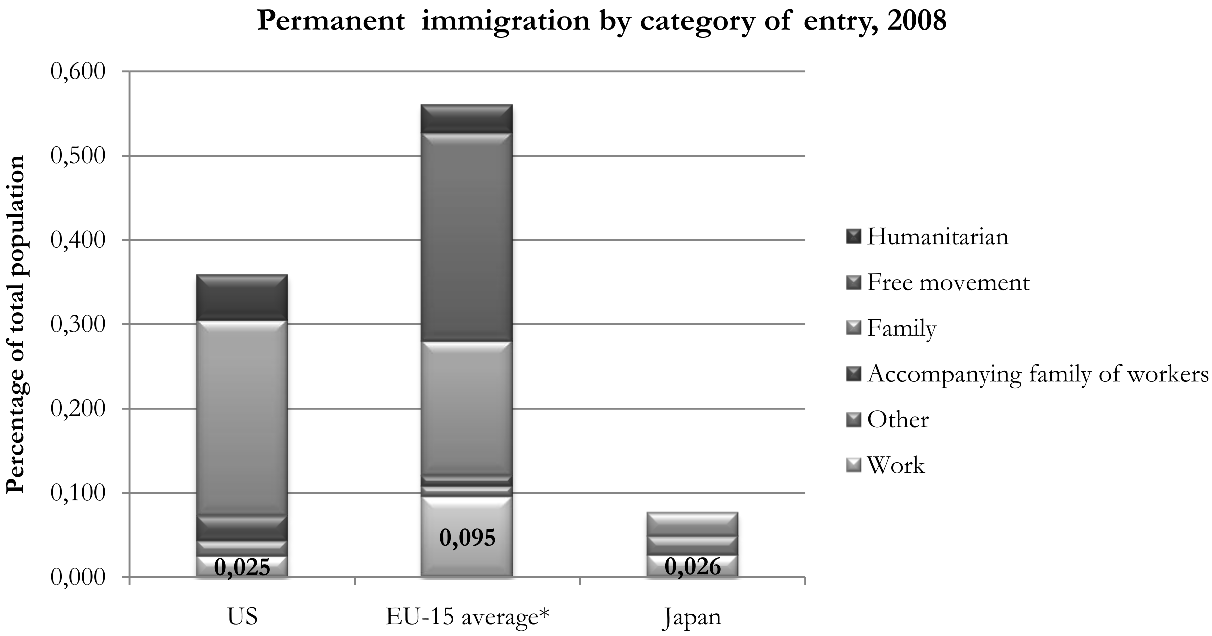

Figure 11.3 Permanent immigration by category of entry (% of total population), 2008
*Excluding Greece, Ireland and Luxembourg
Source: OECD (2010c)

Immigration of persons with tertiary education has increased to the US and to Europe between 2000 and 2008. The increase of immigrants with secondary education has been rather substantial in the EU-15 countries. The share of immigrants with tertiary education in the US remains almost twice the size of the EU-15 share of immigrants with tertiary education. Japan's share of immigrants with tertiary education is almost negligible in comparison to the other regions. Unfortunately, there is no data available of the number of educated immigrants in Japan year 2008.

Table 11.5 Immigrants with secondary and tertiary education to the triad regions, 2000 and 2008

Triad Region	Immigrants with tertiary education (per 1000 inhabitant)		Immigrants with secondary education (per 1000 inhabitant)	
	2000	2008	2000	2008
EU-15	3,052,162[1] (9.9)	5,787,700[2] (16.3)	3,878,397[1] (12.6)	10,273,200[2] (28.9)
EU-27	NA	6,207,700[2] (12.7)	NA	11,403,000[2] (23.4)
USA	5,862,756 (20.8)	8,638,275 (28.4)	8,359,370 (29.6)	NA
Japan	278,277 (2.2)	NA	410,453 (3.2)	NA

[1]Immigrants from countries outside of Europe
[2]Immigrants from countries outside of EU
Source: 2000 round population census from OECD (2010c); 2008 round population census from Eurostat (2010); US MPI (2010)

Europe receives more immigrants with tertiary education from other OECD countries than from the rest of the world, as evident from the Table 11.6. In the US and Japan, the pattern is reversed. European countries also lose a much larger share of its highly educated to other OECD countries than the US and Japan. The statistics below is somewhat misguiding however, since migration flows between countries within the European Union are included.

Table 11.6 Foreign-born persons with tertiary education as a percentage of all residents with tertiary education, circa 2000

Triad region	Immigrants from other OECD countries	Emigrants to other OECD countries	Immigrants from the rest of the world
EU-19 average (OECD countries)	6.57	-10.09	5.10
USA	4.25	-0.70	9.17
Japan	0.17	-1.08	0.52

Source: OECD (2010c)

Europe still lags behind the US in terms of high-skilled immigration; although Europe performs better than Japan in this context. However, the trend of high-skilled migration to Europe is positive; Europe has displayed a stronger growth than the US in both absolute and per capita figures.

12 Conclusions

The purpose of this report has been by means of a literature survey to analyze the capacity of one of the triad regions – Europe or more precisely the European Union (EU) – to keep track of the development of new knowledge in the two other triad nodes via different channels for knowledge flows. In line with earlier research, we focus on the triad EU-USA-Japan to make it possible to make comparisons with earlier research. Future analysis must increasingly consider what is going on outside the triad and not least in China and the other BRIC countries. However, even if the triad regions' share of the worldwide exports of, for example R&D-intensive goods, declined from 82 percent in 1993 to 69 percent in 2004, the triad regions are still major players in the global economy (Gehrke, Krawczyk & Legler, 2007).

The background to our report has been the prominent concern for many years within the European Union (EU); how to strengthen its innovative capability since it is becoming increasingly networked node within the global system (Kale & Little, 2007). One example is the development of a European 'knowledge economy', which has been at the heart of EU's economic policy since the launching of the so-called 'Lisbon strategy' in March 2000. The strategic goal of the Lisbon strategy was that Europe the coming decade should 'become the most dynamic and competitive knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion, and respect for the environment'. Later at the European Council meeting in Barcelona in March 2002 it was agreed that the 'overall spending on R&D and innovation in the Union should be increased with the aim of approaching 3 percent of GDP by 2010. Two-thirds of this new investment should come from the private sector.'[33] Since the Lisbon strategy did not focus enough on the need to increase the flows of knowledge and technology, from the two other triad regions in particular, it was not surprising the ambitious goals were not accomplished.

[33] See http://europa.eu.int/comm/lisbon_strategy/index_en.html

Europe still lacks an integrated R&D and innovation strategy with proper instruments to achieve the goals. Europe lacks cohesion and central decision-making regarding R&D and innovation comparable to what exists in the US and Japan. The individual member states still have a substantial autonomy when it comes to R&D, innovation and higher education. It has been far beyond the scope of this paper to try to design a new R&D and innovation strategy for Europe. Instead, we have focused on one critical factor for a successful such strategy and that is the capacity of Europe to rapidly acquire knowledge developed in the two other triad regions. The importance of such a capacity is well understood as soon as we realise that the gross domestic R&D expenditure in current USD (PPP-adjusted) in the US and Japan taken together is about double of that in the EU, and that researchers in the US and Japan produce approximately the same number of scientific and technical articles as the researchers within the EU (Archibugi & Coco, 2005). The underlying reason why such a capacity is so important is the role of diversity or heterogenity of knowledge for new combinations to emerge, i.e., for the creation of new knowledge and (technological) innovations (Schumpeter, 1939; Nelson & Winter, 1982; Nonaka, 1994; Nooteboom, 2004). According to this perspective, new knowledge and new technology is assumed to emerge from the combination of existing knowledge bits. In this paper, we broaden the scope and concentrate on channels for international knowledge flows and we identify and analyze the following channels for international knowledge flows:

1. Academic channels
2. Patent citations
3. Technology trade (including international consulting)
4. Strategic R&D cooperation
5. Trade networks
6. Foreign direct investments (FDIs)
7. International migration

In terms of academic knowledge flows we can observe that European scientists are deeply engaged in international co-authorships but that is seems as the co-authorships with scientists in the US are declining as a share. This might be an effect of among other things EU's framework programs stimulating cooperation among scientists within Europe. If this is the reason, the EU should consider the possibility to revise the framework programs to include leading scientists from other parts of the world to a higher extent. Another interesting observation is that advanced research programs in Europe only enrol around 15 percent international researchers compared to around 28 percent in the US. This result points in the same direction. Europe must become much more open to engage international researchers in its advanced research programs. These observations might contribute to the fact that the quality of European articles is well below that of US articles as measured by the number of citations.

Turning to patent citations it is evident that European inventors seem to build their new inventions on knowledge embedded in patents from abroad to a larger extent than the other two regions. US and Japanese inventors cite their own and national patents more frequently compared to European inventors. There seems to be little barriers to knowledge flows through patent citations among the European countries and from the other triad regions. It is noteworthy, however, that EU patents cite US scientific publications to a much lower extent that US patents cite EU scientific publications. This is an indication that European inventors do not take full advantage of potential knowledge flows from scientific publications from the US. It is unclear what the barrier might be but it is important that European inventors are made aware that US scientific publications might be an underutilized knowledge source. We can also observe that the EU co-patent with inventors from the US to a larger extent with reference to USPTO patent grants than US inventors co-patent with inventors from the EU. The reverse is true with reference to patent applications to the EPO, although the gap is much smaller.

Considering knowledge flows to Europe via technology trade, we can observe a very rapid increase in the payments for royalty and license fees from the EU member countries indicating a rapid increase in the imports of knowledge to the EU. The payments per inhabitant for the EU are 4.5 times higher than those for Japan, and 6.5 times higher than those for the US. The technology export from the EU is less than 60 percent of the technology export from the US indicating that the EU is not up to standard when it comes to developing new knowledge that is attractive on the world technology market.

Another interesting knowledge channel is strategic R&D alliances between firms. The trend of these type of alliances is increasing and, in particular, it can be observed that it is R&D alliances between firms in the US and firms in the EU that are increasing. The conclusion we can draw is that European firms are interesting partners for international strategic R&D alliances for US firms. This indicates that European firms are taking advantage of this particular knowledge channel.

Imports of high-value goods are an important channel for knowledge imports. The EU countries have rapidly increased their imports of high-tech products since the mid-1990s. However, in per capita terms EU was in 2005 about 30 percent below the US in terms of imports of high-tech products. This indicates that the EU has a large potential to increase its knowledge imports by increasing the imports of high-tech products. Available data also indicates that the unit value of EU's high-tech imports are far below that of the high-tech imports of the US. The unit value of US' high-tech imports is almost 60 percent higher than that of EU's high-tech imports. This indicates that EU fails to import the most advanced high-tech products, i.e. the high-tech products with the highest knowledge content.

Multinational firms play an important but probably underestimated role for international knowledge flows. EU receives massive inflows of foreign direct investments, which indicates the potential for substantial inflows of knowledge as well as a large potential for knowledge spillovers benefitting European firms. EU is also a major origin of foreign direct investments, which potentially is a source for reverse knowledge flows to the extent that the investing firms use their foreign affiliates as listening posts and as sources of innovation. Almost half of the outward stocks of US FDIs are invested in Europe. This trend has remained stable during recent years. About ¼ of the Japanese FDI stocks are invested in Europe, also a trend that has not changed in the past years. Out of all of the FDI stocks in the US, European MNFs account for above 60 percent of the investments. Europe account for around 40 percent of the FDI stocks in Japan. Moreover, Europe invests about the same amount of FDI in the US as the US invests in Europe.

Our final channel for international knowledge flows is international migration. EU has generally a lower share of immigrants among the employed than the US. The share for the EU is 20-30 percent below that for the US. For high-skilled jobs, the difference is about 20 percent. However, for professionals the situation is much more dramatic. Here the figure for Europe is 36 to 43 percent below that of the US. Furthermore, immigrants with tertiary education is lower in Europe (16 per 1000 people) than in the US (28 per 1000 people) in 2008. This indicates clearly that Europe has failed to take advantage of one important source of knowledge, i.e. the immigration of professionals. The reason is of course the rather strict regulation of the labour markets within the EU.

Europe has shown improvements in terms of its absorptive capacity of knowledge flows for a few of the indicators applied and examined in this report. Nevertheless, the indicators show that there are certain types of knowledge channels that Europe must try to use much more extensively. Europe can never become the leading knowledge economy in the world without taking advantage of all the potential benefits of different types of international knowledge channels.

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14 Appendix

Table 14.1 List of countries included in the different EU denominations

EU-15	EU-19	EU-25	EU-27	Euro Area	Western Europe
Austria	Austria	Austria	Austria	Austria	Austria
Belgium	Belgium	Belgium	Belgium	Germany	Belgium
Denmark	Czech Republic	Cyprus	Bulgaria	Greece	Cyprus
Finland	Denmark	Czech Republic	Cyprus	Ireland	Denmark
France	Finland	Denmark	Czech Republic	Italy	Finland
Germany	France	Estonia	Denmark	Luxemburg	Greece
Greece	Germany	Finland	Estonia	Malta	Iceland
Ireland	Greece	France	Finland	Netherlands	Ireland
Italy	Hungary	Germany	France	Portugal	Luxemburg
Luxembourg	Ireland	Greece	Germany	Slovakia	Netherlands
Netherlands	Italy	Hungary	Greece	Slovenia	Norway
Portugal	Luxembourg	Ireland	Hungary	Spain	Portugal
Spain	Netherlands	Italy	Ireland		Spain
Sweden	Poland	Latvia	Italy		Sweden
UK	Portugal	Lithuania	Latvia		Switzerland
	Slovakia	Luxembourg	Lithuania		
	Spain	Malta	Luxembourg		
	Sweden	Netherlands	Malta		
	UK	Poland	Netherlands		
		Portugal	Poland		
		Slovakia	Portugal		
		Slovenia	Romania		
		Spain	Slovakia		
		Sweden	Slovenia		
		United Kingdom	Spain		
			Sweden		
			United Kingdom		

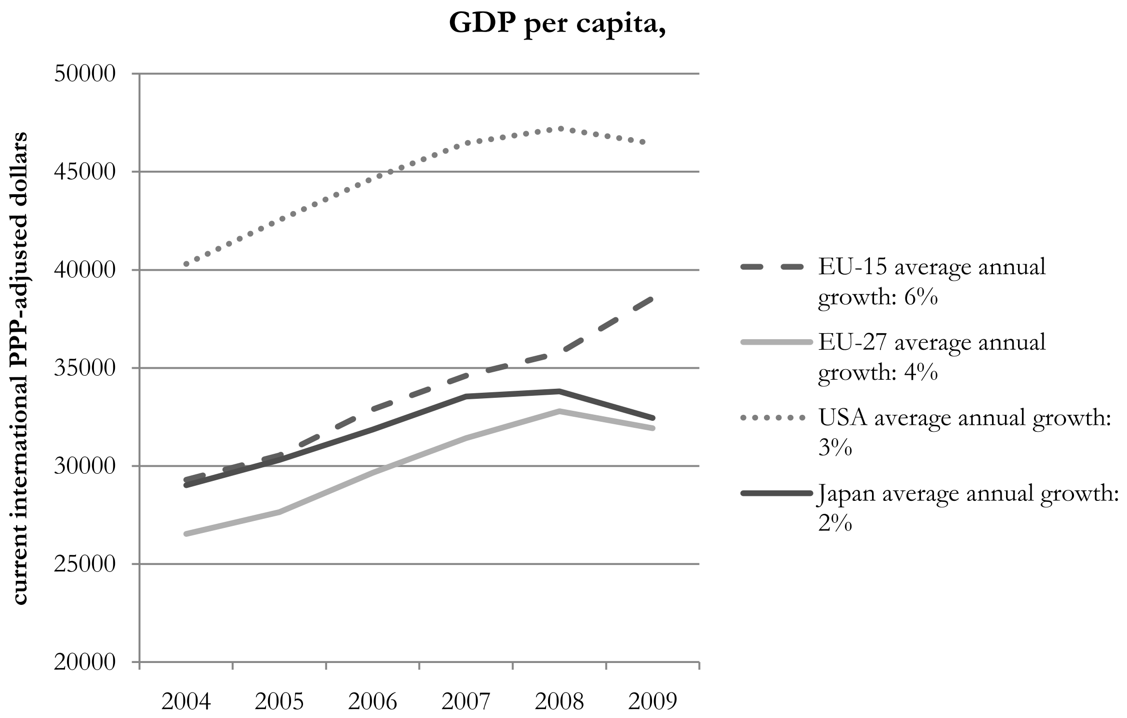

Figure 14.1 Development of GDP per capita (PPP adjusted current international dollars) in the triad region: 2004-2009
Source: OECD (2010a); World Bank (2010a)

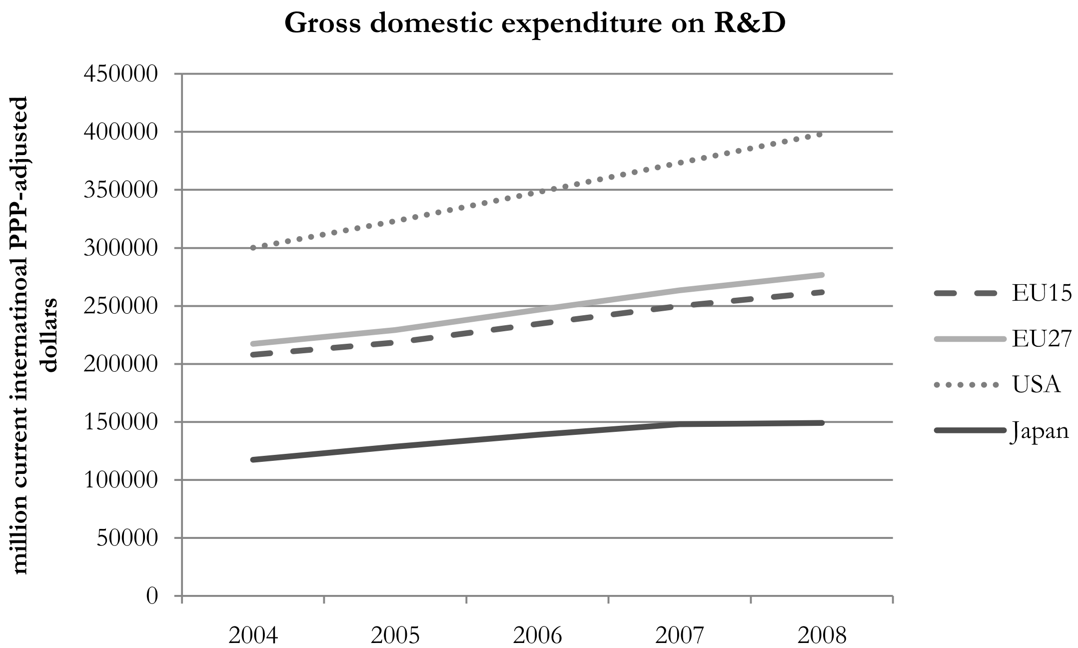

Figure 14.2 Development of gross domestic expenditure on R&D in the triad region: 2004-2008
Source: OECD (2010a)

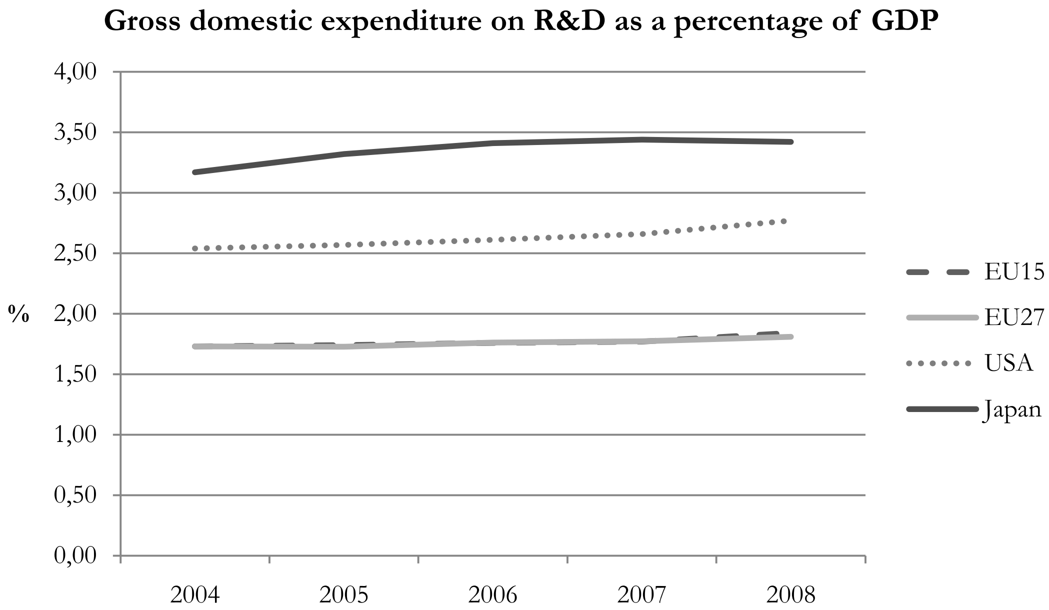

Figure 14.3 Development of GERD as a percentage of GDP
Source: OECD (2010a)

Table 14.2 Royalty and license fees, receipts (BoP, current million US$)

Region	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
EU-15	22,166	27,118	34,255	39,833	41,168	48,011	51,870
EU-27	22,772	27,622	35,007	41,048	42,141	49,504	53,650
USA	44,508	46,988	56,715	64,395	70,727	83,824	91,600
Japan	10,422	12,271	15,701	17,655	20,096	23,229	25,701

Source: World Bank (2010a)

Table 14.3 Royalty and license fees, payments (BoP, current million USD)

Region	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
EU-15	34,829	44,021	50,522	54,483	56,545	67,240	76,690
EU-27	36,232	45,787	53,115	57,731	60,289	72,037	82,303
USA	19,353	19,033	23,266	24,612	23,519	24,656	26,615
Japan	11,021	11,003	13,644	14,653	15,500	16,678	18,312

Source: World Bank (2010a)

Table 14.4 Royalty and license fees, receipts – payments (net export in USD million)

Triad Region	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
EU-15	-12,663	-16,903	-16,267	-14,650	-15,377	-19,229	-24,820
EU-27	-13,460	-18,165	-18,108	-16,683	-18,148	-22,533	-28,653
USA	25,155	27,955	33,449	39,783	47,208	59,168	64,985
Japan	-599	1,268	2,057	3,002	4,596	6,551	7,389

Source: World Bank (2010a)

Table 14.5 FDI inward positions (stocks), billion USD

	2002	2003	2004	2005	2006	2007	2008	2009
EU*	3,497	4,607	5,654	5,614	7,098	8,969	8,392	8,364
US	1,500	1,577	1,727	1,874	2,154	2,411	2,521	2,673
Japan	78	90	97	101	108	133	203	200

Source: OECD (2010d)

Table 14.6 FDI outward positions (stocks), billion USD

Region	2002	2003	2004	2005	2006	2007	2008	2009
EU*	4,129	5,288	6,097	6,182	7,695	9,867	9,690	9,973
US	1,867	2,054	2,498	2,652	2,948	3,553	3,743	4,051
Japan	304	336	371	387	450	543	680	741

Source: OECD (2010d)