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"Intra-Triad knowledge flows"

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Contents

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 (EU) 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] In this paper, the position of Europe as a leading knowledge-based economy is analyzed in relation to the United States and Japan. 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. In addition, knowledge flows to the EU from Australia, Canada and the BRIC countries[2] are included in the analysis to some extent as well as knowledge flows from the triad to specific European countries. 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 analyzed by means of a literature survey and compilations of recent available data.

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

1.1 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 (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

[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

fundamentally changed the conditions for knowledge production (cf., Archibugi & Coco, 2005):

1. The world economy is globalizing 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). Such knowledge mobility shifts the absorption and creation capacity between places.

5. Innovation has in recent decades gone through a globalization 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 licenses (Archibugi & Michie, 1997; Narula & Zanfei, 2005). Innovation processes are increasingly characterized 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 &

[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).

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 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). As a consequence 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 internationalization 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 labor 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 internationalization and innovation are both complex and reciprocal. In other words, internationalization is not only about commercializing 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 internationalization, there are also considerable evidences of the opposite effect, i.e. that internationalization 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 internationalization 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? The proper response to these two challenges have become more complicated in recent years due to a rapid increase in the location of R&D to developing countries including, India, China and Singapore but also to countries in Eastern and Central Europe.

The changing geography of R&D and innovation is on the one hand the result of efforts from a growing number of countries to increase R&D spending. On the other hand, it is the result of deliberate R&D strategies by firms, where one strategy consideration is to augment innovation resources and results by means of merger and acquisition activities.

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 use effectively 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 labor 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 organization 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 be-

[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).

hind 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). Instead, cross-border flows rely on inter-firm networks, which are observed mainly indirectly, and, hence, only documented in fragmented form. This is illustrated clearly 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 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 failed to a large extent.

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 acquire rapidly knowledge developed in the two other triad regions. The importance of such a capacity is well understood as soon as we realize 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 heterogeneity 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.

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

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) globalization 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. Therefore, the analysis is extended to include knowledge flows from other parts of the world such as Australia, Canada and the BRIC countries for some of the indicators. 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). Furthermore, we also attempt to point out the vast differences within the European Union and that the knowledge absorption capacity differs substantially between the European countries.

2 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 4 will then introduce the reader to different forms of knowledge flows and the rest of the paper will analyze Europe's ability to enhance its position through its absorptive capacity of the different types of knowledge flows. The tables and figures refer to different compilations of the European Union (EU-15, EU-19, EU-27, Euro area and Western Europe)[6]. The reason for this is that different sources report data differently. Moreover, it is of interest to observe to what extent EU-15 differs from EU-27 concerning various measures. 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).[7] 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. This section attempts to answer the question of how large the gap between Europe and the other triad regions is when it comes to developing new knowledge and in which particular areas the gap exists.

2.1 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 (see appendix Figure 13.1). 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 13.1). The reason for Europe's apparent superior performance reflects the quite sharp decrease in GDP per capita in the US and Japan in 2008-2009. In Table 2.1, 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 2.1 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 in 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

[6] Complete lists of the countries included in each European region can be found in the Appendix in Table 13.1.
[7] Interestingly similar concerns have been raised in the US (See, e.g. Kennedy, 1988; Pianta, 1988; Nelson, 1989)

budget, grows during this period (see appendix Figure 13.2). 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 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 2-1 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 2.2 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 2-2 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 2.3). What is most interesting to note in Table 2.3 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 2-3 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 2.4. The R&D intensity in the triad regions is further highlighted in Table 2.4 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 2-4 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 2.5, 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 2-5 GERD-to-GDP ratio, industry financed share of GERD and share of medium-high-tech and high-tech R&D*, 2007

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, airplanes and other transport.[8]

Figure 2.1 further illustrates the source of funding for GERD in EU-27 in 2008. Only 56 percent, a slight increase from the previous year, of the funding originates from the business enterprise sector.

[8] It is important to stress that definitions of what is counted as high-tech always tend to be pretty subjective.

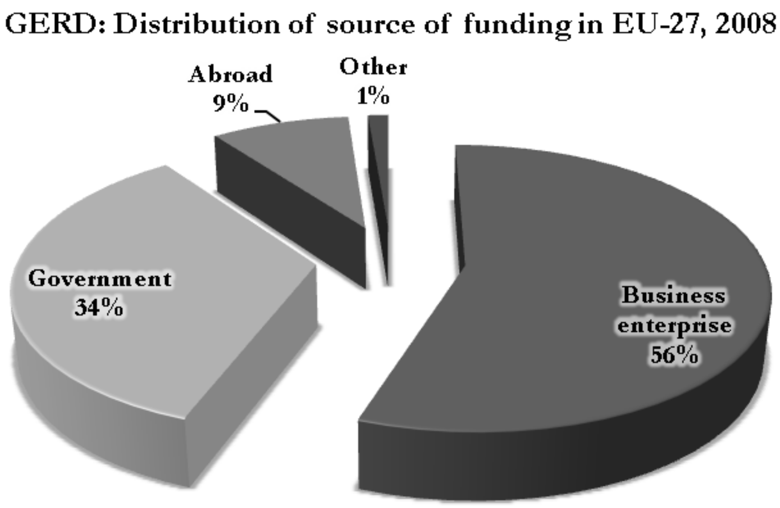

Figure 2-1 GERD: distribution of source of funding in EU-27, 2009
Source: Eurostat (2010)

Figure 2.2 shows the target sectors of R&D spending in EU-27. The business enterprise sector receives a larger share of R&D investments than the sector provides.

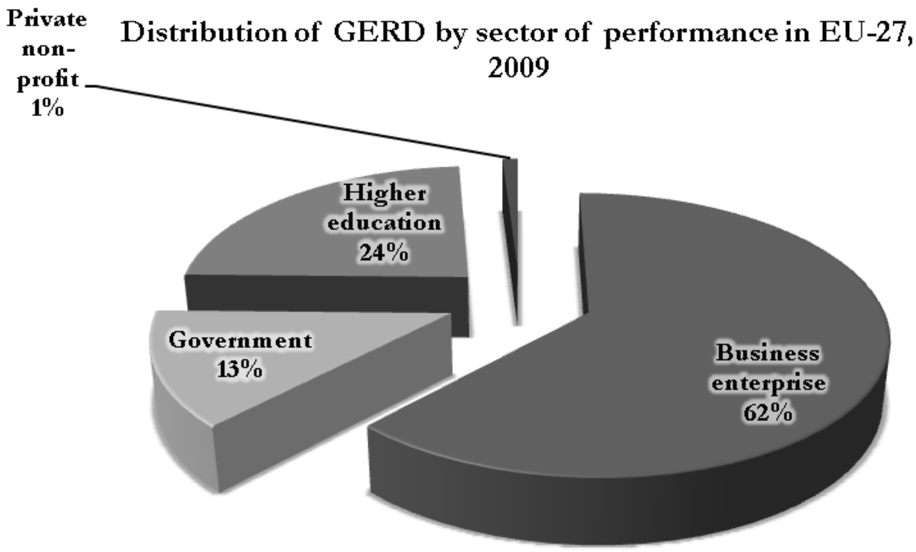

Figure 2-2 Distribution of GERD by sector of performance in EU-27, 2009
Source: Eurostat (2010)

Regardless of the sector of investment, the EU should ensure that the research projects performed generate strong externalities in general.

2.2 Intellectual property

Competition in global markets is based increasingly 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 industrialized 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.[9] 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 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 internationalization, 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 2.6-2.8 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 2.6a 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 had a decline during this period 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).

[9] 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).

Table 2-6a 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 2.6b 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 2-6b 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
Rest of World	6.7	12.9
Total	100	100

Source: NSF (2010)

In Table 2.7 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 2-7 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 2.8 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 2-8 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.

Table 2.9, exhibits data for 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). 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 2-9 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)

We follow up the information presented in Table 2.9 with the triad patent frequency per million population. Table 2.10 shows that 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 2-10 Intellectual Property Protection in the Triad Regions in 2007

Patenting frequency	EU-27	USA	Japan
Triad patents per million population*)	19.6	33.9	87.0

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

Patents granted in the US and applied for in Europe per one million people are illustrated in Table 2.11, 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.

Table 2-11 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)

The 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). Europe is lagging way behind the other triad regions in terms of patenting frequency per capita at all patent offices. 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 asses output, exports and imports (Soete, 1987).

2.3 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 2.12-2.14. We can observe in Table 2.12 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 2-12 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 2.13 below. Remarkably, the value added of commercial knowledge intensive services in Japan has decreased between 1995 and 2007.

Table 2-13 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 2.14). Value added of high-tech manufacturing industries has increased with 75.2 percent in Europe between 1995 and 2007.

Table 2-14 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 2.15). 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. Europe has the lowest output as a share of GDP among the triad regions of both the high-technology manufacturing industry and the ICT industry.

Table 2-15 Output of high-technology manufacturing and ICT industries as a share of GDP: 1995 and 2007 (percent)

Triad region	High-technology manufacturing industries		ICT industries	
	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 2.16, 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 2-16 High-tech gross revenues in triad regions in 1985 and 2005 (millions of 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 2.17 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 2-17 Exports of high-tech products from triad regions in 1995 and 2008 (millions of 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 involve trade only with countries outside of the EU.

Looking at the global export shares for high-tech products we see in Table 2.18 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 2.17.

Table 2-18 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.

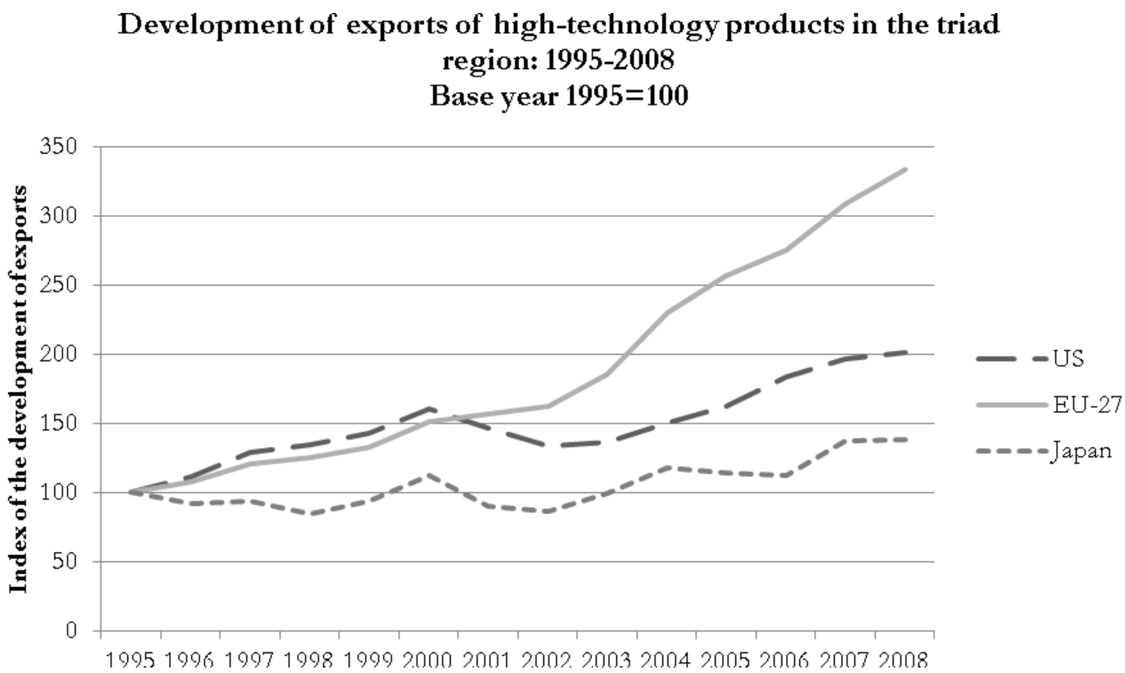

Figure 2-3 Index of the development of high-technology exports: 1995-2008
Source: NSF (2010)
Note: EU exports involve trade only with countries outside of the EU.

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 2.19 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 2-19 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 2.20 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 2-20 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.

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

2.4 Output and quality of research

In Table 2.21, 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 2-21 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)

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 2.22. All triad regions and the US in particular have had a drop in their market share between 1995 and 2008.

Table 2-22 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 2.23). 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 2-23 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 = 99th percentile of citations received (> 21), TOP 10 = 90th 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 2.24 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 2.21. 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 2-24 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)

2.5 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’s spending and use of information and communication technology lag behind the other two triad regions.

- Entrepreneurship is underdeveloped and venture capital is lacking in Europe compared to the US.
- 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. Furthermore, Europe lags behind the other two triad regions in terms of population with higher education.

The Europe 2020 strategy aims enhance growth by being a smart, sustainable and inclusive economy by improving EU's performance in many of the areas where it lags behind the other triad regions. EU and its Member States have decided to *"help Europe recover from the crisis and come out stronger, both internally and at the international level"*.[11] The improvement of education, research and innovation, and information and communication technology has been placed at the heart of this strategy. One of the goals, still remaining from the Lisbon strategy, is that at least three percent of GDP should be invested in R&D by 2020. To address the lack of finance for small- and medium sized firms and innovative start-ups the venture capital passport aiming to remove cross-border barriers has been set up, as well as an initiative to attract long-term foreign investors to the EU. Moreover, by 2020 less than ten percent of the population aged 18-24 should have left school early; and at least 40 percent of the population aged 30-34 should have completed tertiary education. Enhancing the attractiveness of Europe's universities is also a key dimension of the strategy to improve the education level.

Although international cooperation is included in the Europe 2020 strategy, more focus could be put on the extent to which Europe takes advantage of knowledge, skills and technology from other parts of the world and engages in collaborations with third countries in order to create new knowledge. In the next section, such knowledge flows are discussed and how the absorptive capacity of a country/region can generate knowledge spillovers. In Chapter 5-11, Europe's ability to absorb knowledge and technology from other parts of the world through different channels of knowledge flows will be analyzed.

[11] From the Annual Growth Survey Annex 1, Progress Report on Europe 2020, Retrieved 2011-07-05 from http://ec.europa.eu/europe2020/index_en.htm

3 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 simultaneously by several economic agents (Romer, 1990) to develop new knowledge, i.e., inventors can normally not fully prevent other 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 because 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, licenses, 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.[12] 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, internalize 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 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 behavior 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.[13]

The three categories are presented in Table 3.1 together with nine types of knowledge flows.

[12] 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).
[13] 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.

Table 3-1 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)

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 as either 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 assumed generally 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. Certainly,new knowledge and new technologies are 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 labor 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., organizations 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 shared equally 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.

Autant-Bernard, Fadairo and Massard (2010) argue that in a knowledge-based economy, the primary role of innovation policy is to create a variety of mechanisms and channels to facilitate the absorption and diffusion of local and external knowledge. The extent of knowledge flows and knowledge spillovers is generally measured by the patterns of patent and publication citations, technology licensing 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).[14] 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

Europe's potential to absorb knowledge through these seven channels mainly from the triad regions, but also from Australia, Canada and the BRIC countries for some of the indicators, will be analyzed in the following chapters.

[14] 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).

4 Academic knowledge flows

4.1 Intra-triad academic knowledge flows

The purpose of this chapter is to highlight how both codified and tacit knowledge related to academia can spill over across space. Cooperation at both the individual level and the organizational 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 documented normally 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 academic knowledge flows from the other triad regions is put into focus in the following sections of this paper.

4.1.1 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 organizational level involving joint research centers, joint research programs, 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, centers 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 analyze 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).[15] 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)

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

(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 programs 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 collaborations 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 4.1 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 4.2 and Table 4.3. Table 4.1 below shows that international co-authorships are quite common in Europe.[16]

Table 4-1 Percentage of Internationally Co-authored Scientific Papers in the Triad Regions of All Scientific Papers; 1994, 2001 and 2007

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)

It is interesting to observe in Table 4.2 that in 1995-1997 60.3 percent of the US internationally co-authored papers 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 is 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 internationalization. It is unclear to what

[16] 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.

extent this is due to EU's FP programs[17] 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.

Table 4-2 Distribution of Internationally Co-authored Papers Across the Triad Regions (share of all papers); 1986-1988 and 1995-1997

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	NA	8.2	60.3	9.6	NA
Japan	33.3	54.0	NA	39.4	45.6	NA

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 4.1, Table 4.3 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 (although the world includes other EU countries). 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. This information indicates that Europe has become more internationalized beyond the borders of the EU in terms of collaboration in science during the last decade.

Table 4-3 International Co-authored Papers Between the Triad Regions; 1998 and 2008

Triad Region	1998			2008		
	EU-19[A]	USA	Japan	EU-19[A]	USA	Japan
EU-19[A]	-	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[B]	102,438	43,254	10,000	184,394	78,348	16,038

[A] EU-19 excludes Luxembourg and Slovakia
[B] The world also includes countries within the EU-19.
Source: NSF (2010)

The number of co-authored articles should be discussed also 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 4.4)[18]. As mentioned before however, the European articles produced in international collaboration includes cooperation between countries within the EU.

[17] 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
[18] The number of articles produced in international collaboration in 2008 differs slightly between Table 4.3 and Table 5.4 for the triad regions. The figures originate from different sources that might have used slightly different measurements methods.

Table 4-4 Scientific Publications in International Collaboration; 2008

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

Source: UNESCO (2010)
[A] Includes articles produced in collaboration with other EU-27 countries

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 4.5). The share of internationally co-authored articles compared to the region's total articles is 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. This implies that all three regions have become more internationalized when it comes to academic collaboration. On the other hand, the triad region's shares of world's internationally co-authored articles have decreased, indicating that the rest of the world are engaging in international academic cooperation to a larger extent.

Table 4-5 International Collaboration on Science and Engineering Articles (% of Regions Total Article Output and % of World's Internationally Co-authored articles); 1998 and 2008

Triad Region	Share of region/country'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)
Detail adds to more than 100% because articles may have authors from more than two countries/economies

Europe is increasingly taking advantage of knowledge flows via international academic collaborations in general. Furthermore the trend towards a Europeanization of co-authorships that was evident in the 80's and 90's seems to be turning towards an internationalization of co-authorships in the last decade and Europe is increasingly absorbing knowledge via academic collaboration from the other triad regions.

4.1.2 Knowledge flows via citations of scientific contributions

Citation measures have been used increasingly 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.[19] 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 breakthroughs it is possible to get clear evidence of the flows of codified knowledge both within and between countries. In Table 4.6, 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 4.1 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.

Table 4-6 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 4.7. However, the gap between Europe and the US is contracting in all categories except engineering between 1998 and 2008.

Table 4-7 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. The index will be higher if the region's share of world articles is lower.

Although Europe lags behind the US in their share of highly cited articles, it was discovered in section 4.1 that European researchers engage in international cooperation much more. Again, Table 4.8 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).

[19] 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 4-8 Scientific and Engineering Articles with Foreign Co-authorship and Average Number of Citations per Science and Engineering (S&E) Article; 2005

S&E articles with foreign co-authorship	Western Europe	USA	Japan
% 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)

The information given in the tables below shows that articles published by authors from the US are cited more than European and Japanese articles, indicating a higher quality of articles from the US. However, information is lacking regarding to what extent European authors cite articles from the other triad regions, as a means of acquiring knowledge. This would be the appropriate approach to measure to what extent Europe is taking advantage of knowledge flows by making use of the knowledge embedded in articles from the other triad regions in their work.

4.1.3 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. Zucker & Darby (2006) support this claim. Star scientists as well as other highly educated workers are in general more spatially mobile than average workers. The increased globalization of the labor 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. that 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.

It has been recognized, while analyzing the impact of labor mobility, that spinoffs and startups initiated by university scientists are key drivers of knowledge flows (Audretsch & Keilbach, 2004; Schiller & Revilla-Diez, 2009). Moreover, Breschi and Lissoni (2006) conclude that the diffusion of knowledge is greater as the mobility of scientists is higher. Data on the mobility of scientists are rather scarce.However, Table 4.9 and Table 4.10 shed some light on these patterns in the triad. As Table 4.9 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 4-9 International Researchers Enrolled as a Percentage of All Researchers (International Plus Domestic); 2008

Triad Region	Advanced research programs
EU19 average	14.9
USA	28.1
Japan	16.2

Source: OECD (2010b)

Table 4-10 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 4-10 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).

4.1.4 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 2008 amounted to 3.3 million, an increase of 69.7 percent since 2000 (OECD, 2010e).

Table 4.11 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. The data in the table above is somewhat misleading since for example a student from France enrolled in the UK will count as a foreign student, whereas a student from California, enrolled in Pennsylvania will not.

Table 4-11 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 labor market, although some theoretical foundations may be covered in the respective programs.
Source: OECD (2010b)

As Table 4.12 shows, more than half of the students from the US studying abroad were studying in one of the EU-19 countries in 2008, a positive fact in terms of knowledge flows toward Europe. Astonishingly, there are slightly more Japanese students studying abroad than students from the US, despite the fact that the US has a much larger population. Only 19 percent of the Japanese students choose EU-19 as a destination. 65.3 percent of the Japanese foreign students were studying in the US in 2008 (not displayed in the table). This is in line with earlier remarks indicating that Asian foreign students are more common in the US than in Europe.

Europe's market share of foreign students studying in the region decreased from 39.3 percent in 2000 to 38.4 percent in 2008. However, more than a third of the world's foreign students are still studying in Europe in 2008. Slightly less than half of the foreign students in EU-19 are from another European country. 75.7 percent of all the foreign students from EU-19 are studying in another EU-19 country. Only 10.4 percent (or 48,660 students) of all students from EU-19 were studying in the US in 2008 (not displayed in table). The corresponding share of students from EU-19 studying in Japan is 0.5 percent (or 2337 students) (not displayed in table). The low share of European students choosing the US or Japan as a destination is negative in respect of the potential of Europe to absorb knowledge from the triad as the students return home.

Table 4-12 Foreign Students from the Triad in EU-19 and in the World in Tertiary Education; 2008 (unless otherwise stated)

Country of origin	Number of foreign students in EU-19	% of all students abroad	All students abroad (world)
Japan	10,037	19.0%	52,849
USA	28,326	54.1%	52,328
Total from Europe	535,016	65.4%	817,709
of which from EU-19 countries	354,964	75.7%	469,012
Total from all countries, 2008	1,282,244	38.4%	3,343,092
Total from all countries, 2000	775,031	39.3%	1,970,518

Source: OECD (2010e)

The evidence laid forth in the sections above regarding academic knowledge flows has demonstrated a number of remarks. European countries co-author articles with researchers from abroad to a larger extent than the other triad regions do. 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: Although whether European researchers take advantage of the knowledge contributed by articles from the US largely remains unclear. The US also receives more advanced researchers from abroad, 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. More than half of the foreign students from the US study in Europe, whereas only 19 percent of the Japanese foreign students study in Europe. Most Japanese students perform their studies abroad in the US. Lastly, a very low share of European foreign students leaves the borders of Europe to study in the other triad nations. In comparison to the US, Europe seems to be behind in attracting knowledge flows via academic channels. Most of the international academic activity is still taking place within the EU.

According to Cohen, Nelson and Walsh (2002), the most important channels for accessing public research are the public and informal channels such as publications, conferences, and informal interactions. Autant-Bernard, et al. (2010), argue that knowledge spillovers from public research is geographically bounded to a large extent. Hence, the EU must expand the potential for knowledge absorption from the triad through academic channels. Concerns have been raised that public research in the US is more "applied" than in many European countries (Autant-Bernard, et al., 2010). This implies that geographic proximity on research spillover to the industry does not have as strong influence in Europe as it does in the US. It is vital for the future of knowledge-based economies to combine the institutional compatibility of open knowledge with private incentive structures (Foray & Mairesse, 2002). Policy makers in the EU should enhance the creation of more applied research, better research opportunities and higher salaries in Europe in order to attract more foreign researchers and facilitate knowledge diffusion by researchers. One of the main focuses of the EU 2020 strategy is to improve business-academia collaborations in order to strengthen Europe's knowledge base.

4.2 Academic knowledge flows from Australia, Canada and BRIC to EU

Turning to academic knowledge flows from Australia, Canada and the BRIC countries to the EU, a few interesting observations can be made. Figure 4.1 shows both the number of co-authored articles of the countries mentioned above, as well as the US and Japan, with the EU and the percentage of co-authored articles with the EU of all co-authored articles by these countries with the world[20]. In 2008, EU-19 co-authored the largest number of articles with Canada, after the US. Russia was the country in 2008 that co-authored the largest share, 100 percent, of its articles in international collaboration with European researchers. Both the number and the share of articles in collaboration with EU-19 have increased for all nations apart from China (for which the number of articles co-authored with EU-19 increased substantially but the share decreased by 11 percent). Japan and China dedicates the smallest share of their internationally co-authored articles to cooperation with European researchers. The US still dominates the international academic cooperation with Europe by far, but other parts of the world should not be neglected in this context and the EU should ensure to increase the exploitation of these knowledge sources in order to extract new knowledge.

[20] The percentages are inflated since one article with authors from two European countries would have counted as two articles when the number of articles were added together, whereas that same article would only have counted as one article with authors from the world.

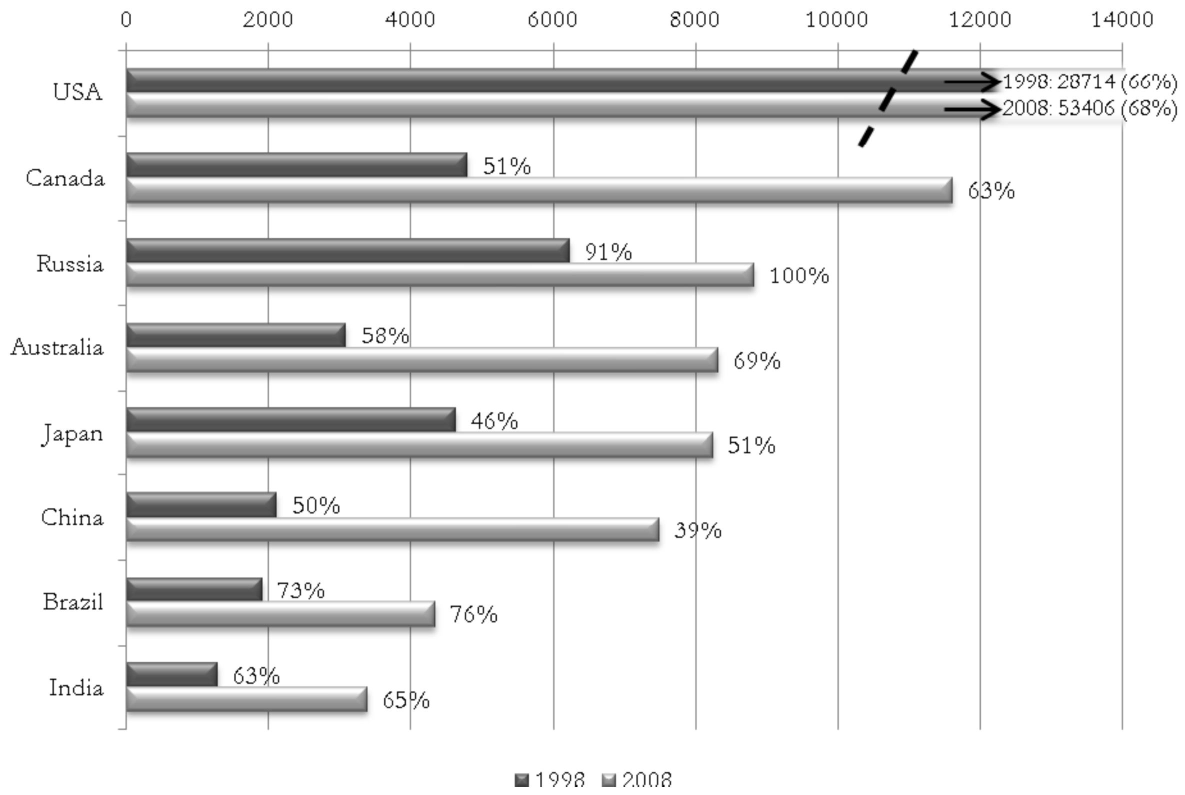

Figure 4-1 Number of Co-authored Articles Between USA, Japan, Australia, Canada, BRIC and EU-19* (% of Co-authored Articles with EU Out of All Coauthored Articles with World); 1998 and 2008

*EU-19 excluding Luxembourg and Slovakia

Source: NSF (2010)

Student mobility figures will cast some further light on the academic network patterns between the EU and Australia, Canada and the BRIC countries. Table 4.13 shows that almost half of all the Brazilian foreign students as well as half of all the Russian foreign students in tertiary education study in one of the EU-19 countries. Only about 20 percent of the foreign students from the two Asian nations, China and India, and from Canada study in EU-19. The share of Australian foreign students in EU-19 is a little larger, but still only about 28 percent. The shares of foreign students in the US of all foreign students enrolled abroad from each country are the following: Australia (30 percent), Canada (64 percent), Brazil (27 percent), Russia (8 percent), India (51 percent) and China (21 percent). Chinese students choose Europe and the US as a destination to the same extent, while Indian students are much more prone to study in the US than in Europe. Unsurprisingly, a large percent of Canadian students study abroad in the US. Chinese foreign students contribute to the largest share (8.5 percent) of all foreign students in the EU-19.

Table 4-13 Number and Share of International Students in EU-19 from Australia, Canada and BRIC in Tertiary Education; 2008

Country of origin	EU-19 total	% of all students abroad	% of all international students in EU-19
Australia	2823	27.7%	0.2%
Canada	9120	20.2%	0.7%
Brazil	13625	49.4%	1.1%
China	108833	21.3%	8.5%
India	34586	18.7%	2.7%
Russia	26805	45.4%	2.1%

Source: OECD (2010e)

Using international collaboration in science and student mobility as indicators of knowledge flows from Australia, Canada and the BRIC nations to Europe has shown that there are possibilities for European students and researchers to take more advantage of the academic channels and the knowledge that these countries, especially the Asian countries, could provide.

4.3 Academic knowledge flows from the Triad to selected EU countries

Before extending the analysis to the academic knowledge flowing to European countries from Japan and the US, it is wise to consider the vast differences between these European countries from an academic perspective. As Table 4.14 displays below, France, Germany, Italy, the Netherlands, Spain and the UK produce most of the internationally co-authored articles in Europe. As can be seen below, there has been a dramatic increase in internationally co-authored papers in all countries, which demonstrates the globalization in the generation of knowledge. This increase is, of course, assisted by the diffusion of internet and email communication The remaining question is how many of these articles are published in collaboration with the US or Japan.

Table 4-14 Internationally Co-authored Science and Engineering Articles with World in Selected European Countries, the US and Japan; 1998 and 2000

Country	1 998	2 008	Growth 98-08 (%)
Austria	2,551	5,180	103
Belgium	4,022	7,418	84
Denmark	3,164	5,038	59
Finland	2,358	3,945	67
France	15,293	25,097	64
Germany	19,869	33,541	69
Ireland	859	2,419	182
Italy	9,519	17,136	80
Netherlands	6,421	11,618	81
Portugal	1,010	3,225	219
Spain	5,852	13,786	136
Sweden	5,390	8,601	60
UK	18,360	33,948	85
USA	43,254	78,348	81
Japan	10,000	16,038	60

Source: NSF (2010)

In 2008, researchers from the UK collaborated to the largest extent in Europe with the US, in comparison to 1998 when Germany was the largest partner for co-authorship with researchers from the US (Figure 4.2). The number of co-authored articles with the US has essentially doubled between 1998 and 2008 for most of the European countries displayed in the figure below. The selected European countries co-author between 20 and 32 percent of their internationally co-authored articles with the US. This share has not changed remarkably since 1998 (not displayed in figure).

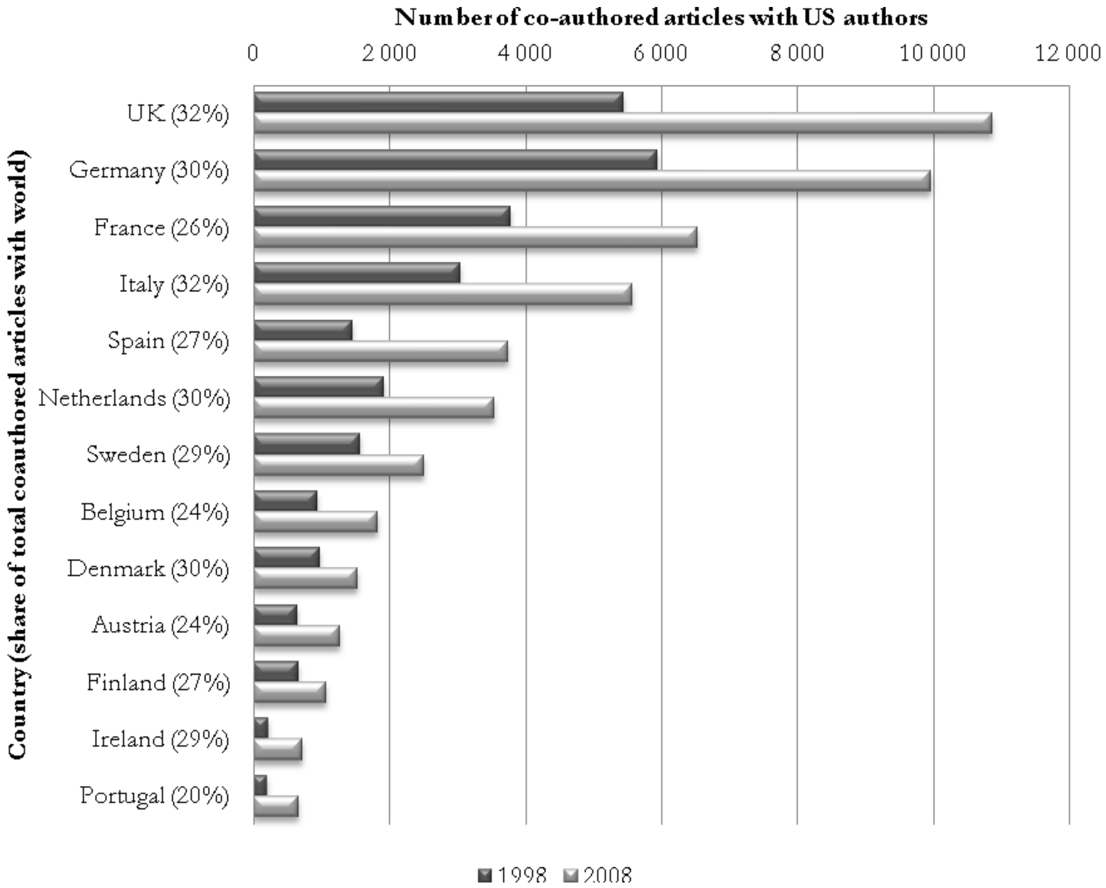

Figure 4-2 Number of Co-authored Articles with US Authors (% of Total Co-authored Articles with World 2008); 1998 and 2008
NSF (2010)

The same European countries that dominate academic collaboration with the US, also dominate collaboration with Japan. Again, the number of articles in collaboration with Japan has increased considerably during the 10-year period.

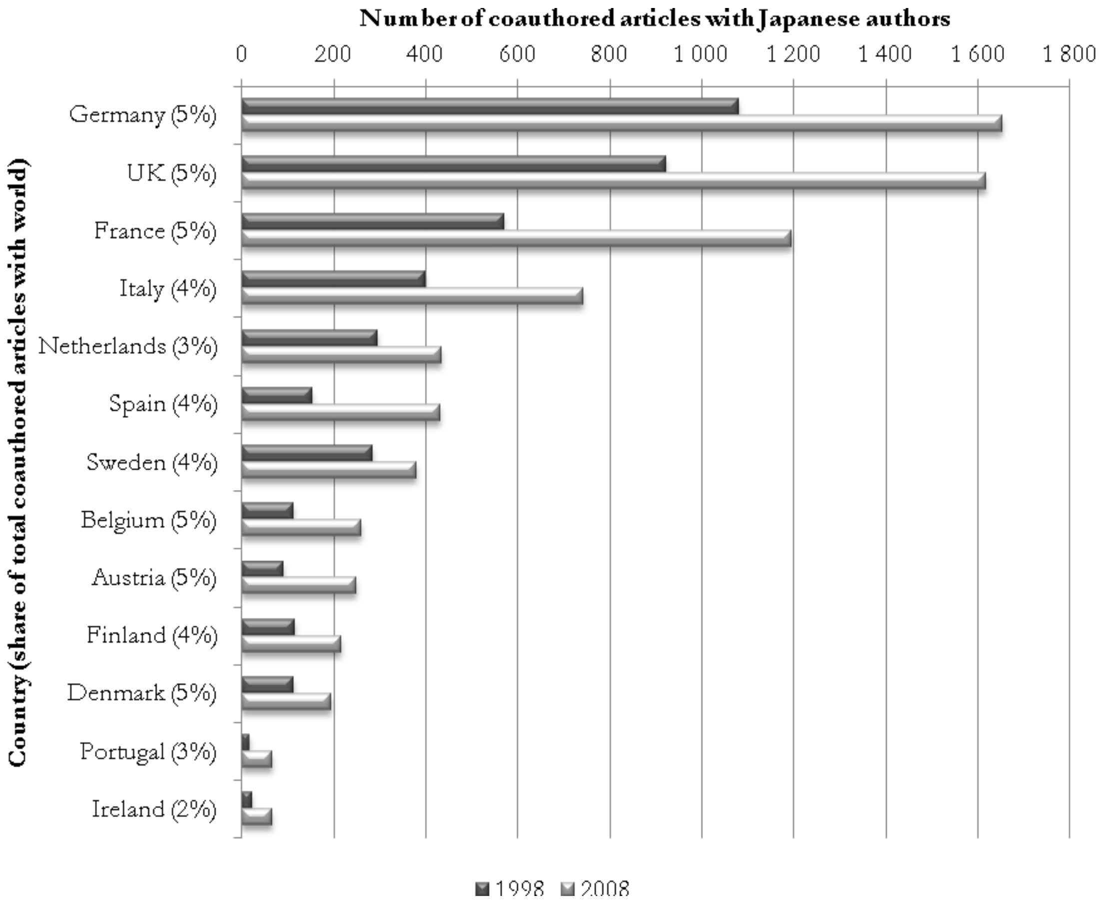

Figure 4-3 Number of Co-authored Articles with Japanese authors (% of totaled co-authored articles with world 2008); 1998 and 2008
Source: NSF (2010)

The academic community in Europe is a valuable asset for acquisition of knowledge and expertise beyond the borders of the countries (Archibugi & Coco, 2005). The Scandinavian countries, including Finland, as well as the Netherlands have the largest potential of acquiring knowledge from the US and Japan in Europe considering the countries' populations through collaboration in scientific research.

Table 4-15 Number of Co-authored Articles per Million Inhabitant in Selected European Countries with USA and Japan; 2008

Country	USA	Japan
Austria	152	30
Belgium	170	24
Denmark	278	35
Finland	202	41
France	102	19
Germany	121	20
Ireland	160	15
Italy	93	12
Netherlands	216	26
Portugal	61	6
Spain	83	10
Sweden	273	41
UK	178	26

Source: NSF (2010)

Table 4.16 shows that the UK receives the largest amount of foreign students in Europe from Japan, the US and all countries in 2008. Out of all foreign students in Ireland, about 22 percent are from the US, the corresponding figure for the UK is about 4 percent, and it is around 1 percent for the remaining European countries. With Ireland being an exception, it is clear that the number of foreign students from the US in European countries is almost negligible. Evidently, most of the foreign students in the selected European countries are from other member states. The number of foreign students has increased in all the countries displayed below between 2000 and 2008.

Table 4-16 Number and Share of Foreign Students in Tertiary Education from the Triad to Selected European Countries, 2000 and 2008

	Japan		United States		Europe		All countries	
Country	Japanese foreign students, 2008	% of all foreign students, 2008	US foreign students, 2008	% of all foreign students, 2008	European foreign students, 2008	% of all foreign students, 2008	Total foreign students, 2000	Total foreign students, 2008
Austria	384	0.7	564	1.1	44,037	82.5	30,382	53,396
Belgium	142	0.3	213	0.5	30,101	70.9	38,799	42,484
Denmark	50	0.1	319	1.3	13,099	72.1	12,871	19,121
Finland	112	1.0	225	2.0	5,017	44.4	5,570	11,303
France	1,908	0.8	3,228	1.3	51,909	21.3	137,085	243,436
Germany	2,234	1.0	3,304	1.6	116,842	43.6	187,033	245,522
Ireland	65	0.5	2,802	21.9	3,867	30.2	7,413	12,794
Italy	-	-	368	0.5	34,153	50.0	24,929	68,273
Netherlands	215	0.2	501	0.4	28,272	56.1	14,012	40,795
Portugal	8	0.1	158	0.9	3,275	20.2	10,616	18,584
Spain	148	0.1	651	1.2	20,353	22.7	25,502	64,906
Sweden	176	0.4	464	0.8	12,021	20.8	25,548	34,556
UK	4,465	1.3	13,895	4.1	111,909	33.3	222,936	335,870

Source: OECD (2010e)

Academic knowledge flows from the triad to specific European countries, differ substantially between the member states. The Scandinavian countries exploit co-authorships as a knowledge source to a much larger extent than the other nations. Ireland and UK receives the relatively large amount of foreign students from the US, a fact that in some part can be attributed to the language. An Europeanization of student mobility is much more evident than an internationalization. The next chapter will discuss how knowledge can flow through patents.

5 Knowledge flows via patents

5.1 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).

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.

5.1.1 Knowledge flows via patent citations

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). 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 the results from patent citation analyses has to be interpreted with care.

Regardless of these complications, patent citations can be considered as indicators of technological relevance.

Table 5.1 shows that in the beginning of the 21st century, EU patents cited patents from other EU countries and from the US to the same extent (30 percent of total citations), when considering patent citations at the EPO. In 2008/2009 the share of EU citations to other EU patents had declined to 25 percent of total citations, whereas the corresponding share of citations to US patents only declined by 1 percent since 2000/2001. In total, the number of EU citations to both EU and US patents has increased during the decade, while citations to Japanese patents have decreased. The EU also devotes a larger share of the cited patents to patents from other parts of the world than the triad in recent years.

For comparison reasons, citations in US and Japanese patents to triadic patents have been included in the table. The total number of EPO citations to the world in both US (93,768) and Japanese (80,901) patents in 2008/2009 is about half that of EU citations (169,118) to the world. US patents cite other US patents to a much larger extent than both EU and Japanese patents. The EU is becoming less Europeanized and more internationalized when it comes to taking advantage of knowledge embodied in patents. The opposite pattern is occurring in both the US and Japan since they cite their own patents increasingly more.

Table 5-1 Counts of Citations in EU, US and Japanese Patent Publications (Patent Citations at the EPO); 2000/2001 and 2008/2009

Citing patent origin→ Cited patent origin	2000/2001 average	% of total citations	2008/2009 average	% of total citations
EU→EU	37,786	30%	42,897	25%
EU→USA	37,959	30%	49,826	29%
EU→Japan	6,283	5%	5,928	4%
EU→world	127,451	100%	169,118	100%
USA→EU	8,847	11%	6,267	7%
USA→USA	39,939	49%	50,391	54%
USA→Japan	4,221	5%	1,990	2%
USA→world	80,808	100%	93,768	100%
Japan→EU	7,949	11%	4,606	6%
Japan→USA	25,689	36%	22,217	27%
Japan→Japan	16,446	23%	31,462	39%
Japan→world	71,721	100%	80,901	100%

Source: Authors' elaboration from OECD (2011a) and OECD (2011b).
EU: EU-25 excluding Cyprus, Lithuania and Luxembourg.

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 5.1 (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 British 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 correlated positively with the development of new products. Frietsch et al. (2010) assert that patents are a means to increase absorptive capacity within a firm; both through stock measures (number of patents) and quality measures (counts of citations received). Self-citations have been used as an 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 5.2 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 statistics indicate that Europe is better at taking advantage of knowledge from abroad in their use of previous patents when creating new knowledge.

Table 5-2 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 5.3 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 5-3 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	38.0	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 not equal to 1 since a few countries have been excluded and the sum of the EU countries has been added).
Source: Mancusi (2008)

5.1.2 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 5.4 and 5.5, 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 5-4 Geographic Distribution of Citation Flows to Published Literature Present in Triad USPTO Patents (Percent); 1987-1991 and 1992-1996

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 5-5 Geographic Distribution of Citation Flows to Published Literature Present in Triad EPO Patents (Percent); 1987-1991 and 1992-1996

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 5.6 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 5-6 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 5.7), 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 5-7 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 5.6-5.7 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?

5.1.3 Cross-border patenting

In addition to patent citations, co-patenting involving different organizations in an innovative project also reflects spill-over effects (Frietsch, et al., 2010). When different organizations engage in a collaborative project, the benefits will not be confined within the specific project but will rather influence the organizations innovative processes and activities (Feldman & Kelley, 2006).

Furthermore, Winter (1987) argues that social welfare can be enhanced through co-patenting by allowing for more efficient use of expertise and assets. Similarly, co-patenting can imply a shortening of the innovation cycle, and decreasing risks and costs of generating innovations, while also reducing duplicated work, resource waste, and patent races (Reinganum, 1989).

Cross-border inventions as a share of all inventions measured by patents are increasing, reflecting the globalization of firms, R&D and technology. Cross-border patents (corresponding to MNFs inventions abroad)[21] 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[22] (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.

- 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 5.8 and Table 5.9 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 more than they cooperate with Japan.

[21] 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.
[22] The same indicators can be used for the triad regions.

Table 5-8 International Cooperation in Patents - Patent Applications to the EPO; 2007

Region	Total Patents	Cooperation with abroad				Cooperation with abroad (%)			
		Total	EU-27	USA	Japan	Total	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 in 2007. 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 5.10). The US co-invents only 8.4 percent of its patents applied at the EPO with inventors from Europe (Table 5.9). 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 5-9 International Cooperation in Patents – Patents Granted by the USPTO, 2007

Region	Total Patents	Cooperation with abroad				Cooperation with abroad (%)			
		Total	EU-27	USA	Japan	Total	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 more often than the other triad regions.

5.2 Knowledge flows via patents from Australia, Canada and BRIC to EU

The number of citations in EU patents to Australia, Canada and the BRIC countries is only about one percent of EU's total citations to the world, as shown in Table 5.10. Nevertheless, this seems to be a rapidly changing pattern since patent citations to these countries have more than doubled in the last decade. Excluding China, the share of EU citations to these countries of total citations to world increased from 0.5 percent to 0.8 percent. China contributed to the largest number of citations in 2000, but this number has decreased in the last decade and Canada surpassed China in 2009 as the country, which patents are cited the most by EU inventors.

Table 5-10 Counts of Citations in EU Patents to Prior Work from Australia, Canada and BRIC countries (patents applied at the EPO); 2000-2009

Year	Australia	Canada	Brazil	Russia	India	China
2000	299	258	14	24	..	785
2001	280	264	10	48	..	736
2002	291	307	13	48	..	706
2003	325	304	16	35	5	640
2004	357	309	9	49	1	651
2005	329	354	15	40	15	674
2006	409	424	21	66	12	648
2007	493	439	18	72	22	652
2008	483	504	18	86	40	666
2009	519	623	32	80	70	618
Increase 2000-2009	74%	141%	129%	233%	-	-21%

Source: Authors' elaboration from OECD (2011a) and OECD (2011b).

Australia, Canada and the BRIC countries co-patent between 28 to 60 percent of their total inventions in cooperation with abroad with the EU in 2007, as measured by applications to the EPO (Table 5.11). The share has increased since 2000 for Brazil, China and Russia, while it has declined for Australia, Canada and India. The number of patent applications to the EPO by Chinese inventors has increased dramatically, from 412 to 2588, between 2000 and 2007. This increase places China ahead of both Australia and Canada, as well as the other BRIC countries, in regards to total patent applications as well as the number of patent applications in cooperation with the EU in 2007. Almost half, 42 percent, of this type of knowledge transfer from China flows to Europe. If the trend continues, China will soon become a more important partner in for Europe in terms of patent cooperation. Canada is the country that devotes the lowest share of its cross border patenting activities to the EU as measured by patent applications to the EPO in 2007. Presumably, the US is a much larger partner for Canada for international cooperation in projects that lead to patent applications.

Table 5-11 Patent Applications to EPO in Cooperation with Abroad

Country	2000				2007			
	Total Patents	Cooperation with abroad			Total Patents	Cooperation with abroad		
		Total	EU-27	EU-27 (%)		Total	EU-27	EU-27 (%)
Australia	1121	218	97	44%	1017	235	94	40%
Canada	2016	652	206	32%	2567	780	221	28%
Brazil	141	39	21	54%	317	105	63	60%
China	412	146	58	40%	2588	558	233	42%
India	229	76	32	42%	769	306	115	38%
Russia	286	119	59	50%	301	107	57	53%

Source: OECD (2010a)

All countries, except China, in Table 5.12 have decreased their number of patents granted by the USPTO substantially between 2000 and 2007. In addition, the share of internationally co-patented inventions in cooperation with the EU granted by the USPTO has also decreased. China co-patented 18 percent of its inventions in international collaboration with the EU in 2000, while the corresponding figure was only 5 percent in 2007. Lower grant rates in the

USA have their origin in the difference of application procedures at the USPTO and at international offices (Frietsch, et al., 2010).

Table 5-12 Patents Granted by USPTO in Cooperation with Abroad

Country	2000				2007			
	Total Patents	Cooperation with abroad			Total Patents	Cooperation with abroad		
		Total	EU-27	EU-27 (%)		Total	EU-27	EU-27 (%)
Australia	1374	265	84	32%	212	32	8	25%
Canada	5078	1165	214	18%	1109	276	33	12%
Brazil	177	56	25	45%	35	7	..	..
China	671	243	44	18%	974	392	20	5%
India	474	151	30	20%	264	140	17	12%
Russia	368	196	64	33%	50	27	3	11%

Source: (OECDa)

International collaboration in patents and the number of citations in EU patents to patents from Australia, Canada and the BRIC countries is still negligible as a supply of knowledge transfers to Europe in comparison with the triad. However, the trend is changing and European inventors are increasingly utilizing knowledge sources from these countries. China has had a dramatic increase in the number of patents applied for at the EPO in cooperation with abroad, a development that European inventors have been taking advantage of as well.

5.3 Knowledge flows via patents from the triad to selected EU countries

Cross-border patent citations reflect knowledge transfers across European nations and the triad in Table 5.15. The table demonstrates citations in patents applied at the EPO by selected European countries to Japanese, US, and EU patent publications. All countries have increased their total number of citations to the world in the last decade. Germany is the country that cites the largest number of patents in 2008/2009, followed by France, Italy, the UK and the Netherlands. All countries except the Scandinavian countries (Sweden, Finland, and Denmark) have decreased their share of citations to European patents, as well as their share of citations to Japanese patents. However, the UK and Italy are the only countries where the number of citations to EU patents decreased in absolute numbers. The share of citations to US patents have been increasing for some EU countries and decreasing for others. This share has increased the most for Denmark (from 27 percent to 36 percent; corresponding an increase of 971 citations) and Sweden (from 23 percent to 30 percent; corresponding an increase of 1078 citations). In absolute numbers, all countries increased their number of citations to US patents during the time period in question.

Table 5-13 Percentage of Citations in Patents of Selected EU Countries to Triadic patents and the World (EPO patent citations), 2000/2001 and 2008/2009

Citing country	2000/2001 average % citation counts to triad of total citations to world			Total to World	2008/2009 average % citation counts to triad of total citations to world			Total to World
	Japan	USA	EU		Japan	USA	EU	
Austria	4%	28%	37%	2976	4%	27%	31%	4830
Belgium	6%	33%	22%	3065	4%	36%	19%	5774
Denmark	3%	27%	21%	1642	3%	36%	22%	3929
Finland	5%	30%	15%	2501	3%	33%	15%	3927
France	5%	31%	28%	20604	4%	33%	24%	26183
Germany	5%	28%	35%	62261	3%	26%	31%	77093
Ireland	3%	40%	21%	592	2%	37%	15%	887
Italy	6%	37%	28%	11358	4%	34%	23%	13512
Netherlands	5%	31%	20%	6857	3%	32%	16%	10046
Portugal	7%	27%	28%	85	3%	30%	21%	214
Spain	5%	33%	29%	1561	4%	29%	24%	3771
Sweden	3%	23%	15%	3924	4%	30%	17%	6454
UK	4%	32%	20%	9651	2%	34%	16%	10767

Source: Authors' elaboration from OECD (2011a) and OECD (2011b).

The information in the table above indicates an increase in knowledge transfers in the form of patent citations from across borders. Most of the selected European countries are utilizing knowledge sources from the US to a larger extent in their new inventions than European knowledge sources, a trend that seems to be consistent during the last decade. Austria and Germany are the only countries that cite a larger share of patents from the EU than from the US in 2008/2009. Another important remark is the vast difference in the number of patent citations between the European countries. The country that cites the largest number of patents, Germany, cites 360 times as many patents as Portugal, the country that cites the least amount of patents in 2008/2009, despite that Germany's population is only about 8 times as big as Portugal's.

For all of the selected European countries in Table 5.14, except for the UK, the number of patent applications in cooperation with abroad to the EPO has increased between 2000 and 2007. Austria is the most 'Europeanized' country rather than internationalized since it co-patents 72 percent of total patents in cooperation with abroad with other European countries and only 8 percent with the US in 2007. The UK on the other hand engage in an almost equal amount of projects resulting in patent applications to the EPO with USA and EU, 40 percent and 42 percent respectively in 2007. Both France and Germany have increased their shares of international cooperation in patent applications with Japan to 5 percent in 2007, while the cooperation with the US has decreased as a share from 2000 for the same countries. In fact, most European countries (except Sweden) have become more 'Europeanized' in regards to cooperation in patent applications, at the expense of collaboration with US inventors.

Table 5-14 Patent Applications to EPO in Cooperation with Abroad

Country	2000					2007				
	Total patents	Cooperation with abroad				Total patents	Cooperation with abroad			
		Total	with Japan	with USA	with EU-27		Total	with Japan	with USA	with EU-27
Austria	1386	515	1%	6%	70%	1940	782	1%	8%	72%
Belgium	1636	809	1%	41%	53%	1916	847	2%	33%	61%
Denmark	1044	241	2%	26%	56%	1379	305	1%	26%	58%
Finland	1530	188	1%	31%	56%	1382	218	0%	16%	72%
France	8016	1908	2%	34%	44%	9453	2194	5%	22%	44%
Germany	23491	3424	3%	33%	39%	25552	4451	5%	26%	36%
Italy	4238	841	2%	32%	48%	5091	1075	1%	23%	58%
Netherlands	3769	787	2%	30%	55%	3760	1008	1%	21%	69%
Spain	922	320	3%	30%	60%	1567	471	3%	20%	69%
Sweden	2501	479	1%	24%	53%	3053	672	0%	26%	45%
UK	6858	2709	4%	52%	34%	6271	2475	5%	40%	42%

Source: (OECDa)

The same pattern that has been seen before of a declining rate of patent grants by the USPTO is again visible in Table 5.15. The decline is quite remarkable. In the case of patents granted by the USPTO, the share of patent grants in cooperation with abroad has been increasing for cooperation with US inventors for all European countries except Finland during 2000 and 2007, and decreasing for cooperation with inventors from other EU countries (except Austria and Finland).

Table 5-15 Patents Granted by USPTO in Cooperation with Abroad

Country	2000					2007				
	Total patents	Cooperation with abroad				Total patents	Cooperation with abroad			
		Total	with Japan	with USA	with EU-27		Total	with Japan	with USA	with EU-27
Austria	846	463	2%	15%	63%	99	71	3%	18%	66%
Belgium	1027	638	2%	58%	36%	90	77	3%	77%	18%
Denmark	668	206	0%	46%	34%	39	26	-	77%	23%
Finland	1144	179	1%	42%	45%	86	28	-	29%	57%
France	5056	1739	6%	54%	26%	352	190	1%	67%	17%
Germany	14247	2871	3%	56%	26%	1104	357	4%	72%	11%
Italy	2300	615	2%	55%	33%	186	78	-	73%	14%
Netherlands	2126	772	2%	67%	26%	165	77	1%	73%	14%
Spain	492	258	3%	54%	36%	75	47	4%	62%	30%
Sweden	1936	405	1%	38%	36%	122	42	-	52%	19%
UK	5666	3057	5%	66%	19%	524	372	3%	79%	10%

Source: (OECDa)

It seems that Europe is not as Europeanized when it comes to exploiting knowledge from abroad through patent citations as it used to be. There are also vast differences of the extent of internationalization of patents and patent citations between the European countries. The European countries cooperate relatively less with the US in terms of patents applied at the

EPO, while these countries cooperates relatively more with other European countries in 2007 compared with 2000. In this case there is still a tendency toward a Europeanization of cooperation in patents, which is negative as regards to the ability of European countries to acquire knowledge from the other triads. In the next chapter, a different type of channel for knowledge flows will be analyzed - technology trade.

6 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 commercialize 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 to what extent Europe is utilizing technology trade as a source of knowledge transfer 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 6.1). As mentioned earlier, this could be an indication suggesting that Europe does not invest enough in R&D. However, the region is successfully taking advantage of other countries' knowledge and technology through the import of royalty and license fees.

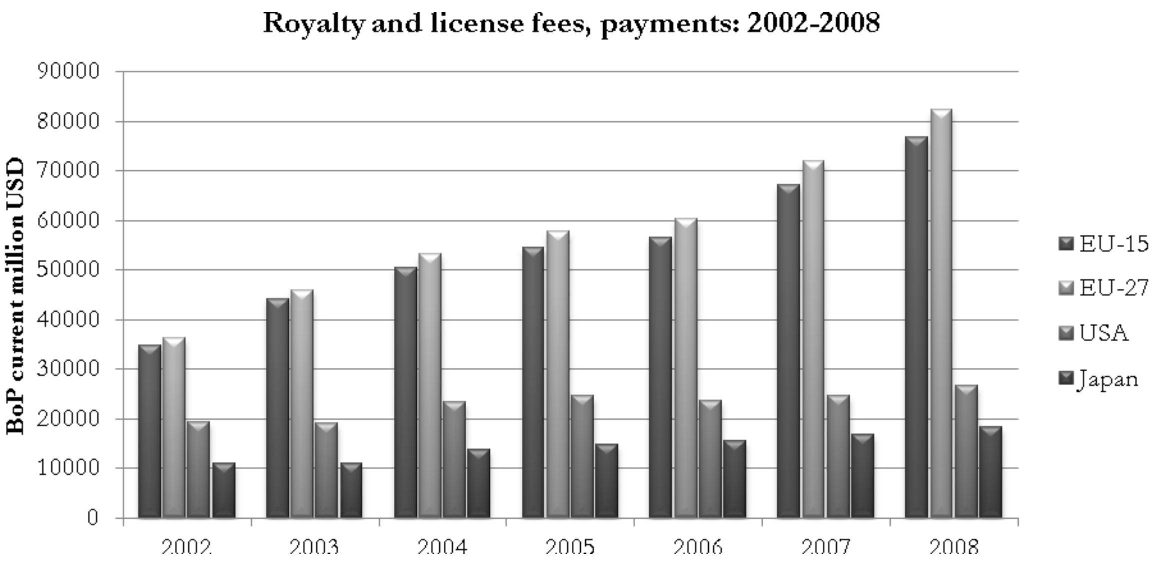

Figure 6-1 Royalty and license fees, payments BoP, current million USD (See appendix, Table 13.3 for exact data)
Source: World Bank (2010a)

Figure 6.2 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.

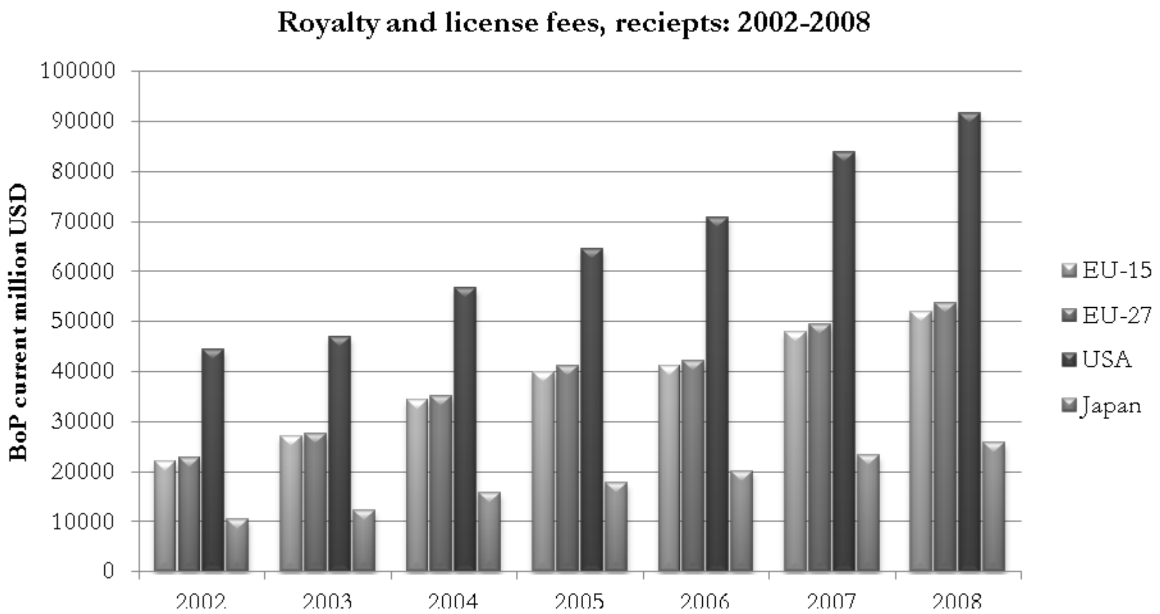

Figure 6-2 Royalty and license fees, receipts (BoP, current million US$) (See appendix, Table 14.2 for exact data)
Source: World Bank (2010a)

As can be seen in Figure 6.3 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 13.4 for exact data).

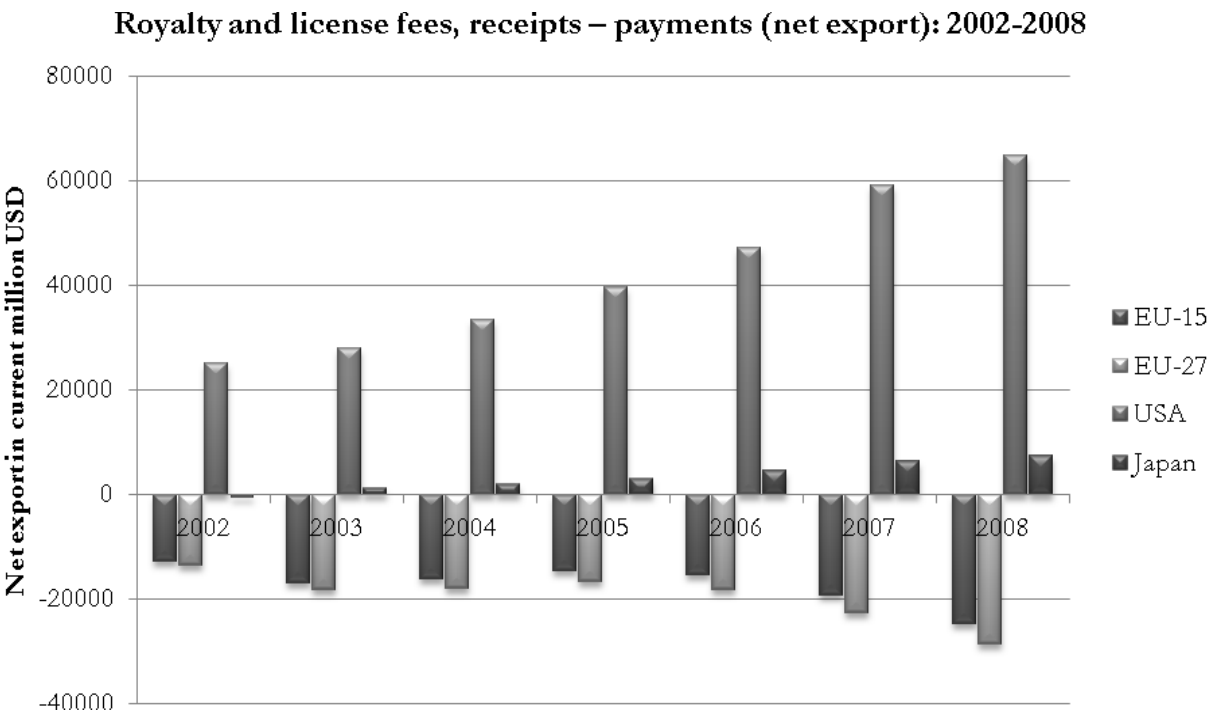

Figure 6-3 Royalty and license fees, receipts – payments (net export in USD million) (See appendix Table 13.4 for exact data)
Source: World Bank (2010a)

It might be more interesting to relate the figures above to the size of the regions and their population. The EU (both EU-15 and EU-27) imports about twice as much technology than the US per capita in 2008. The US exports the most in form of royalty and license fees per capita. The EU 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 6-1 Royalty and License Fees Figures per Capita, 2008

Technology trade	EU-15	EU-27	USA	Japan
Royalty and License Fees Payments (US$/pop.)	195	169	87	143
Royalty and License Fees Receipts (US$/pop.)	132	110	301	201
Royalty and License Fees Receipts – Payments (US$/pop.) (exports - imports)	-63	-59	214	58

Source: World Bank (2010a)

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.

7 Knowledge flows via strategic R&D cooperation

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

One source of knowledge generation 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[23]. 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[24]: 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 organizations ((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).

[23] 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).
[24] 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.

- 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.
- 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 under such circumstances may provide a mechanism for internalizing 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 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 because firms need to speed up the innovation process in a world with an intensified competition as a result of the globalization 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, where 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 internalize outgoing knowledge spillovers 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).

Generally, international alliances are 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 behavior, 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). Recent data on strategic R&D alliances shows an upward trend towards more cooperation in R&D projects when measured by the number of total new alliances in the world. Table 7.1 shows that strategic alliances between Europe and the US are dominating. The number of alliances formed with at least one EU firm and one US firm has decreased slightly however between the two time periods in the table. In comparison, the number of new alliances formed including at least on EU member and one non-EU member has increased by 15 percent.

Firms in the US engage in strategic R&D cooperation to a much larger degree than firms from the EU, especially considering that the EU population is much larger than the US population. In fact, The US is part of 81 percent of all new alliances that formed in the world between 1993 and 1996 and part of 71 percent of the new alliances formed between 2000 and 2006. However the table shows that almost half of the US strategic partnerships involve only firms from the US. Of all the new alliances with at least one EU ally, only about 25 percent (22 percent in the earlier period and 28 percent in the latter period) involve only EU firms. Thus, about 75 percent of the new alliances formed between 1993 and 2006 with at least one EU partner included firms outside of the EU. The EU therefore has a proportionally greater potential to absorb knowledge from international (non-EU) sources through strategic partnership.

Table 7-1 New strategic R&D alliances in the triad region (sum of new alliances in 1993-1999 and 2000-2006)

Member of alliance	1993-1999 sum	2000-2006 sum	% change
EU allies only	365	540	48%
US allies only	1882	1628	-13%
At least one EU ally	1673	1923	15%
At least one US ally	3522	3437	-2%
At least one Japanese ally	548	642	17%
EU-Rest of world (At least one EU ally and one non-EU ally)	1308	1383	15%
US-Rest of world (At least one US ally and one non-US ally)	1640	1809	10%
EU-USA (at least one EU ally and one US ally)	1005	941	-6%
EU-Japan (at least one EU ally and one Japanese ally)	147	134	-9%
USA-Japan (at least one US ally and one Japanese ally)	325	276	-15%
Total new alliances in world	4349	4834	11%

Source: Author's calculation from the MERIT-CATI Database[25]
EU: EU-19 and Slovakia

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 7.2 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 7-2 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)

It is also worth mentioning that the knowledge flows that potentially emerge when organizations engage in R&D cooperation might be indicated by using the co-patent measure. When two or more organizations 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 organizations involved (Feldman & Kelley, 2006).

[25] The CATI database is a relational database that contains over 15000 cooperative agreements involving some 9500 firms. Cooperative agreements are defined as common interests between independent (industrial) partners who are not connected through (majority) ownership. In the CATI database only those inter-firm agreements are being collected that contain some arrangements for transferring technology or joint research.

In terms of absorption capabilities of knowledge flows, the high degree of cooperation of European firms with firms from the US, Japan and other parts of the world in the form of strategic R&D alliances is a positive sign. Both the US and Japan spend a considerable larger share of their GDP on R&D investment. This fact emphasizes the point that Europe should continue to be open to R&D cooperation with third countries.

7.2 Knowledge flows via strategic R&D cooperation from Australia, Canada and BRIC to the EU

Table 7.3 shows the sum of the newly formed strategic R&D alliances between European firms (at least one) and firms (at least one) from Australia, Canada or the BRIC countries in 1993-1999 as well as in 2000-2006. Clearly, the number of new alliances involving these countries has almost doubled between the two time periods. EU and Canada provide the largest number of alliances, whereas EU and Brazil has no alliances in the first time period and only three in the more recent time period. Among these nations, Australia represents the largest increase in the number of strategic R&D alliances with the EU. Table 8.3 showed that the number of new alliances involving at least one EU firm and at least one US or Japanese firm had decreased in later years, but the total number of new alliances with a firm from the EU and one from the world has increased. The majority of this increase is likely to be due to an increase in alliances formed between European firms and firms from Australia, Canada and the BRIC countries. This trend is positive in terms of knowledge absorption through knowledge flows to Europe from these countries.

Table 7-3 New strategic R&D alliances between EU and Australia, Canada and the BRIC countries (sum of new alliances in 1993-1999 and 2001-2006)

	1993-1999: sum	2000-2006: sum	% change
EU-Australia	8	30	275%
EU-Canada	39	51	31%
EU-Brazil	0	3	-
EU-Russia	7	17	143%
EU-India	8	24	200%
EU-China	22	37	68%
TOTAL	**84**	**162**	**93%**
EU-World	1308	1383	15%

Source: Author's calculation from the MERIT-CATI Database

7.3 Knowledge flows via strategic R&D cooperation from the triad to selected European countries

Specific European countries receive knowledge from the triad to a very differing extent. Unsurprisingly, the UK, Germany and France contribute to the largest number of new strategic R&D alliances with the triad, as shown in Table 7.4. However, the number of new alliances formed between the triad and these countries has decreased between 1993-1999 and 2000-2006. Instead Denmark seem to be cooperating more intensively with firms from the US. Also Belgium, Finland and Italy has increased their cooperation with US firms. In total, these European countries have decreased their cooperation in the form of strategic R&D alliances with Japan between 1993-1999 and 2000-2006. However, the number of new alliances between Belgian firms and Japanese firms jumped from two new alliances in 1993-1999 to 11 new alliances in 2000-2006. In short, these European countries seem to be cooperating less with the other triad countries in the form of strategic R&D partnership.

Table 7-4 New strategic R&D alliances between selected European countries and the US and Japan respectively (sum of new alliances in 1993-1999 and 2001-2006)

	USA			Japan		
	1993-1999: sum	2000-2006: sum	% change	1993-1999: sum	2000-2006: sum	% change
Belgium	38	47	24%	2	11	450%
Denmark	19	43	126%	2	1	-50%
Finland	17	19	12%	2	4	100%
France	160	122	-24%	21	14	-33%
Germany	288	236	-18%	51	42	-18%
Italy	32	39	22%	4	4	0%
Netherlands	114	84	-26%	22	10	-55%
Sweden	67	49	-27%	8	8	0%
UK	301	295	-2%	42	39	-7%
TOTAL	**998**	**887**	**-11%**	**152**	**122**	**-20%**

Source: Author’s calculation from the MERIT-CATI Database

The next chapter emphasizes the importance of imports of goods as a channel for knowledge transfers.

8 Knowledge flows via trade networks

8.1 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[26], 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 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 even 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 analyze 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.

8.1.1 Intra-triad knowledge flows via imports of goods

In Table 8.1, we illustrate the imports of high-tech products in triad regions in 1995 and 2008. EU-27 takes shares from the US and become the largest importer of high-tech goods in 2008. The total amount of imports, measured by USD, almost tripled in the triad between 1995 and

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

2008. Since the population of the US is about 3/5 that of EU-27, one should except imports to the union to be substantially higher.

Table 8-1 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 involve trade only with countries outside of the EU.

In Table 8.2, figures for imports of high-tech products of USD per capita to the triad are given. The imports per capita of high-tech products in Europe are lower than in Japan and substantially lower than in the US. If we assume that high-tech imports are an important channel for knowledge and technology inflows for any geographical unit, we may reach the conclusion that one reason why Europe underperforms in terms of economic growth is due to low imports of high-tech products per capita. Although, EU-27 has been catching up to the other triad regions between 1995 and 2008, which is a positive trend in terms of potential knowledge flows.

Table 8-2 Imports of High-tech Products per Capita in Triad Regions in 1995 and 2008 (USD/Capita)

Triad region	1995	2008	Total growth 1995-2008 (%)
EU-27*	297.4	865.7	191.0
USA	641.6	1287.0	100.6
Japan	428.6	1071.4	150.0

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

In order to get a more dynamic picture of the growth 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. Again, EU-27 shows strong signs of catching up to the other triad regions in this area.

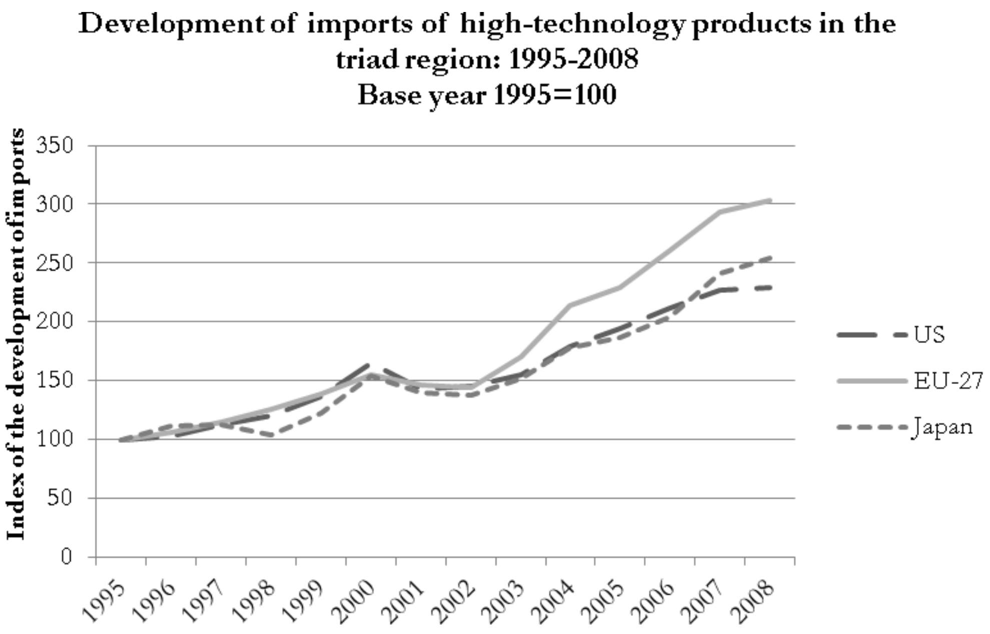

Figure 8-1 Index: Development of Imports of High-technology Products to the Triad; 1995-2008
Source: NSF (2010)

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 8-3 United States', EU's, and Japan's Imports of ICT Goods, by Selected Economy of Origin (millions of current USD); 1995 and 2008

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	100	257,120	100
	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	100	256,638	100
	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	100	95,324	100
	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.

8.1.2 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 8.4, 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. This is a surprising observation considering that the Europe imports much more royalty and license fees per capita than the other triad regions. 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 8-4 Sectoral Structure of the Service Imports in the Triad Regions in 2007 (percent)

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 Services	100	100	100

Source: Havlik, et al., (2009)

8.1.3 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. 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). Aiginger further argues that 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, in markets where quality, product innovation, and the adaptation of the product to specialized needs are important, unit values 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.

In Table 8.5 and 8.6 the import flows of between 3000 and 5000 products (depending on the country of origin) during a ten-year period (2000-2009) have been aggregated according to OECDs classification of industry. The total value of the imports and the total weight of the imports have been summed up over the time period and then a per-kilo-price (unit value) has been calculated. The aggregation smoothens the data and eliminates the effect of outliers. Some products for which their nominal quantity measure is not reported in kilograms have been excluded from the calculations that will follow below. As can be seen in Table 9.5, the unit value of imported high-technology products is much higher for the US than for the other two triad regions (the other industries are included for comparison). This can imply either 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 8-5 Unit Values of Imports of Products to EU-27, USA and Japan in Different Sectors from the World during the Last Decade (2000-2009)

Classification according to OECD	EU-27	USA	Japan
Capital-intensive	0.8	0.7	1.0
Labor-intensive	5.6	5.4	6.8
Scale-intensive	1.3	1.4	1.8
Differentiated products	12.0	11.9	11.4
High-technology	**22.8**	**36.5**	**25.4**

Source: Own compilation of UN Comtrade (2010) statistics

The difference of the unit values of imports of high-technology goods can be emphasized by measuring relative unit values. The unit value of import of high-technological goods to Europe is only 62 percent of the unit value of high-technology imports to the US. The quotient of unit values of imports to EU-27 divided by the unit value of imports to Japan is 0.90. Even though Table 8.1 showed that Europe imports more high-technology products, the US imports high-technology products of more advanced quality.

Table 8.6 shows the unit values of all imports of products in different categories to EU-27 from the world, the US and Japan in the last decade. EU imports high-technology products with a much higher unit value from the US than from Japan as well as from the world. The unit value of imported high-technology products to EU from Japan is lower than the unit value of high-technology imports from the world. Do the following figures indicate that Europe is taking advantage of knowledge flows from the US to a larger extent by importing superior technology than from Japan? Are Japanese high-technology products of lower quality?

8-6 Unit Values of Imports to EU-27 of Products in Different Sectors from the World, USA and Japan during the last decade (2000-2009)

Classification according to OECD	EU-World	EU-USA	EU-Japan
Capital-intensive	0.8	0.7	1.8
Labor-intensive	5.6	13.3	6.9
Scale-intensive	1.3	3.3	6.6
Differentiated products	12.0	33.2	18.6
High-technology	**22.8**	**41.5**	**10.8**

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 to the US have a higher unit value, indicating a more sophisticated quality. Similarly, the imports of high-tech products from the US to the EU have a much higher unit value than the world average unit value of high-tech imports to Europe. Europe has 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. The EU has successively liberalized external trade in the latest decades, which most probably has stimulated the rapid increase in high-tech imports. Although, much liberalization has taken place, the EU maintains strong defenses against sensitive imports. It is vital for the member states to adapt policies and institution to decrease heterogeneity between the countries and ensure that differences in regulations, market institutions, technical standards and taxes do not deter a common external trade policy (Brulhart & Matthews, 2007). ‘Regionalism’, which favors trade between specific countries and in effect limits trade with third countries will hinder the ability of the EU to absorb knowledge from external, third-party, sources through import of goods and services.

In addition, concerns have been raised in the US that the EU poses informal barriers to high-tech trade by unfairly subsidizing high-tech sectors such aviation (Brulhart & Matthews, 2007). Previous resistance to the so called Japanese “import penetration” in markets such as passenger cars has quiet down in recent years (Brulhart & Matthews, 2007). One of the reasons for this is that EU manufacturing companies have raised productivity by copying Japanese techniques. Some of the EU-27 countries, such as Romania, still have substantial tariffs on imported goods and services. Engman (2005) argues that improved and simplified customs procedures, as well as improved logistics, has a positive impact on trade flows. For example, removing barriers to trade in services would increase the efficiency of services as intermediate inputs into the productive sector and technology transfer will accompany the service liberalization (Goldberg, Branstetter, Goddard & Kuriakose, 2008). All European governments should recognize the fact that international trade mediates flows of knowledge, which in turn raises productivity.

8.2 Knowledge flows via imports of high-technology goods to EU from Australia, Canada and BRIC countries

The total imports of high-technology goods from Australia, Canada and the BRIC nations to the EU differ in terms of trade value substantially and have changed considerably during the last decade. Canada remains the largest provider of high-technology goods out of the six countries presented in Figure 8.2. India surpassed both Australia and China during the time period and became the second largest source of high-technology imports for the EU in later years. The total import value of high-technology goods from Russia remain the lowest during the time period in question. High-technology imports from China have decreased since 2001 in terms of total dollar-value.

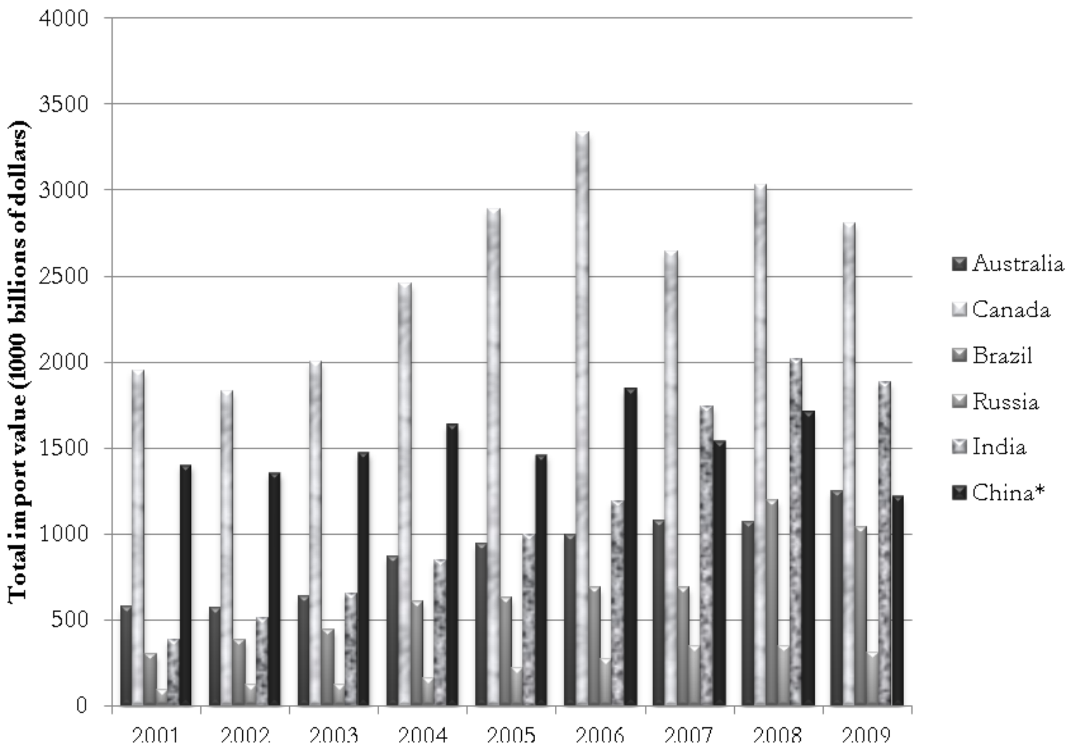

Figure 8-2 Total Import Value of High-technology Goods According to OECD Classification to EU-27 from Australia, Canada and BRIC Countries
*Including Hong Kong
Source: Own compilation of UN Comtrade (2010) statistics

In order to determine the quality of the high-technology imports, the unit prices of the imports of these goods can be compared between the different countries. Table 8.8 shows that the unit values of imports of high-technology goods differ substantially between Australia, Canada and the BRIC countries. Australia, Canada and China seem to provide high-quality and more advanced high-technology goods. Keeping in mind the world average unit value of high-technology imports to the EU-27 of 22.8; the unit values of high-technology imports from Brazil especially, but also Russia and India, are very low. Although, the EU receives large amounts of high-tech products from India, these are in general of rather low quality.

Table 8-7 Unit Values of Imports to EU-27 of Products in Different Sectors from the Australia, Canada and BRIC countries during the last decade (2000-2009)

Classification according to OECD	Australia	Canada	Brazil	Russia	India	China*
Capital-intensive	1.5	1.2	0.6	0.6	0.8	8.9
Labor-intensive	6.8	7.0	5.7	2.5	5.6	15.3
Scale-intensive	1.3	1.5	1.2	0.5	1.9	4.8
Differentiated products	32.5	25.6	7.0	4.6	6.7	13.7
High technology	**47.1**	**41.7**	**3.1**	**8.5**	**14.4**	**43.2**

*Including Hong Kong
Source: Own compilation of UN Comtrade (2010) statistics

9 Knowledge flows via FDIs

9.1 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 internationalization of the innovative activities of MNFs has lagged behind the internationalization 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 attempted mainly in order to establish Europe's position and ability to absorb knowledge through intra-MNF networks. However, data on FDI is also presented and discussed in a knowledge flow context.

9.1.1 Intra-triad knowledge flows via intra-MNF networks

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. Furthermore, 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 internationalization of R&D show a tendency for 'triadisation' rather than globalization 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 internationalizing R&D is European firms undertaking 58 percent, US firms undertaking 33 percent and Japanese firms undertaking 10 percent of all internationalized 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 an 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 internalize 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.[27] An underlying motivation for this claim is that due to the cumulativeness and path-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 unfold 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 analyze

- 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 million USD on R&D investments in the world in 2006 (NSF, 2010). 18,628

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

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 spent 25,803 million USD on R&D in the US in 2006. Japanese owned affiliates in the US spent 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 is 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 9.1, 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 are not available at this stage.

Table 9-1 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

9.1.2 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 existing 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.
- *Labor mobility*. Labor 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).[28] 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.[29]

[28] 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.

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

- 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).

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.[30]

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 be observed also 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

[30] 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.

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 had 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 labor 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.

The literature in the field contains a rather large number of industry- and firm-level studies from various countries. Most of these studies show a positive correlation between the presence of MNFs and the average labor 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.[31] It may, for example, be the case that MNFs tend to invest in industries with high labor 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).[32] 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 do-

[31] 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.
[32] The study of UK by Girma, Greenaway & Wakelin (2001) did generate insignificant results.

mestic suppliers (Blalock, 2001; Smarzynska Javorcik, 2004; Blalock & Gertler, 2008).[33] 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).

Having put the effects of FDI in an analytical context, some actual data will be presented beneath. Table 9.2 shows the inward positions (stocks) of FDI and its share of GDP in the triad in 2002 and 2009. The 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)

The US receives about twice the amount of FDI that the EU does, both in dollar values and as a share of GDP in 2000. The growth of FDI stocks has been stronger in the EU compared to the US, but the US still remains the largest recipient of FDI stocks in 2009. Japan is also catching up in terms of FDI inflows.

Table 9-2 FDI Inward Positions at Year End, 2000 and 2009 (billion USD)

Triad region	2000		2009		2000/2009
	Inward FDI	% of GDP	Inward FDI	% of GDP	growth
EU-19*	633	6.4	1476	9.9	133%
USA	1257	12.7	2320	16.5	85%
Japan	50	1.6	200	4.9	298%

Source: OECD (2010d)

*Excludes Belgium and excludes FDI from other European countries.

Europe is behind the US, although ahead of Japan, in terms of the possibility to acquire knowledge from MNFs. However, the above statistics does not contain information of the origin of the FDI. Table 9.3 shows the amount of inward FDI stocks to EU-19 from Europe, USA and Japan. Evidently, most of the inward FDI stocks in the EU-19 countries originate from other European countries. The EU receives much more stocks of FDI in total compared to the US if the inward FDI stocks from other European countries are taken into account as well as the inward FDI stocks from the rest of the world. The FDI flows have increased substantially, by 233 percent, within Europe between 2000 and 2009. The inward FDI stocks from the US and Japan have increased in absolute numbers as well, although they have decreased as a share of all outgoing FDI from especially American, but also from Japanese, MNFs to the world. In relative figures, American MNFs are investing less in Europe, which limits the possibilities for knowledge transfers from these firms to Europe.

Table 9-3 Inward Positions to EU-19* from Europe, USA and Japan, 2000 and 2009 (billion USD)

Partner	2000		2009		Growth 2000/2009
	Inward FDI	% of total flows from partner	Inward FDI	% of total flows from partner	
Europe	1545	-	5152	-	233%
USA	427	32.4	767	21.9	80%

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

Japan	42	15.0	104	14.0	149%

Source: OECD (2010d)
*Excludes Belgium

9.1.3 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 in 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.[34] 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

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

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 labor 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 inward stocks of FDI, Table 9.4 shows that the US dominates the market of outward stocks of FDI, although the gap between the US and EU is smaller in this case. Japan increased its outward stocks considerably between 2000 and 2009, and spends a larger percentage of GDP on outward FDI stocks than Europe in 2009. Europe has had the lowest growth of outward FDI of the triad regions. All triad regions spend much more on FDI abroad than they receive in FDI from the rest of the world.

Table 9-4 FDI Outward Positions at Year End, 2000 and 2009 (billion USD)

Triad region	2000		2009		2000/2009
	Outward FDI	% of GDP	Outward FDI	% of GDP	growth
EU-19	1097	11.0	2632	17.6	140%
USA	1316	13.3	3508	25.0	167%
Japan	278	8.6	741	18.1	166%

Source: OECD (2010d)
*Excludes Belgium and excludes FDI to other European countries.

Both American and Japanese MNFs have a greater potential to acquire knowledge and strategic advantages from foreign countries since they spend a relatively larger amount on FDI in other countries. From Table 9.5, one can recognize that EU-19 contributes to about half of the FDI inflows and stocks to the US. Furthermore, EU-19 is a major partner for FDI investments in Japan, although the share of FDI in Japan contributed by MNFs from the EU-19 countries has decreased drastically, from 52 percent in 2000 to 31 percent in 2009. Most of the outward FDI stocks from EU-19 are invested in other parts of Europe.

Table 9-5 Outward Positions from EU-19* to Europe, USA and Japan, 2000 and 2009 (billion USD)

Partner	2000		2009		Growth 2000/2009
	Outward FDI	% of total flows to partner	Outward FDI	% of total flows to partner	
Europe	1729	-	5625	-	225%
USA	608	48.4	1181	50.9	94%
Japan	26	51.7	62	31.2	141%

Source: OECD (2010d)
*Excludes Belgium

Including the FDI flows from other European countries, 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. However, when FDI from Europe is excluded, the EU receives only half the amount of the FDI stocks that the US receives. In addition, although Europe is still a major destination for FDI from the US, the share of FDI to Europe out of all outward FDI stocks from the US decreased by about ten percent in the last decade. The share of Japanese FDI in Europe out of all outward Japanese FDI stocks has remained stable, but only around 15 percent. In the context of knowledge absorption, these results are worrying. If the EU seeks to encourage knowledge absorption through foreign firm expansion, it should examine potential barriers to FDI.

One example of a policy that would reduce such barriers would be to allow multinationals to obtain greater post-tax benefits on their investments, encouraging them to increase FDI (Goldberg, et al., 2008). Since there seems to be no barriers to FDI flows within the EU, regulatory reforms that liberalize entry to the union are likely to induce investment. Policies, applicable in some of the European countries, aiming at improving financial and infrastructure services, including telecommunications, power, and transport are highly correlated with inward FDI (Eschenbach & Hoekman, 2005). Since a firm's capacity to absorb knowledge, and to benefit from absorption, depends on the skills and training of the workforce, public-private co-investment in worker training might be a case for consideration (Goldberg, et al., 2008).

As MNFs might gain even more knowledge from their foreign locations than the knowledge they contribute to these locations, it is a positive sign that European MNFs are highly represented in the US. Out of all of the FDI stocks in the US, European MNFs account for about half of the investments, a share that has remained stable in the last decade. In contrast, European MNFs accounts for around 30 percent of the FDI stocks in Japan in 2009 a decrease by 20 percent from 2000. Moreover, European MNFs invest more in the US than American MNFs invest in Europe. Japanese FDI in Europe exceeds that of European investments in Japan. European MNFs appear to take advantages of the high-level R&D capabilities in the US to a larger degree than in Japan.

9.2 Knowledge flows via FDIs from Australia, Canada, and BRIC to EU

Furthering the analysis to knowledge flows via FDIs to Europe from Australia, Canada and the BRIC countries, one can see in Table 9.6 that both the inward and outward stocks of FDI to and from these countries have increased substantially between 2001 and 2009. The most remarkable growth of inward FDI stocks to Europe are from China and India. EU-19 performs FDI in Australia, Canada and the BRIC countries much more, then it receives in inward investments from these countries.

Table 9-6 Inward and outward FDI stocks between Australia, Canada, BRIC and EU-19

Direction of FDI		Australia	Canada	Brazil	Russia	India	China
FDI inward stocks to EU-19	2001	17469	25588	897	3079	364	353
	2009	21270	82113	13694	18358	7040	13886
	Growth %	21.8	220.9	1426.6	496.2	1834.1	3833.7
FDI outward stocks from EU-19	2001	34081	61590	34260	7912	5188	16007
	2009	91029	125751	133713	82974	24838	70823
	Growth %	167.1	104.2	290.3	948.7	378.8	342.5

Source: OECD (2010d)

9.3 Knowledge flows via FDIs from USA and Japan to selected EU countries

In Table 9.7, it can be observed that UK is the largest receiver of stocks of FDI from both Japan and the US. Netherlands, Germany and France are also nations that receive large amounts of FDI from the triad. For a few European countries, such as Denmark and Ireland, the stocks of FDI from the US have actually decreased between 2001 and 2009, whereas for France for example, the US FDI stocks have almost tripled. The amount of inward FDIs from the triad differs substantially between the European countries. Portugal and Finland receives the least FDIs from the triad. Regarding outward FDIs from the selected European countries to the triad, UK is again the largest contributor to FDI in the US. However, France supplies the largest stocks of FDIs in Japan.

Table 9-7 Inward and Outward Stocks of FDI between Japan, USA and Selected European Countries, 2001 and 2009

	FDI inward stocks from triad				FDI outward stocks to triad			
Reporting country	Japan		USA		Japan		USA	
	2001	2009	2001	2009	2001	2009	2001	2009
Austria	678	3,563	1,979	16,704	6	105	2,079	4,694
Belgium	..	31,938	..	..	..	3,537	..	..
Denmark	189	197	20,904	12,548	352	916	11,597	17,917
Finland	209	231	672	890	111	-20	6,365	11,023
France	4,681	12,883	41,344	111,168	7,702	29,945	139,150	227,754
Germany	8,751	20,038	80,226	97,582	6,619	12,411	179,482	201,188
Ireland	..	3,018	27,645	6,240	..	..	11,071	23,538
Italy	2,017	4,581	13,942	28,895	1,036	1,734	20,295	35,907
Netherlands	9,785	15,377	70,599	120,772	885	8,555	88,896	116,159
Portugal	165	150	1,143	1,612	0	5	276	882
Spain	2,325	2,629	46,539	60,602	1,999	631	23,294	50,137
Sweden	-40	2,594	20,380	26,599	786	3,060	25,354	43,178
UK	15,809	40,407	198,657	320,538	2,544	3,735	208,534	374,380

Source: OECD (2010d)

9.4 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 globalized 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). 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 also 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.

10 Knowledge flows via high-skilled migration

10.1 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). As mentioned earlier, knowledge includes codified and non-codified components; of which both are important in order for inventors to access and apply knowledge. 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 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 is 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.

10.1.1 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 believed in general to be more important when it comes to high-skilled migration.

10.1.2 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 10.1 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 10-1 Size of the 15-19 Cohort Relative to that of the 60-64 Cohort, Based on the Current Age Structure of the Resident Population (%)

Region/country	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.

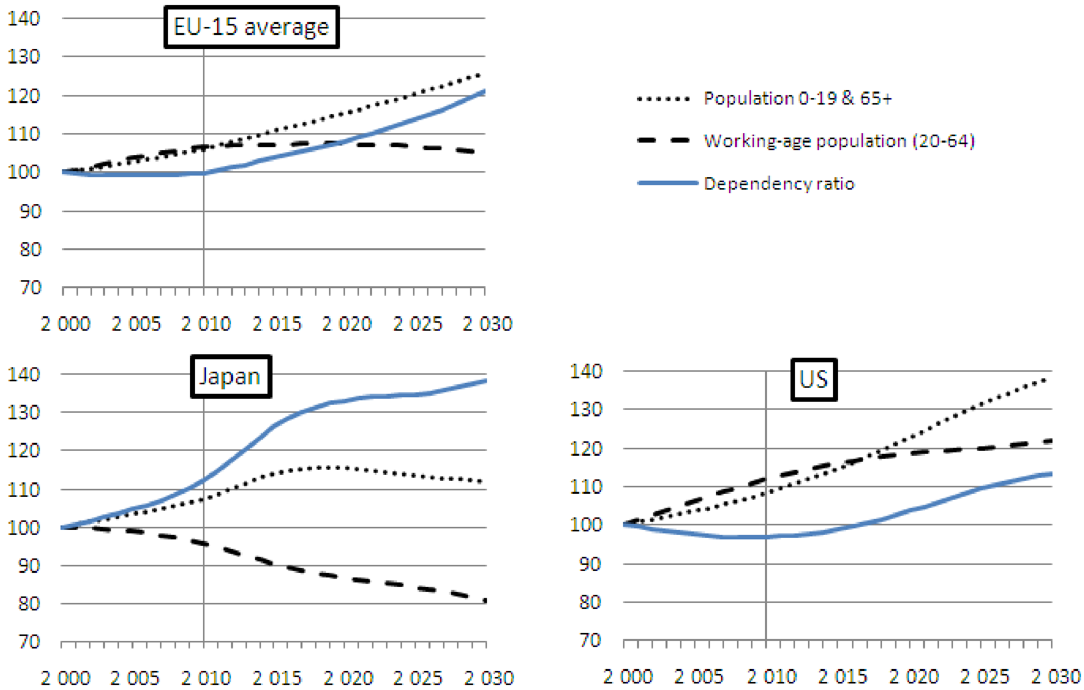

Figure 10-1 Evolution of Dependency Ratios over the Period 2000-2030, Year 2000 = 100
Source: OECD (2010c)

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. The United States is projected also to experience 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 10.1 and Figure 10.1 suggest that countries will have to compete for skilled migrants in the decades to come in order to satisfy the labor 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 resources 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 labor mobility, Europe must have a strategy ensuring an adequate supply of R&D and HRST.

Successful countries in attracting highly skilled labor 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) 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). 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 of 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 10-2 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 labor market test and occupation list	• Limited immigration
Netherlands	• Reduce immigration by people with few skills and little Dutch language	•Exemptions from strict language and labor 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 labor 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.

10.1.3 Europe's position and capacity for attracting skilled laborers

Table 10.3 shows recent trends in highly qualified immigration for the EU-15 countries and the United States. There are 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 compared to the United States is substantially higher, 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. 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 a lesser 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.

Table 10-3 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 % of all employed immigrants having arrived in previous ten years			Quantity in 2006 relative to quantity in 1995	As a % 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)

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 in the US, a phenomenon that is not as prominent in the EU.

The table below displays the share of recent immigrants in highly skilled occupations. Recent immigrants to the United States and Europe are represented to a larger degree 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 more often of lower skilled nature and that qualifications are not easily transferred. Furthermore, the English language facilitates immigration to countries like the United States and the United Kingdom.

Table 10-4 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 % of total employment	Employed immigrants having arrived during 1995-2006 as new entrants[1] as a % of total employment	Immigrants in high-skill jobs as a % of all persons in high-skill jobs	Immigrants in high-skill jobs having arrived during 1995-2006 as a % of new entrants[1] in high-skill jobs	Immigrant professionals[3] as a % of all professionals in employment	Immigrant professionals[3] having arrived during 1995-2006 as a % 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)

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 10.2 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 labor force each year and is more than the number entering the United States in similar categories (NSF, 2010).

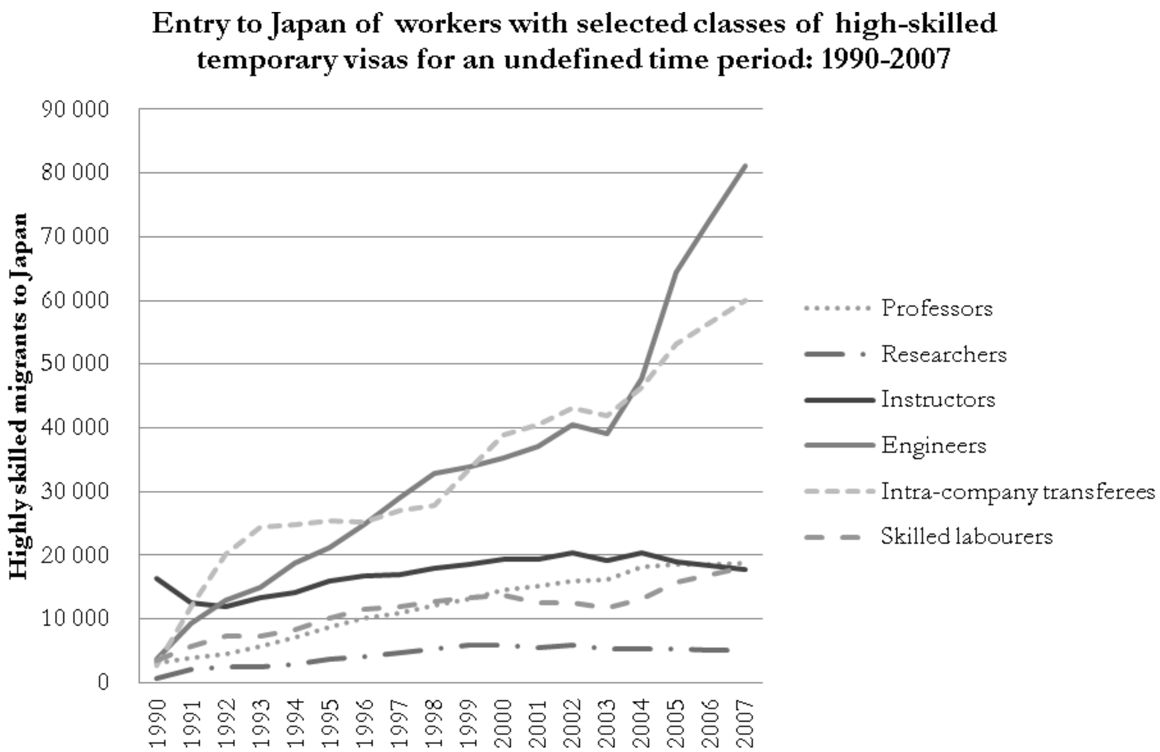

Figure 10-2 Entry to Japan of workers with selected classes of high-skilled temporary visas for an undefined time period: 1990-2007.

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[35] 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, labor migrants only account for a small part of total permanent migration in the US and the average EU-15 country. In Japan, however, labor migration is approximately one fourth of total migration, although it is lower than the labor migration to the average EU-15 country relative to its total population.

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

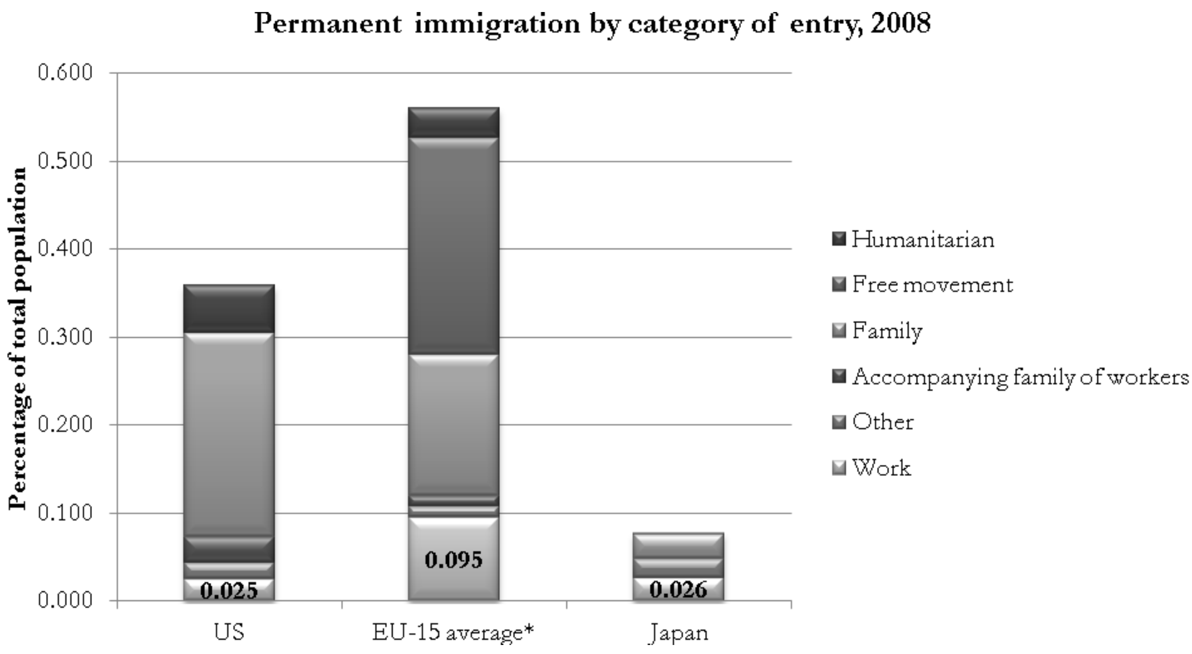

Figure 10-3 Permanent immigration by category of entry (% of total population), 2008
*Excluding Greece, Ireland and Luxembourg
Source: OECD (2010c)

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 more than 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 10-5 Immigrants with secondary and tertiary education to the triad regions, 2000 and 2008

Triad Region	Immigrants with tertiary education (per 1000 inhab.)		Immigrants with secondary education (per 1000 inhab.)	
	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)

According to Table 10.6, the number of immigrants that with tertiary education arriving to Europe from the US and Japan is essentially negligible. Immigrants from all countries constitute about 10 percent of the total population with tertiary education in EU-19. Almost half of these originate from other European countries. Europe does not take fully advantage of highly migrants as a knowledge source beyond the borders of the union.

Table 10-6 Immigrants with Tertiary Education to EU-19 from the Triad, 2000

Country/region of origin	EU-19	% of total population with tertiary education in EU-19
USA	167,674	0.30
Japan	35,793	0.06
Europe	2,621,391	4.73
World excluding Europe	3,072,024	5.54
World including Europe	5,693,415	10.27

OECD (2010c)

Europe receives more immigrants with tertiary education from other OECD countries than from the rest of the world, as evident from the Table 10.7. 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 10-7 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. Roeger (2010) suggests that attracting and integrating high skilled immigrants to Europe could be a cost effective strategy to increase the productivity level in Europe. Immigration of high skilled workers would imply lower wages for domestic high skilled workers. However, productivity spillovers would benefit lower skilled workers. This policy would have to be accompanied by a less progressive income tax system in order to make it acceptable by domestic high skilled workers and to not reduce incentives for tertiary education (Roeger, 2010).

10.2 Knowledge flows via high-skilled migration from Australia, Canada and the BRIC countries to EU

Recalling that there were about 167,000 immigrants with tertiary education in the EU-19 countries from the US and about 35,000 Japanese immigrants with tertiary education in EU-19, it becomes evident from Table 10.8 that the triad is not the largest provider of knowledge flows through high-skilled migration. Immigration with tertiary education from Russia exceeds similar migration from the US and India is almost on the same level as US in 2000. Australia, Canada, Brazil and China all provide more high-skilled immigrants to EU-19 than

Japan does. In total, these countries represent almost exactly one percent of the total population in EU-19 with tertiary education. Immigration of high skilled labor to Europe from Australia, Canada and the BRIC countries is a source of knowledge that could be utilized to a higher degree.

Table 10-8 Immigrants with Tertiary Education to EU-19 from Australia, Canada and BRIC Countries, 2000

Country of origin	EU-19	% of total pop. in EU-19 with tertiary education
Australia	63,111	0.11
Canada	50,436	0.09
Brazil	37,745	0.07
Russia	218,528	0.39
India	154,521	0.28
China	49,417	0.09

Source: OECD (2010c)

10.3 Knowledge flows via high-skilled migration from the triad to selected European countries

In Table 10.9, the UK is the European country that receives the largest number of immigrants with tertiary education from the world (excluding Europe) in 2000, closely followed by France and Germany. Most of the immigrants arriving to the selected countries in the table come from another European country, and there are vast differences between the countries. While the European country with the least immigrants in the table from US and Japan, Finland, had received less than 1000 high-skilled immigrants, the country receiving the most, the UK, had received almost 100,000 high-skilled immigrants in 2000. The table clearly shows that there is much more mobility of high-skilled personnel within Europe, and the movement of immigrants from the US and Japan to Europe is rather lacking in numbers.

Table 10-9 Immigrants with Tertiary Education to Selected European Countries from USA, Japan and Europe, 2000

Country of residence	USA	% of total pop. with tertiary education	Japan	% of total pop. with tertiary education	Europe	% of total pop. With tertiary education	World excluding Europe
Austria	2,439	0.33	857	0.12	83,978	11.48	20,764
Belgium	4,097	0.23	1,624	0.09	111,977	6.22	79,086
Denmark	2,610	0.32	339	0.04	37,059	4.53	25,177
Finland	545	0.06	105	0.01	17,080	1.73	4,265
France	19,935	0.24	8,745	0.11	334,318	4.09	677,106
Germany	18,030	0.15	..	..	643,318	5.41	528,808
Ireland	8,190	1.15	441	0.06	90,747	12.73	38,010
Italy	11,955	0.30	2,927	0.07	131,736	3.26	115,189
Netherlands	5,772	0.24	..	..	103,498	4.35	166,350
Portugal	1,379	0.19	152	0.02	33,538	4.53	79,810
Spain	8,920	0.14	1,600	0.03	172,900	2.74	228,400
Sweden	5,500	0.38	1,035	0.07	121,505	8.32	83,945
UK	69,543	0.81	17,293	0.20	412,477	4.79	961,930

Source: OECD (2010c)

11 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. Furthermore, the analysis is extended to consider what is going on outside the triad, in countries such as Australia, Canada and the BRIC countries. In addition, knowledge flows from the triad to specific European countries, rather than the EU as a whole, are included for some of the indicators.

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 three percent of GDP by 2010. Two-thirds of this new investment should come from the private sector.[36] 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 that the ambitious goals were not accomplished.

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 acquire rapidly knowledge developed in the two other triad regions. The importance of such a capacity is well understood as soon as we realize 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 heterogeneity 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:

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

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. This might be an effect of, among other things, EU's framework programs[37] stimulating cooperation among scientists within Europe. It seems that the co-authorships with scientists in the US and in Japan have remained rather stable as a share. Another interesting observation is that advanced research programs in Europe only enroll around 15 percent international researchers (despite the fact that a researcher counts as international even if he/she is from another EU country) compared to around 28 percent in the US. Europe must become much more open to engage international researchers in its advanced research programs. The EU should also consider the possibility to revise the framework programs to include leading scientists from other parts of the world to a higher extent. 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. Furthermore, more than half of the US American students studying abroad choose Europe as a destination whereas Japanese foreign students are much more common in the US than in Europe. The share of European foreign students choosing the US or Japan as a destination is very low. This is negative with regard to the potential of Europe to absorb knowledge from the triad as the students return home. In comparison to the US, Europe seems to be behind in attracting knowledge flows via academic channels. Most of the international academic activity is still taking place within the EU.

Almost half of all the Russian foreign students as well as all the Brazilian foreign students study in Europe. China and India send a much larger amount of foreign students to Europe than both the US and Japan send. However, it is only about 20 percent of the foreign students from China and India that choose Europe as a destination. In comparison to the US, the number of articles produced in collaboration with European researchers and researchers from Australia, Canada and the BRIC countries are very small, although these collaborations have increased substantially in the last decade and should therefore not be overlooked. There are possibilities for European students and researchers to take more advantage of the academic channels and the knowledge that these countries, especially the Asian countries, could provide. Furthermore, there has been a dramatic increase in internationally co-authored papers in all European countries, which demonstrates the globalization in the generation of knowledge. This increase is assisted of course by the diffusion of internet and email communication. The Scandinavian countries, including Finland, as well as the Netherlands, exploit co-authorships as a knowledge source much more than the other nations. Ireland and UK receives a relatively large amount of foreign students from the US, a fact that in some part can be attributed to the language. An Europeanization of student mobility is much more evident than an internationalization.

[37] 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

Turning to patent citations it is evident that European inventors seem to build their new inventions on knowledge embedded in patents from abroad much more than the other two regions. American 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-patents with inventors from the US with reference to USPTO patent grants more often 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.

The number of citations in EU patents to Australia, Canada and the BRIC countries is only about one percent of EU's total citations to the world. Nevertheless, this seems to be a rapidly changing pattern since patent citations to these countries have more than doubled in the last decade. In terms of co-patenting China is becoming an important partner for the EU. In terms of knowledge flows, it is positive that European inventors have taken advantage of the development of the research performed in China. Most of the selected European countries are utilizing knowledge sources through citations from the US to a larger extent in their new inventions than European knowledge sources, a trend that seems to be consistent during the last decade. It seems that Europe is not as Europeanized when it comes to exploiting knowledge from abroad through patent citations as it used to be. However, in the case of cooperation in patents there is still a tendency toward a Europeanization, which is negative as regards to the ability of European countries to acquire knowledge from the other triads.

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 about twice that of the US and, also, higher than that of Japan. As mentioned earlier, this could be an indication suggesting that Europe does not invest enough in R&D. However, the region is successfully taking advantage of other countries' knowledge and technology through the import of royalty and license fees. The technology export from the EU is less than half of the technology export from the US per capita 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 strategic alliances between Europe and the US are dominating. Firms in the US engage in strategic R&D cooperation to a much larger extent than firms from the EU. However the table shows that almost half of the US strategic partnerships involve only firms from the US, whereas about 75 percent of the new alliances formed with at least one EU partner included firms outside of the EU. The EU therefore has a proportionally greater potential to absorb knowledge from international (non-EU) sources through strategic partnership. In fact, the number of new strategic R&D alliances between European firms and firms from Australia, Canada or the BRIC countries these countries have almost doubled since the 1990's. 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 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 imports per capita of high-tech products in Europe are lower than in Japan and substantially lower than in the US. If we assume that high-tech imports are an important channel for knowledge and technology inflows for any geographical unit, we may reach the conclusion that one reason why Europe underperforms in terms of economic growth is due to low imports of high-tech products per capita. Although, EU-27 has been catching up to the other triad regions between 1995 and 2008. 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. The unit values of high-technology imports to Europe from Brazil especially, but also Russia and India, are very low. Although, the EU receives large amounts of high-tech products from India, these are in general of rather low quality. Unit values of imports indicate that Australia, Canada and China seem to provide more advanced high-technology goods to Europe.

Multinational firms play an important but probably underestimated role for international knowledge flows. Including the FDI flows from other European countries, 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. However, the amount of inflows of FDI that EU receives from the other triad region is rather limited and has decreased in the last decade as a share. The EU should examine potential barriers to inward FDI from outside the union in order to encourage foreign (non-European) firm expansion in the EU. Outside of the triad, China and India represent the most remarkable growth of inward FDI stocks to Europe in the last decade.

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. Out of all of the FDI stocks in the US, European MNFs account for about half of the investments, a share that has remained stable in the last decade. In contrast, European MNFs accounts for around 30 percent of the FDI stocks in Japan in 2009 a decrease by 20 percent from 2000. European MNFs appears to take advantages of the high-level R&D capabilities more often in the US than in Japan. Moreover, European MNFs invest more in the US than American MNFs invest in Europe. Japanese FDI in Europe exceeds that of European investments in Japan. In addition, the EU performs FDI in Australia, Canada and the BRIC countries to a larger extent, then it receives in inward investments from these countries.

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 are 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 number of immigrants with tertiary education arriving to Europe from the US and Japan is essentially negligible. Immigrants from all countries constitute about 10 percent of the total population with tertiary education in EU-19. Almost half of these originate from other European countries.

Evidently, the triad is not the largest provider of knowledge flows through high-skilled migration. Immigration with tertiary education from Russia exceeds similar immigration from the US and India is almost on the same level as the US in 2000. Australia, Canada, Brazil and China all provide more high-skilled immigrants to the EU than Japan does. In total, these countries represent almost exactly one percent of the total population in EU-19 with tertiary education. Immigration of high skilled labor to Europe from Australia, Canada and the BRIC countries is a source of knowledge that could be utilized to a higher degree. There is much more mobility of high-skilled personnel within Europe, and the movement of immigrants from the US and Japan to Europe is rather lacking in numbers. Europe does not take fully advantage of highly skilled migrants as a knowledge source beyond the borders of the union. The reason is of course the rather strict regulation of the labor 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. Policy makers within the EU must continuously encourage an opening of firms and institutions towards the outside and diversity. Relations between individuals across borders should be stimulated as they foster knowledge diffusion in cases where spillovers due to geographical proximity is not possible. The probability that external workers, researchers, firms and institutions will form collaborative ventures with parties in the EU ultimately depends on the attractiveness of the region. Factors such as the quality of the infrastructure, institutions, communication, the education, the business climate, and the innovation system determine the attractiveness of the EU.

As a response to the recent economic crisis, the EU launched the Europe 2020 strategy aiming to enhance sustainable growth through the improvement of education, R&D and innovation, and information and communication technology. One of the targets of the Europe 2020 strategy is, once again, to invest three percent of GDP on R&D. Unless this target is reached, top scientists will continue to move where the environment is more favorable and Europe will not be the preferred choice of destination for researchers from other parts of the world. Another target of the strategy involve strengthening the quality of education and enhance the attractiveness of Europe’s universities to foreigners. The achievement of this target is vital in order for Europe to be able to attract both researchers and firms. The probability of the success of Europe 2020 will depend upon Europe’s ability to provide the right building blocks for the development of new knowledge within Europe, but also that the EU increasingly ensures a steady inflow of knowledge from other parts of the world. Europe can never become the leading knowledge economy in the world without attracting and taking advantage of all the potential benefits of different types of international knowledge channels.

12 References

Adams, J.D. et al., (2005), Scientific Teams and Institutional Collaborations: Evidence from U.S. Universities, 1981-1999, *Research Policy 34*, 259-285

Aghion, P. & P. Howitt (1992), A Model of Growth through Creative Destruction, *Econometrica 60*, 323-351

Aghion, P. & P. Howitt (2006), “Joseph Schumpeter Lecture” Appropriate Growth Policy: A unifying Framework, *Journal of the European Economic Association 4*, 269-314

Ahammad, M.F & K.W. Glaister (2008), Recent Trends in UK Cross-Border Mergers and Acquisitions, *Management Research News 31*, 86-98

Aitken, B.J. & A.E. Harrison (1999), Do Domestic Firms Benefit from Direct Foreign Investments: Evidence from Venezuela, *American Economic Review 89*, 605-618

Alcacer, J. & M. Gittelmann (2004), How Do I Know What You Know?, Patent Examiners and the Generation of Patent Citations, *Review of Economics and Statistics 88*, 774-779

Almeida, P. & A. Phene (2004), Subsidiaries and Knowledge Creation: The Influence of the MNC and Host Country on Innovation, *Strategic Management Journal 25*, 847-864

Allen, T.J. (1977), *Managing the Flow of Technology*, The MIT Press, Cambridge, MA

Andersen, B. (2004), If ‘Intellectual Property Rights’ Is the Answer, What Is the Question? Revisiting the Patent Controversies, *Economics of Innovation and New Technology 13*, 417-442

Andersson, Å.E. & O. Persson (1993), Networking Scientists, *Annals of Regional Science 27*, 11-21

Andreasen, L., et al., (1995) (Eds.), *Europe’s Next Step: Organizational Innovation, Competition and Employment*, Frank Cass, Ilford

Andriani, P. (2001), Diversity, Knowledge and Complexity Theory: Some Introductory Issues, *International Journal of Innovation Management 5*, 257-275

Antonelli, C. (2001), *The Microeconomics of Technological Systems*, Oxford University Press, Oxford

Archibuigi, D. (1988), In Search of a Useful Measure of Technological Innovation (to Make Economists Happy without Discontenting Technologists), *Technological Forecasting and Social Change 34*, 253-277

Archibugi, D. & A. Coco (2004), International Partnerships for Knowledge in Business and Academia. A Comparison between Europe and the USA, *Technovation 24*, 517-528

Archibugi, D. & A. Coco (2005), Is Europe Becoming the Most Dynamic Knowledge Economy in the World?, *Journal of Common Market Studies 43*, 433-459

Archibugi, D., J. Howells, & J. Michie (1999) (Eds.), *Innovation Systems in the Global Economy*, Cambridge University Press, Cambridge

Archibugi, D. & J. Michie (1995), The Globalization of Technology: A New Taxonomy, *Cambridge Journal of Economics 19*, 121-140

Archibugi, D. & J. Michie (1997), *Technology, Globalisation and Economic Performance*, Cambridge University Press, Cambridge

Archibugi, D. & B.-Å. Lundvall (2001) (Eds.), *The Globalizing Knowledge Economy*, Oxford University Press, Oxford

Archibugi, D. & M. Pianta (1992), *The Technological Specialization of Advanced Countries. A Report to the EEC on International Science and Technology Activities*, Kluwer, Boston

Arrow, K.J. (1994), The Production and Distribution of Knowledge, in Silverberg, G. & L. Soete (1994) (Eds.), *The Economics of Growth and Technical Change: Technologies, Nations, Agents*, Edward Elgar, Aldershot, ?-?

Arundel, A. & P. Patel (2003), Strategic Patenting, Background Report for the Trend Chart Policy Benchmarking Workshop "New Trends in IPR Policy"

Asakawa, K. (2001), Evolving Headquarters-Subsidiary Dynamics in International R&D: The Case of Japanese Multinationals, *R&D Management 31*, 1-14

Audretsch, D.B. (2007) *The Entrepreneurial Society*, New York: Oxford University Press.

Audretsch, D.B. & M.P. Feldman (1996), R&D Spillovers and the Geography of Innovation and Production, *American Economic Review 86*, 630-640

Audretsch, D.B. & M.P. Feldman (2004), Knowledge Spillovers and the Geography of Innovation, in Henderson, J.V. & J.-F. Thisse (2004) (Eds.), *Handbook of Regional and Urban Economics*, Elsevier, Amsterdam, 2713-2739

Audretsch D.B. & M. Keilbach (2004), Entreprenurship, Capital and Economic Performance, *Regional Studies,39*, 949.

Barkema, H. & F. Vermeulen (1998), International Acquisition through Start-Up or Acquisition: A Learning Perspective, *Academy of Management Journal 41*, 7-26

Bartlett, C. & S. Ghoshal (1989), *Managing Across Borders: The Transnational Solution*, Harvard Business School Press, Boston, MA

Bassiani, A., L. Nunziata & D. Venn (2009), Job Protection Legislation and Productivity Growth in OECD Countries, *Economic Policy 24*, 349-402

Baumol, W.J. (2002), *The Free-Market Innovation Machine*, Princeton University Press, Princeton, NJ

Beamish, P.W. (1988), Multinational Joint Ventures in Developing Countries, Routledge, London

Belitz, H., J. Edler & C. Grenzmann (2006), Internationalisation in Industrial R&D, in Schmoch, U., C. Rammer & H. Legler (2006) (Eds.), *National Systems of Innovation in Comparison. Structure and Performance Indicators for Knowledge Societies*, Springer, Dordrecht, ?-?

Bessen, J. (2008), The Value of U.S. Patents by Owner and Patent Characteristics, *Research Policy 37*, 932-945

Blalock, G. (2001), Technology from Foreign Direct Investment: Strategic Transfer through Supply Chains, Haas School of Business, University of California, Berkeley (mimeo)

Blalock, G. & P.J. Gertler (2008), Welfare Gains from Foreign Direct Investment through Technology Transfer to Local Suppliers, *Journal of International Economics 74*, 402-421

Blind, K., et al., (2006), Motives to Patent: Evidence from Germany, *Research Policy 35*, 655-672

Blind, K. & R. Frietsch (2006), Integration verschiedener Technologieindikatoren, in BMBF (2006) (Eds.), *Studien zum Deutschen Innovationssystem*, Nr. 16-2006, Bundesministerium für Bildung und Forschung, Berlin, ?-?

Blomström, M. (1986), Foreign Investment and Productive Efficiency: The Case of Mexico, *The Journal of Industrial Economics 35*, 97-110

Blomström, M. & A. Kokko (1998), Multinational Corporations and Spillovers, *Journal of Economic Surveys 12*, 1-31

Blomström, M., A. Kokko & M. Zejan (2000), *Foreign Direct Investment: Firm and Host Country Strategies*, Macmillan, Basingstoke

Blomström, M. & H. Persson (1983), Foreign Investment and 'Spillover' Efficiency in an Underdeveloped Economy. Evidence from the Mexican Manufacturing Industry, *World Development 11*, 493-501

Blomström, M. & F. Sjöholm (1999), Technology Transfer and Spillovers: Does Local Participation with Multinationals Matter?, *European Economic Review 43*, 915-923

Blomström, M. & E.N. Wolff (1994), Multinational Corporations and Productivity Spillovers in Mexico, in Baumol, W.J., R.R. Nelson & E.N. Wolff (1994) (Eds.), *Convergence of Productivity: Cross National Studies and Historical Evidence*, Oxford University Press, Oxford, 263-283

Breschi, S. & F. Lissoni (2006), Mobility of Inventors and the Geography of Knowledge Spillovers. New Evidence on US data, *CESPRI Working Paper, No. 184*

Breschi, S. & F. Lissoni (2001a), Localized Knowledge Spillovers vs. Innovative Milieux: Knowledge "Tacitness" Reconsidered, *Papers in Regional Science 80*, 255-273

Breschi, S. & F. Lissoni (2001b), Knowledge Spillovers and Local Innovation Systems: A Critical Survey, *Industrial and Corporate Change 10*, 975-1005

Bresnman, H., J. Birkinshaw & R. Nobel (1999), Knowledge Transfer in International Acquisitions, *Journal of International Business Studies 30*, 439-462

Breznitz, D. (2007), *Innovation and the State*, Yale University Press, New Haven, CT

Broda, C., J. Greenfield & D. Weinstein (2006), From Groundnuts to Globalisation: A Structural Estimate of Trade and Growth, *NBER Working Paper No. 12512*, National Bureau of Economic Research, Cambridge, MA

Brousseau, E. & R. Coeurderoy (2005), The Governance of Intellectual Property Rights in Knowledge Transfers: An Empirical Analysis of Supervision Provisions in Technology Licensing Agreements, *International Journal of the Economics of Business 12*, 403-424

Brulhart, M & A. Matthews (2007), EU External Trade Policy, in Ali M. El-Agraa (ed.) *The European Union: Economics & Policies*, 8th edition, Cambridge University Press.

Buckley, P.J. & M.C. Casson (1976), *The Future of the Multinational Enterprise*, Macmillan, London

Buckley, P.J. & M.C. Casson (1985), *The Economic Theory of the Multinational Enterprise: Selected Papers*, Macmillan, London

Buckley, P.J. & M.J. Carter (1999), Managing Cross-Border Complementary Knowledge, *International Studies of Management and Organization 29*, 80-104

Busom, I., & A, Fernández-Ribas (2008), The Impact of Firm Participation in R&D Programs on R&D Partnerships, *Research Policy 37*, 240-257

Caloghirou, Y., S. Ioannides & N.S. Vonortas (2003), Research Joint Ventures, *Journal of Economic Surveys 17*, 541-570

Cantwell, J.A. (1989), *Technological Innovation and Multinational Corporations*, Basil Blackwell, Oxford

Cantwell, J.A. (1991), the Theory of Technological Competence and Its Application to International Production, in McFetridge, D.G. (1991) (Ed.), *Foreign Investment, Technology and Economic Growth*, University of Calgary Press, Calgary, ?-?

Cantwell, J.A. (1992), The Internationalization of Technological Activity and Its Implications for Competitiveness, in Granstrand, O., L. Håkanson & S. Sjölander (1992) (Eds.), *Technology Management and International Business Internationalization of R&D and Technology*, John Wiley & Sons, Chichester, 75-95

Cantwell, J.A. (1995), The Globalization of Technology: What Remains of the Product Cycle Model?, *Cambridge Journal of Economics 19*, 155-174

Cantwell, J.A. & S. Iammarino (2000), Multinational Corporations and the Location of Technological Innovation in the UK Regions, *Regional Studies 34*, ?-?

Cantwell, J.A. & O. Janne (1999), Technological Globalisation and Innovative Centres. The Role of Corporate Technological Leadership and Location Hierarchy, *Research Policy 28*, 119-144

Cantwell, J.A. & U. Kotecha (1997), The Internationalization of Technological Activitity. The French Evidence in a Comparative Setting, in Howells, J. & J. Michie (1997) (Eds.), *Technology, Innovation and Competitiveness*, Edward Elgar, Aldershot, 126-173

Cantwell, J.A. & R. Narula (2001), The Eclectic Paradigm of the Global Economy, *International Journal of Economics and Business 8*, 155-172

Cassiman, B. & R. Veuglers (2002), R&D Cooperation and Spillovers: Some Evidence from Belgium, *American Economic Review 92*, 1169-1184

Casson, M., R.D. Pearce & S. Singh (1992), Business Culture and International Technology: Research Managers' Perceptions of Recent Changes in Corporate R&D, in Granstrand,O., L. Håkanson & S. Sjölander (1992) (Eds.), *Technology Management and International Business: Internationalization of R&D and Technology*, John Wiley & Sons, New York, 117-135

Caves, R.E. (1974), Multinational Firms, Competition, and Productivity in Host-Country, *Economica 41*, 176-193

Caves, R.E. (1982), *Multinational Enterprise and Economic Analysis*, Cambridge University Press, Cambridge

Caves, R.E. (1996), *Economic Analysis of the Multinational Enterprise*, 2nd ed., Cambridge University Press, Cambridge

Caves, E., H. Crookel & P.J. Killing (1983), The Imperfect Market for Technology Licenses, *Oxford Bulletin for Economics and Statistics 45*, 249-267

Chaloff, J. and G. Lemaitre (2009). Managing Highly-Skilled Labour Migration: A Comparative Analysis of Migration Policies and Challenges in OECD Countries, OECD Social, Employment and Migration Working Paper 79, Paris.

Chellaraj, G., K.E. Maskus, & A. Mattoo. (2005), *The Contribution of Skilled Immigration and International Graduate Students to U.S. Innovation.* World Bank Manuscript, Washington, DC.

Chesbrough, H. (2003), *Open Innovation*, Harvard Business Press, Cambridge, MA

Chiesa, V. (1996),Strategies for Global R&D, *Research Technology Management 39*,19-26

Child, J., D. Falkner & R. Pitketly (2001), *The Management of International Acquisitions*, Oxford University Press, Oxford

Chiswick, B. R. (2005). High skilled immigration in the international arena. *IZA Discussion Paper,. 1782.*

Chuang, Y. & C. Lin (1999), Foreign Direct Investment, R&D and Spillover Efficiency: Evidence from Taiwan's Manufacturing Firms, *Journal of Development Studies 35*, 117-137

Chung, W. & J. Alcacer (2002), Knowledge Seeking and Location Choice of Foreign Direct Investment in the United States, *Management Science 48*, 1534-1554

Ciborra, C. (1991), Alliances as Learning Experiments: Cooperation, Competition and Change in High-Tech Industries, in Mytelka, L.K. (1991) (Ed.), *Strategic Partnerships and the World Economy*, Pinter, London, 51-77

Cohen, D. (1998), Toward a Knowledge Context: Report on the First Annual UC Berkeley Forum on Knowledge and the Firm, *California Management Review 40*, 22-40

Cohen, W.M. & D.A. Levinthal (1989), Innovation and Learning: The Two Faces of R&D, *Economic Journal 99*, 569-596

Cohen, W.M. & D.A. Levinthal (1990), Absorptive Capacity: A New Perspective on Learning and Innovation, *Administrative Science Quarterly 35*, 128-152

Cohen, W.M., R.R. Nelson & J. Walsh (2000), Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not), *NBER Working Paper No. 7552*

Cohen, W.M., A. Goto, A. Nagata, R.R. Nelson & J.P. Walsh (2002), R&D Spillovers, Patents and the Incentives to Innovate in Japan and the United States, *Research Policy 31*, 1349-1367

Cohen, W.M., R.R. Nelson & J.P. Walsh (2002), Links and Impacts: The Influence on Public Research on Industrial R&D, *Management Science*, *48*(1), 1-23

Cooke, P. (2006), Global Bioregions: Knowledge Domains, Capabilities and Innovation System Networks, *Industry and Innovation 13*, 437-458

Cowan, R., P.A. David & D. Foray (2000), The Explicit Economics of Knowledge Codification and Tacitness, *Industrial and Corporate Change 9*, 211-253

Crespi, G., A. Geuna & L. Nesta (2006), Labour Mobility of Academic Inventors: Career Decisions and Knowledge Transfer, *EUI Working Papers RSCAS No. 2006/06*, European University Institute, Florence

Criscuolo, P. & B. Verspagen (2008), Does it matter where patent citations come from? Inventor vs. examiner citations in European patents, *Research Policy*, *37*(10), 1892-1908

Davenport, E. & B. Cronin (2000), Knowledge Management: Semantic Drift or Conceptual Shift?, *Journal of Education for Library and Information Sciences 41*, 294-306

David, P. & D. Foray (1995), Accessing and Expanding the Science and Technology Base, *STI Review*, OECD, Paris, 13-68

Delanghe, H., Muldur, U. & Soete, L. (2009). *European science and technology policy towards integration or fragmentation?*. Cheltenham, UK: Edward Elgar.

D'Este, P. & P. Patel (2007), University-Industry Linkages in the UK: What are the Factors Underlying the Variety of Interactions with Industry, *Research Policy 36*, 1295-1313

Dernis, H. & M. Kahn (2004), Triadic Patent Families Methodology, *STI Working Paper 2004/2*, OECD, Paris

Djankov, S. & B. Hoekman (2000), Foreign Investment and Productivity Growth in Czech Enterprises, *World Bank Economic Review 14*, 49-64

Dollar, D., E.N. Wolff & W.J. Baumol (1988), The Factor-Price Equalisation Model and Industry Labour Productivity: An Empirical Test across Countries, in Fenstra, R.C. (1988) (Ed.) *Empirical Methods for International Trade*, The MIT Press, Cambridge, MA, ?-?

Dosi, G., K. Pavitt & L. Soete (1990), *The Economics of Technological Change and International Trade*, Harvester Wheatsheaf, New York

Dosi, G. & L. Soete (1983), Technology Gaps and Cost-Based Adjustment: Some Explorations on the Determinants of International Competitiveness, *Metroeconomica 35*, 197-222

Dosi, G. & L. Soete (1991), Technical Change and International Trade, in Dosi, G., et al., (1991) (Eds.), *Technical Change and Economic Theory*, Pinter Publishers, London, 401-431

Driffield, N. (2001), The Impact of Domestic Productivity of Inward Investment in the UK, *Manchester School 69*, 103-119

Driffield, N. & M. Munday (2000), Industrial Performance, Agglomeration and Foreign Manufacturing Investment in the UK, *Journal of International Business Studies 31*, 21-37

Driffield, N. & Love (2002), Does the Motivation for Foreign Direct Investment Affect Productivity Spillovers to the Domestic Sector?, *Working Paper RP2002*, Aston Business School, Birmingham

Duce, M. (2003), Definitions of foreign direct investment (FDI): A methodological note. Banco de Espana.

Dunning, J.H. (1980), Towards an Eclectic Theory of International Production: Some Empirical Tests, *Journal of International Business Studies 11*, 9-31

Dunning, J.H. (1993), *Multinational Enterprises and the Global Economy*, Addison-Wesley. Wokingham

Dunning, J.H. (1994), Multinational Enterprises and the Globalization of Innovatory Capacity, *Research Policy 23*, 67-88

Dunning, J.H. (1998), Location and the Multinational Enterprise: A Neglected Factor?, *Journal of International Business Studies 29*, 45-67

Dunning, J.H. & R. Narula (1995), The R&D Activities of Foreign Firms in the United States, *International Studies of Management and Organization 25*, 39-73

Dunning, J.H. & S.M. Lundan (2009), The Internationalization of Corporate R&D: A Review of the Evidence and Some Policy Implications for Home Countries, *Review of Policy Research 26*, 13-33

Döring; T. & J. Schnellenbach, 2006), What Do We Know about Geographical Knowledge Spillovers and Regional Growth?: A Survey of the Literature, *Regional Studies 40*, 375-395

EC (2000), *Push and pull factors of international migration : a comparative report.* Office for Official Publications of the European Communities, Luxemburg.

EC (2007), *The Competitiveness of European Industry*, European Commission

Echeverri-Carrol, E. (2001), Knowledge Spillovers in High Technology Agglomerations: Measurement and Modelling, in Fischer, M.M & J. Fröhlich (2001) (Eds.), *Knowledge, Complexity and Innovation Systems*, Springer, Berlin, 146-161

Edquist, C. & M. McKelvey (2000), *Systems of Innovation. Growth, Competitiveness and Employment*, Edward Elgar, Northampton MA

EIS (2007), *European Innovation Scoreboard 2007*, Commission of European Communities, Brussels

Engman, M. (2005), The Economic Impact of Trade Facilitation, *OECD Trade Policy Working Papers*, No. 21, OECD Publishing.

Erickson, G.S. (2008), Patent Systems: Does One Really Fit All?, School of Business Ithaca College, New York.

(Eschenbach, F. & B. Hoekman (2005), Services Policy Reform and Economic Growth in Transition Economies, 1990-2004, *Policy Research Working Paper 3663, The World Bank, Washington, D.C.*

Eurostat. (2007), How mobile are highly qualified human resources in science and technology? Eurostat Publication, 75.

Eurostat (2010) *Eurostat*, (database). European Commission. (Acccessed January 2011)

Fagerberg, J. (1996), Competitiveness, Scale & R&D, *NUPI Working Paper No. 545*

Feldman, M.P. & D.B. Audretsch (1996), Location, Location, Location: The Geography of Innovation and Knowledge Spillovers, *Discussion Paper No. FS IV 96-28*, WZB, Berlin

Feldman, M.P. & M.R. Kelley (2006), The Ex Ante Assessment of Knowledge Spillovers: Government R&D Policy, Economic Incentives and Private Firm Behaviour, *Research Policy 35*, 1509-1521

Fischer, M.M (2001), Innovation, Knowledge Creation and Systems of Innovation, *Annals of Regional Science 35*, 199-216

Florida, R. (1997), The Globalization of R&D: Results of a Survey of Foreign Affiliated R&D Laboratories in the USA, *Research Policy 26*, 85-103

Foray, D. (2004), *The Economics of Knowledge*, The MIT Press, Cambridge MA

Foray, D. & J. Mairesse (2002), *The Knowledge Dilemma and the Geography of Innovation*, Kluwer Academic Publishers, Boston, Dordrecht, London, 35-54

Fosfuri, A. & M. Motta (1999), Multinationals without Advantages, *Scandinavian Journal of Economics 101*, 617-630

Freeman, C. (1982), *The Economics of Industrial Innovation*, Pinter Publishers, London

Freeman, C. (1987), *Technology Policy and Economic Performance: Lessons from Japan*, Pinter Publishers, London

Freeman, C. & F. Louca (2001), *As Time Goes by: From the Industrial Revolutions to the Information Revolution*, Oxford University Press, Oxford

Frietsch, R. & U. Schmoch (2006), Technological Structures and Performance Reflected by Patent Indicators, in Schmoch, U., C. Rammer & H. Legler (2006) (Eds.), *National Systems of Innovation in Comparison. Structure and Performance Indicators for Knowledge Societies*, Springer, Dordrecht, ?-?

Frietsch, R. & U. Schmoch (2010), Transnational Patents and International Markets, *Scientometrics 82*, 185-200

Frietsch, R, U. Schmoch, B. van Looy, J. P. Walsh, R. Devroede, M. Du Plessis, T. Jung, Y. Meng, P. Neuhäusler, B. Peeters, T. Schubert (2010), The Value and Indicator Function of Patents, *Studien zum deutschen Innovationssystem Nr. 15-2010*, Frauenhofer Institute for Systems and Innovation Research, Berlin

Frost, T.S. (2001), The Geographic Sources of Foreign Subsidiaries' Innovations, *Strategic Management Journal, 22*, 101-123

Gehrke, B., O. Krawczyk & H. Legler (2007), Forschungs- und Wissen-intensive Wirtschaftszweige in Deutschland: Aussenhandel, Spezialisierung, Beschäftigung und Qualifikationserfordernisse, in BMBF (2007) (Ed.), *Studien zum deutschen Innovationssystem Nr. 17-2007*, Bundesministerium für Bildung und Forschung, Berlin, ?-?

Georghiou, L. (1998), Global Corporation in Research, *Research Policy 27*, 611-626

Gerybadze, A. & G. Reger (1999), Globalization of R&D: Recent Changes in the Management of Innovation in Transnational Corporations, *Research Policy 28*, ?-?

Ghoshal, S. & C. Barlett (1988), Creation, Adoption and Diffusion of Innovations by Subsidiaries of Multinational Corporations, *Journal of International Business Studies 19*, 365-388

Gibbons, M., et al., (1994), *The New Production of Knowledge*, Sage, London

Gilbert, R. & C. Shapiro (1990), Optimal Patent Length and Breadth, *RAND Journal of Economics 21*, 87-99

Girma, S., D. Greenaway & K. Wakelin (2001), Who Benefits from Foreign Direct Investment in the UK?, *Scottish Journal of Political Economy 48*, 119-133

Glaeser, E.L., et al., (1992), Growth in Cities, *Journal of Political Economy 100*, 1126-1152

Glassman, O. (2001), Multicultural Teams: Increasing Creativity and Innovation by Diversity, *Creativity and Innovation Management 10*, 88-95

Glissmann, H.H. & E. Horn (1988), Comparative Invention Performance of Major Industrial Countries: Patterns and Explanations, *Management Science 34*, 1169-1187

Globerman, S. (1979), Foreign Direct Investment and 'Spillover' Efficiency Benefits in Canadian Manufacturing Industries, *Canadian Journal of Economics 12*, 42-56

Glänzel, W. (2001), National Characteristics in International Scientific Co-Authorship Relations, *Scientometrics 51*, 69-115

Glänzel, W. & A. Schubert (2001), Double Effort = Double Impact? A Critical Review of International Co-Authorship in Chemistry, *Scientometrics 50*, 199-214

Goldberg, I., L. Branstetter, J.G. Goddard & S. Kuriakose (2008), *Globalization and Technology Absorption in Europe and Central Asia: The Role of Trade, FDI, and Cross-border Knowledge Flows*, The World Bank, Washington, D.C.

Gordon, I.R. & P. McCann (2000), Industrial Clusters: Complexes, Agglomeration and/or Social Networks, *Urban Studies 37*, 513-532

Granstrand, O. (1999), *The Economics and Management of Intellectual Property: Towards Intellectual Capitalism*, Edward Elgar, Cheltenham

Grant, R.M. & C. Baden-Fuller (2004), A Knowledge Assessing Theory of Strategic Alliances, *Journal of Management Studies 41*, 61-84

Greenhalg, C. (1990), Innovation and Trade Performance in the UK, *Economic Journal 100*, 105-118

Greenhalg, C., P. Taylor & R. Wilson (1994), Innovation and Export Volumes and Prices – A Disagggregated Study, *Oxford Economic Papers 46*, 102-134

Griffith, R., S. Redding & J. Van Reenen (2004), Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Countries, *Review of Economics and Statistics 86*, 883-895

Griffith, R. & H. Simpson (2002), Characteristics of Foreign-Owned Firms in British Manufacturing, in Blundell, R., D. Car & R. Freeman (2002) (Eds.), *Creating a Premier League Economy*, Chicago University Press, Chicago, IL, ?-?

Griliches, Z. (1979), Issues in Assessing the Contribution of R&D to Productivity Growth, *Bell Journal of Economics 10*, 92-116

Griliches, Z. (1989), Patents: Recent Trends and Puzzles, *Brookings Papers on Economic Activity: Microeconomics*, 291-330

Griliches, Z. (1990), Patent Statistics as Economic Indicators: A Survey, *Journal of Economic Literature 28*, 1661-1707

Griliches, Z. (1992), The Search for R&D Spillovers, *Scandinavian Journal of Economics 94*, ?-?

Grossman, G.M. & E. Helpman (1991a), *Innovation and Growth in the Global Economy*, The MIT Press, Cambridge MA

Grossman, G.M. & E. Helpman (1991b), Trade, Knowledge Spillovers, and Growth. *European Economic Review ?*, 517-526

Grossman, G.M. & E. Helpman (1994), *Technology and Trade*, The MIT Press, Cambridge, MA

Grupp, H. (1998), *Foundations of the Economics of Innovation – Theory, Measurement and Practice*, Edward Elgar, Cheltenham

Grupp, H., G. Münt & U. Schmoch (1996), Assessing Different Types of Patent Data for Describing High-Technology Export Performance, in OECD (1996) (Ed.), *Innovation, Patents and Technological Strategies*, Proceedings of a Workshop Held at OECD Headquarters in Paris, 8-9 December 1994, OECD, Paris, 271-287

Guellec, D. & M.P. Zuniga (2008), Globalization of Technology Captured with Patent Data. A Preliminary Investigation at the Country Level, in Statistics Sweden (2008) (Ed.), *Yearbook on Productivity 2007*, Statistics Sweden, Örebro, 109-126

Guellec, D. & B. van Pottelsberghe de la Potterie (2001), The Internationalization of Technology Analysed with Patent Data, *Research Policy 30*, 1253-1266

Gupta, A.K. & V. Govindarajan (1991), Knowledge Flows and the Structure of Control within Multinational Corporations, *Academy of Management Review 16*, 768-792

Görg, H. & E. Strobl (2001), Multinational Companies and Productivity Spillovers: A Meta-Analysis, *Economic Journal 111*, 723-739

Haddad, M. & A.E. Harrison (1993), Are There Positive Spillovers from Direct Foreign Investments? Evidence from Panel Data for Mexico, *Journal of Development Economics 42*, 51-74

Hagedoorn, J. (1996), Trends and Patterns in Strategic Technology Partnering Since the Early Seventies, *Review of Industrial Organization 11*, 601-616

Hagedoorn, J. (2002), Inter-firm R&D Partnerships: An Overview of Major Trends and Patterns since 1960, *Research Policy 31*, 477-492

Hagedoorn, J.; Cloodt, M. (2003): Measuring innovative performance: is there an advantage in using multiple indicators? *Research Policy, 32*(8), 1365-1379.

Hagedoorn, J. & G.M. Duysters (2002), External Sources of Innovative Capabilities: The Preference for Strategic Alliances or Mergers and Acquisitions, *Journal of Management Studies 39*, 167-188

Hagedoorn, J., A. Link & N. Vonortas (2000), Research Partnerships, *Research Policy 29*, 567-586

Hagedoorn, J. & S.M. Lundan (2001), Strategic Technology Alliances: Trends and Patterns since the Early 1980s, in Plunket, A., C. Voisin & B. Bellon (2001) (Eds.), *The Dynamics of Industrial Collaboration*, Edward Elgar, Cheltenham, 88-101

Hagedoorn, J. & B. Sadowski (1999), The Transition from Strategic Technology Alliances to Mergers and Acquisitions, *Journal of Management Studies 36*, 87-107

Hagedoorn, J., H. van Kranenburg & R.N. Osborn (2003), Joint Patenting among Companies – Exploring the Effects of Inter-Firm R&D Partnering and Experience, *Managerial and Decision Economics 24*, 71-84

Hall, B.H. & R.M. Ham (1999), The Patent Paradox Revisited: Determinants of Patenting in the U.S. Semiconductor Industry, 1980-1994, *NBER Working Paper No. 7062*

Hall, B.M. & R.M. Ziedonis (2001), The Patenting Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1979-1995, *Rand Journal of Economics 32*, 101-128

Hallak, J.C. & J. Levinsohn (2004), Fooling Ourselves: Evaluating the Globalisation and Growth Debate, *NBER Working Paper No. 10244*, National Bureau of Economic Research, Cambridge, MA

Harabi, N. (1995), Appropriability of Technical Innovations: An Empirical Analysis, *Research Policy 24*, 981-992

Harhoff, D., F.M. Scherer & K. Vopel (2003), Citations, Family Size, Opposition and the Value of Patent Rights, *Research Policy 32*, 1343-1363

Haskel, J.E., Pereira & M.J. Slaughter (2002), Does Inward Foreign Direct Investment Boost the Productivity of Domestic Firms?, *NBER Working Paper 8724*, National Bureau of Economic Research, Cambridge, MA

Havlik, P., R. Stollinger, O. Pindyuk & G. Hunya (2009), *EU and BRICs Challenges and Opportunities for European Competitiveness and Cooperation*, Industrial Policy and Economic Reform Papers No. 13, Enterprise and Industry Directorate-General, European Commission

Hedge, D. & D. Hicks (2008), The Maturation of Global Corporate R&D: Evidence from the Activity of U.S. Foreign Subsidiaries, *Research Policy 37*, 390-406

Held, D. & A. McGrew (with D. Goldblatt & J. Perraton) (1999), *Global Flows: Politics, Economics and Culture*, Polity, Cambridge

Helpman, E. (1997), R&D and Productivity: The International Connection, *NBER Working Paper No. 6101*, National Bureau of Economic Research, Cambridge, MA

Hennert, J.-F. (1988), The Transaction Cost Theory of Equity Joint Ventures, *Strategic Management Journal 9*, 361-374

Hennart, J.-F. (2007), The Theoretical Rationale for a Multi-nationality-Performance Relationship, *Management International Review 47*, 423-452

Hicks, D. & F. Narin (2001), Strategic Research Alliances and 360 Degree Bibliometric Indicators, in Janowski, J.E., A.N. Link & N.S. Vonortas (2001) (Eds.), *Strategic Research Partnerships – Proceedings from a National Science Foundation Workshop*, National Science Foundation, Washington, D.C., 133-145

Hirschman, A.O. (1958), *The Strategy of Economic Development*, Yale, University Press, New Haven
Howells, J. (1998), Innovation and Technology Transfer within Multinational Firms, in Michie, J. & J. Grieve Smith (1998) (Eds.), *Globalization, Growth and Governance: Creating an Innovative Economy*, Oxford University Press, Oxford, 50-70
Hymer, S.H. (1976), *The International Operations of National Firms: A Study of Foreign Direct Investments*, MIT Press, Boston, MA
Håkanson, L. & R. Nobel (2001), Organizational Characteristics and Reverse Technology Transfer, *Management International Review 41*, 395-420
Inkpen, A.C. (2000), Learning through Joint Ventures: A Framework of Knowledge Acquisition, *Journal of Management Studies 37*, 1019-1043
Iwasa, T. & H. Ogadiri (2004), Overseas R&D, Knowledge Sourcing and Patenting: An Empirical Study of Japanese R&D Investment in the US, *Research Policy 33*, 807-828
Jacobs, J. (1969), *The Economy of Cities*, Vintage Books, New York
Jaffe, A.B. (1986), Technological Opportunity and Spillovers of R&D: Evidence from Firm's Patents, Profits, and Market Value, *American Economic Review 76*, 984-1001
Jaffe, A.B. (2000), The U.S. Patent System in Transition: Policy Innovation and the Innovation Process, *Research Policy 29*, 531-557
Jaffe, A.B., M.S. Fogarty & B.A. Banks (1998), Evidence from Patents and Patent Citations of the Impact of NASA and other Federal Labs on Commercial innovation, *Journal of Industrial Economics 46*, 183-205
Jaffe, A.B., M. Trajtenberg & M.S. Fogarty (2000), Knowledge Spillovers and Patent Citations: Evidence from a Survey of Inventors, *American Economic Review 90*, ?-?
Jaffe, A.B., M. Trajtenberg & R. Henderson (1993), Geographical Localization of Knowledge Spillovers as Evidenced by Patent Citations, *Quarterly Journal of Economics 108*, 577-598
Janz, N., G. Licht & T. Doherr (2001), Innovation Activities and European Patenting of German Firms: A Panel Data Analysis, Paper Presented at the Annual Conference of the European Association of Research in Industrial Economics
Japanese Statistics Bureau (2010), Judicial System and Research Department, Minister's Secretariat, Ministry of Justice.
Johansson, B. & C. Karlsson (2001), Geographic Transaction Costs and Specialisation Opportunities of Small and Medium-Sized Regions: Scale Economies and Market Extension, in Johansson, B., C. Karlsson & R.R. Stough (2001) (Eds.), *Theories of Endogenous Regional Growth. Lessons for Regional Policies*, Springer, Berlin, 150-180
Kang, N. & S. Johansson (2000), Cross-Border Mergers and Acquisitions: Their Role in Industrial Globalization, Working Paper, Directorate for Science and Technology, OECD, Paris
Kale, D. & S.E. Little (2007), Flows and Cohesion: Balancing Capabilities across en Expanded Union, *Mobilities 2*, 99-108
Karlsson, C. & M. Andersson (2009), The Location of Industry R&D and the Location of University R&D: How Are They Related, in Karlsosn, C., et al., (2009) (Eds.), *New Direction in Regional Development*, Springer, Berlin, 267-290
Karlsson, C. & B. Johansson (2006), Dynamics and Entrepreneurship in a Knowledge-Based Economy, in Karlsson, C., B. Johansson & R.R. Stough (2006) (Eds.), *Entrepreneurship and Dynamics in the Knowledge Economy*, Routledge, New York, 12-46
Karlsson, C., B. Johansson & R.R. Stough (2010), Introduction, in Karlsson, C., B. Johansson & R.R. Stough (2010) (Eds.), *Entrepreneurship and Regional Development. Local Processes and Global Patterns*, Edward Elgar, Cheltenham, 1-27

Kathuria, V. (2000), Productivity Spillovers from Technology Transfer to Indian Manufacturing Firms, *Journal of International Development 12*, 343-369
Katsoulakos, Y. & D. Ulph (1998), Endogenous Spillovers and the Performance of Research Joint Ventures, *The Journal of Industrial Economics 46*, 333-354
Katz, J.L. & B.R. Martin (1997), What Is Research Collaboration?, *Research Policy 26*, 1-18
Katz, M.L. (1986),An Analysis of Cooperative Research and Development, *The RAND Journal of Economics 17*, 527-543
Kaufman, S. (1995), *At Home in the Universe: The Search for the Laws of Self-Organization and Complexity*, Oxford University Press, New York
Keller, W. (2000), Do Trade Patterns and Technology Flows Affect Productivity Growth?, *The World Bank Economic Review 14*, 17-47
Keller, W. & S. Yeaple (2003), Multinational Enterprises, International Trade and Productivity Growth: Firm Level Evidence from the United States, *NBER Working Paper 9504*, National Bureau of Economic Research, Cambridge, MA
Kennedy, P. (1988), *The Rise and Fall of Great Powers*, Unwin Hyman, London
Kleinknecht, A. & R. Oostendorp (2002), R&D and Export Performance: Taking Account of Simultaneity, in Kleinknecht, A. & P. Mohnen (2002) (Eds.), *Innovation and Firm Performance*, ?. New York, 310-320
Kleinknecht, A. & T. Poot (1992) Do Regions Matter for R&D? *Regional Studies 26***,** 221-232
Klemperer, P. (1990), How Broad Should the Scope of Patent Protection Be?, *RAND Journal of Economics 21*, 113-130
Kogut, B. & S.J. Chang (1991), Technological Capabilities and Japanese Foreign Direct Investment in the United States, *Review of Economics and Statistics 73*, 401-413
Kokko, A. (1994), Technology, Market Characteristics and Spillovers, *Journal of Development Economics 43*, 279-293
Kokko, A. (1996), Productivity Spillovers from Competition between Local Firms and Foreign Affiliates, *Journal of International Development 8*, 517-530
Kokko, A., R. Tansini & M.C. Zejan (1996), Local Technological Capability and Productivity Spillovers from FDI in the Uruguayan Manufacturing Sector, *Journal of Development Studies 32*, 602-611
Konings, J. (2001), The Effects of Foreign Direct Investment on Domestic Firms, *Economics of Transition 9*, 619-633
Kortum, S. & J. Lerner (1997), Stronger Protection or Technological Revolution: What Is behind the Recent Surge in Patenting?, *NBER Working Paper No. 6204*
Kortum, S. & J. Lerner (1999), What Is behind the Recent Surge in Patenting?, *Research Policy 28*, 1-22
Kotabe, M., D. Dunlap-Hinkler, R. Parente & H. A. Mishra (2007), Determinants of Cross-National Knowledge Transfer and Its Effect on Firm Innovation, *Journal of International Business Studies 38*, 259-282
Krugman, P. (1979), A Model of Innovation, Technology Transfer, and the World Distribution of Income, *Journal of Political Economy 87*, 253-266
Kuemmerle, W. (1997), Building Effective R&D Capabilities Abroad, *Harvard Business Review*, (March-April), 61-69
Kuemmerle, W. (1999a), The Drivers of Foreign Direct Investments into Research and Development: An Empirical Investigation, *Journal of International Business Studies 30*, 1-24
Kuemmerle, W. (1999b), Foreign Direct Investment in Industrial Research in the Pharmaceuticals and Electronics Industries – Results from a Survey of Multinational Firms, *Research Policy 28*, ?-?
Lall, S. (1979), The International Allocation of Research Activity by US Multinationals, *Oxford Bulletin of Economics and Statistics 41*, 313-331

Le Bas, C. & C. Sierra (2002), Location versus Home Country Advantages in R&D Activities: Some Further Results on Multinationals' Location Strategies, *Research Policy 31*, 589-609

Legler, H. & O. Krawczyk (2006), The Global Distribution of R&D Activities, in Schmoch, U., C. Rammer & H. Legler (2006) (Eds.), *National Systems of Innovation in Comparison. Structure and Performance Indicators for Knowledge Societies*, Springer, Dordrecht, 31-45

Lehrer, M. (2007), Organizing Knowledge Spillovers When Basic and Applied Research Are Interdependent: German Biotechnology Policy in Historical Perspective, *Journal of Technology Transfer 32*, 277-296

Lehrer, M. & K. Asakawa (2004), Pushing Scientists into the Market Place: Promoting Science Entrepreneurship, *California Management Journal 46*, 55-76

Lemley, M.A. & R.K. Tangri (2003), Ending Patent Law's Willfulness Game, *Berkeley Technology Law Journal 18*, ?-?

Leonard-Barton, D. (1995), *Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation*, Harvard Business School Press, Boston, MA

Levin, R.C., et al., (1987), Appropriating the Returns from Industrial Research and Development, *Brookings papers on Economic Activity*, 3, ?-?

Lewison, G. & P. Cunningham (1991), Bibliometric Studies for the Evaluation of Trans-National Research, *Scientometrics 21*, 223-244

Link, A., D. Siegel & B. Bozeman (2007), An Empirical Analysis of the Propensity of Academics to Engage in Informal University Technology Transfer, *Industrial & Corporate Change 16*, 641-655

Liu, X., et al., (2000), Productivity Spillovers from Foreign Direct Investment: Evidence from UK Industry Level Panel Data, *Journal of International Business Studies 31*, 407-425

Lorenz, C. (1983), Managing a 1 Billion Dollar R&D Budget, *Europe Profile 32*, 15-17

Luukkonen, T., O. Persson & G. Sivertsen (1992), Understanding Patterns of International Scientific Collaboration, *Science, Technology & Human Values 17*, 101-126

Luukkonen, T., et al., (1993), The Measurement of International Scientific Collaboration, *Scientometrics 28*, 15-36

Lundan, S.M. & J. Hagedoorn (2001), Alliances, Acquisitions and Multinational Advantage, *International Journal of Economics and Business 8*, 229-242

Lundvall, B.-Å. (1992) (Ed.), *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, Pinter Publishers, London

Lundvall, B.-Å. & D. Foray (1996), The Knowledge-Based Economy, in OECD (1996) (Ed.), *Employment and Growth in the Knowledge-Based Economy*, OECD, Paris, ?-?

Madsen, J.B. (2008), Innovations and Manufacturing Export Performance in the OECD Countries, *Oxford Economic Papers 60*, 143-167

Mai, N. (2004). 'Looking for a More Modern Life…': the Role of Italian Television in the Albanian Migration to Italy. *Westminster Papers in Communication and Culture 1*(1), 3-22.

Mancusi M.L. (2008), International spillovers and absorptive capacity: A cross-country cross-sector analysis based on patents and citations. *Journal of International Economics,76*, 155-165.

Malecki, E. (1991), *Technology and Economic Development. The Dynamics of Local, Regional and National Change*, Longman, Harlow

Mancusi M.L. (2008), International spillovers and absorptive capacity: A cross-country cross-sector analysis based on patents and citations. *Journal of International Economics,76*, 155-165.

Mansfield, E. & A. Romeo (1980), Technology Transfer to Overseas Subsidiaries by U.S. Based Firms, *Quarterly Journal of Economics 95*, 737-749
Mariani, M. (2000), Networks of Inventors in the Chemical Industry, Discussion Paper, University of Urbino, Urbino
Marin, D. (1995) Learning and Dynamic Comparative Advantage: Lessons from Austria's Post-war Pattern of Growth for Eastern Europe. *CEPR Discussion Papers*
Martin, S. (1994), R&D Joint Ventures and Tacit Product Market Collusion, *European Journal of Political Economy 11*, 733-741
Maskus, K.E. & M. Penubarti (1995), How Trade-Related Are Intellectual Property Rights?, *Journal of International Economics 39*, 227-248
Mattsson, P., et al., (2008), Intra-EU vs. Extra-EU Scientific Co-Publication Patterns in EU, *Scientometrics 75*, 555-574
Maurseth, P.B. & B. Verspagen (2002), Knowledge-Spillovers in Europe: A Patent Citation Analysis, *Scandinavian Journal of Economics 104*, 531-545
McCann, P. , (2008), Globalization and Economic Geography: The World is Curved, not Flat, *Cambridge Journal of Regions, Economy and Society, 1*(3), 357-370.
Merton, R.K. (1979), *The Sociology of Science, Theoretical and Empirical Investigations*, The University of Chicago Press, Chicago
Meyer, M., K. Debackere & W. Glänzel (2010), Can Applied Science Be ‘Good Science’? Exploring the Relationship between Patent Citations and Citation Impact in Nanoscience, *Scientometrics 85*, 527-539
Meyer-Krahmer, F. (2000), Increasing Role of Basic Research for Innovation: The Case of Science Based Technologies. Empirical Evidence and Institutional Consequences, Conference paper, ISI Karlsruhe
Meyer-Krahmer, F. & G. Reger (1999), New perspectives on the Innovation Strategies of Multinational Enterprises: Lessons for Technology Policy in Europe, *Research Policy 28*, ?-?
Michel, J. & B. Bettels (2001), Patent Citation Analysis. A Closer Look at the Basic Input Data from Patent Search Reports, *Scientometrics 51*, 185-201
Michie, J. (1998), Introduction: The Internationalization of the Innovation Process, *International Journal of the Economics of Business 5*, 261-278
Mowery, D. (1992a), International Collaborative Ventures and the Commercialization of New Technologies, in Rosenberg, N., R. landau & D. Mowery (1992) (Eds.), *Technology and the Wealth of Nations*, Stanford University Press, Stanford, ?-?
Mowery, D. (1992b), The US National Innovation System: Origins and Prospects for Change, *Research Policy 21*, 125-143
Mowery, D. & R.R. Nelson (1999) (Eds.), *The Sources of Industrial Leadership*, Cambridge University Press, Cambridge
Mowery, D. & D.J. Teece (1993), Japan’s Growing Capabilities in Industrial Technology: Implications for US Managers and Policy Makers, *California Management Review 35*, 9-34
Münt, G. (1996), *Dynamik von Innovation und Aussenhandel. Entwicklung technologischer und wirtschaftlicher Spezialisierungsmuster*, Physika-Verlag, Heidelberg
Mytelka, L.K. (2001), Mergers, Acquisitions, and Inter-Firm Technology Agreements in the Global Learning Economy, in Archibugi, D. & B.-Å. Lundvall (2001) (Eds.), *The Globalising Learning Economy*, Oxford University Press, Oxford, ?-?
Narin, F., K.S. Hamilton & D. Olivastro (1995), Linkage between Agency Supported Research and Patented Industrial Technology, *Research Evaluation 5*, 183-187
Narin, F., K.S. Hamilton & D. Olivastro (1997), The Increasing Linkage between US Technology and Public Science, *Research Policy 26*, 317-330

Narin, F. & E. Noma (1985), Is Technology Becoming Science?, *Scientometrics 7*, 369-381
Narula, R. & J. Hagedoorn (1999), Innovating through Strategic Alliances. Moving Towards International Partnerships and Contractual Agreements, *Technovation 19*, 283-294
Narula, R. & A. Zanfei (2005), Globalization of Innovation: The Role of Multinational Enterprises, in Fagerberg, J., D.C. Mowery & R.R. Nelson (2005) (Eds.), *The Oxford Handbook of Innovation*, Oxford University Press, Oxford, ?-?
Nelson, A.J. (2009), Measuring Knowledge Spillovers: What Patents, Licenses and Publications Reveal about Innovation Diffusion, *Research Policy 38*, 994-1005
Nelson, R.R. (1984), *High Technology Policies: A Five-Nation Comparison*, American Enterprise Institute for Public Policy Research, Washington, D.C.
Nelson, R.R. (1989), US Technological Leadership. Where Did It Come from and Where Did It Go?, *Research Policy 19*, 117-132
Nelson, R.R (1993) (Ed.), *National Systems of Innovation: A Comparative Analysis*, Oxford University Press, London
Nelson, R.R. & P.M. Romer (1996), Science, Economic Growth, and Public Policy, in Smith, B.L.R. & C.E. Barfield (1996) (Eds.), *Technology, R&D and the Economy*, The Brookings Institution, Washington, D.C., ?-?
Nelson, R.R. & S.G. Winter (1982), *An Evolutionary Theory of Economic Change*, Belknap Press of Harvard University Press, Cambridge, MA
Neven, D. & G. Siotis (1996), Technology Sourcing and FDI in the EC: An Empirical Evaluation, *International Journal of Industrial Organization 14*, 543-560
Nicoletti, G. & S. Scarpetta (2003), Regulation, Productivity and Growth: OECD Evidence, *Economic Policy 18*, 9-72
Noguer, M. & M. Siscart (2005), Trade Raises Income: A Precise and Robust Result, *Journal of International Economics 65*, ?-?
Noguer, M. & M. Siscart (2006), FDI, Trade and Income: A Causal Analysis, Queens School of Business (mimeo)
Nonaka, I. (1994), A Dynamic Theory of Organizational Knowledge Creation, *Organization Science 5*, 14-37
Nonoka, I. & H. Takeuchi (1995), *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*, Oxford University Press, New York
Nooteboom, M. (2004), *Inter-Firm Collaboration, Learning and Networks; An Integrated Approach*, Routledge, London
North, D. (1990), *Institutions, Institutional Change and Economic Performance*, Cambridge University Press, Cambridge
NSF (2000), *Science and Engineering Indicators*, National Science Foundation, US GPO, Washington, DC
NSF (2002), *Science and Engineering Indicators*, National Science Foundation, US GPO, Washington, DC
NSF (2010), *Science and Engineering Indicators 2010*, National Science Foundation, Arlington, VA.
OECD (2002), *Science, Technology and Industry Outlook 2002*, OECD, Paris
OECD (2004), *Compendium on Patent Statistics 2004*, Organization for Economic Cooperation and Development, Paris
OECD (2010a), *OECD.Stat*, (database). (Accessed January 2011)
OECD (2010b), *Measuring Globalisation: OECD Economic Globalisation Indicators 2010*,
OECD Publishing.
OECD (2010c), *International Migration Outlook 2010*, OECD Publishing.
OECD (2010d), *Foreign direct investment: main aggregates*, OECD International Direct Investment Statistics (database). (Acccessed January 2011)

OECD (2010e), *Education at a Glance 2010: OECD Indicators*, OECD Publishing. doi: 10.1787/eag-2010-en

OECD (2010f), *Measuring Innovation: A New Perspective*, OECD Publishing. doi: 10.1787/9789264059474-en

OECD (2011a), REGPAT database.

OECD (2011b), Citations database.

Oettl, A. och Agrawal, A., (2007), International Labor Mobility and Knowledge Flow Externalities, *Journal of International Business Studies, 39*, 1242-1260.

Ohmae, K. (1985), *Triad Power: the coming shape of global competition*, New York: The Free Press.

Ohmae, K. (1995), *The End of the Nation State: The Rise of Regional Economies*, New York

Oster, S.M. (1992), *Modern Competitive Analysis*, Oxford University Press, New York

Oxley, J.E. (1999), Institutional Environment and the Mechanisms of Governance: The Impact of Intellectual Property Protection on the Structure of Inter-Firm Alliances, *Journal of Economic Behaviour and Organization 38*, 283-309

Oxley, J.E. & R. Sampson (2004), The Scope and Governance of International R&D Alliances, *Strategic Management Journal 25*, 723-749

Parente, S. & E.C. Prescott (2000), *Barriers to Riches*, MIT Press, Cambridge MA

Patel, P.& K. Pavitt (1987), Is Western Europe Losing the Technological Race?, in Freeman, C. (1987) (Ed.), *Output Measurement in Science and Technology*, North-Holland, Amsterdam, ?-?

Patel, P & K. Pavitt (1991), Large Firms in the Production of the World's Technology: An Important Case of Non-Globalization, *Journal of International Business Studies 22*, 1-21

Patel, P. & M. Vega (1999), Patterns of Internationalisation of Corporate Technology: Location vs. Home Country Advantages, *Research Policy 28*, ?-?

Patel, V.L., D.R. Kaufman & S.A. Madger (1996), The Acquisition of Medical Expertise in Complex Dynamic Environments, in Ericsson, A. (1996) (Ed.), *The Road to Excellence: The Acquisition of Expert Performance in the Arts and Sciences, Sports and Games*, Lawrence Erlbaum Associates, Mahwah, NJ, 127-165

Pavitt, K. (1999), *Technology, Management and Systems of Innovation*, Edward Elgar, Cheltenham

Persson, O., W. Glänzel & R. Danell (2004), Inflationary Bibliometric Values: The Role of Scientific Collaboration and the Need for Relative Indicators in Evaluative Studies, *Sceintometrics 60*, 421-432

Pianta, M. (1988), *New Technologies across the Atlantic: US Leadership or European Autonomy?*, Harvester-Wheatsheaf, Hemel Hempstead

Plant, A. (1934), The Economic Theory Concerning Patents for Inventions, *Economica ?*, 30-51

Polanyi, M. (1966), *The Tacit Dimension*, Doubleday, New York

Polt, W., C. Rammer, D. Schartinger, H. Gassler & A. Shibany (2000), Benchmarking Industry-Science Relations in Europe – The Role of Framework Conditions, Conference on: *Benchmarking Europe's Industrial Competitiveness*, A benchmarking project on industry science relations (ISR)

Ponds, R., F. van Oort & K. Frenken (2007), The Geographical and Institutional Proximity of Research Collaboration, *Papers in Regional Science 86*, 423-443

Porter, M.E. (1990), *The Competitive Advantage of Nations*, Macmillan, London

Posner, M.V. (1961), International Trade and Technical Change, *Oxford Economic Papers 13*, 323-341

Prescott, E.C. (1998), Needed: A Theory of Total Factor Productivity, *International Economic Review 39*, 525-552

Ramachandran, V. (1993), Technology Transfer, Firm Ownership, and Investment in Human Capital, *Review of Economics and Statistics 75*, 664-670

Redding, S. (2002), Path Dependence, Endogenous Innovation and Growth, *International Economic Review 43*, 1215-1249

Reinganum, J.F. (1989), The Timing of Innovation: Research, Development and innovation, in Schmalensee, R. & R.D. Willig (1989) (Eds.), *Handbook of Industrial Organization*, North Holland, Amsterdam, 849-908

Rigby, J. & J. Edler (2005), Peering Inside Research Networks: Some Observations on the Effect of the Intensity of Collaboration on the Variability of Research Quality, *Research Policy 34*, 784-794

Rivera-Batiz, L.A. & P. Romer (1991), Economic Integration and Endogenous Growth, *Quarterly Journal of Economics 106*, 531-555

Rivette, K.G. & D. Kline (2000), Discovering New Value in Intellectual Property, *Harvard Business Review*, 1-12

Robinson, R.D. (1988), *The International Transfer of Technology: Theory, Issues and Practice*, Ballinger Publishing Company, Cambridge

Rodriguez, F. & D. Rodrik (2001), Trade Policy and Economic Growth: A Sceptic's Guide to the Cross-National Evidence, in Benarke, B. & K.S. Rogoff (2001) (Eds.), *Macroeconomics Annual 2000*, MIT Press for NBER, Cambridge, MA, ?-?

Roeger, W. (2010), Assessing Alternative Strategies to Promote Growth in the EU, *European Commission/DG ECFIN*

Romer, P.M. (1990). Endogenous technological Change. *Journal of Political Economy, 98*(5 part 2), 71-102.

Rosenberg, N. (1982), *Inside the Black Box: Technology and Economics*, Cambridge University Press, Cambridge

Rozenblat, C. & D. Pumain (1993), The Location of Multinational Firms in the European Urban System, *Urban Studies 30*, ?-?

Röller, L.-H., R. Siebert & M.M. Tombak (2007), Why Firms Form (or Do not Form) RJVS, *Economic Journal 117*, 1122-1144

Saggi, K. (2002), Trade, Foreign Direct Investment, and International Technology Transfer: A Survey, *The World Bank Research Observer 17*, 191-235

Sakakibara, M. (2003), Knowledge Sharing in Cooperative Research and Development, *Managerial and Decision Economics 24*, 117-132

Sakakibara, M. & M.E. Porter (2001), Competing at Home to Win Abroad: Evidence from Japanese Industry, *Review of Economics and Statistics 83*, 311-423

Sala-i-Martin, X. (1997), I Just Ran Two Million Regressions, *American Economic Review 87*, 178-183

Sampat, B.N. (2005), Determinants of patent quality: an empirical analysis. Mimeo Columbia University.

Sapir, A., et al., (2004), *An Agenda for Growth in Europe: The Sapir Report*, Oxford University Press, Oxford

Scherer, F. & D. Ross (1990), *Industrial Market Structure and Economic Performance*, 3rd ed., Houghton Mifflin Co, Boston, MA

Schiller, D. & J. Revilla Diez (2009), Mobile Star Scientists as regional Knowledge Spillover Agents, *IAEREG Working Paper No. 2.7*

Schmoch, U. & T. Schubert (2008), Are International Co-publications an Indicator of Quality of Scientific Research?, *Scientometrics 74*, ?-?

Schoors, K. & B. van der Tol (2001), The Productivity Effect of Foreign Ownership on Domestic Firms in Hungary, University of Ghent (mimeo)
Schumpeter, J. (1934), *The Theory of Economic Development*, The MIT Press, Cambridge, MA
Schumpeter, J. (1939), *Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process*, McGraw Hill, New York
Scotchmer, S. (1991), Standing on the Shoulders of Giants: Cumulative Research and the Patent Law, *Journal of Economic Perspectives 5*, 29-41
Sena, V. (2004), The Return of the Prince of Denmark: A Survey on Recent Developments in the Economics of Innovation, *The Economic Journal 114*, F312-F332
Servan-Schreiber, J.-J. (1968), *The American Challenge*, Penguin, Harmondsworth
Shapiro, A.R. (1990), Responding to the Changing Patent System, *Research-Technology Management ?*, 38-43
Shapiro, C. (2000), Navigating the Patent Ticket: Cross Licences, Patent Pools, and Standard Setting, in Jaffe, A.B., J. Lerner & S. Stern (2000) (Eds.), *Innovation Policy and the Economy*, The MIT Press, Cambridge, MA, 119-150
Sheehan, J. C. Martinez & D. Guellec (2004), Understanding Business Patenting and Licensing: Results from a Survey, in OECD (2004) (Ed.), *Patents Innovation and Economic Performance – OECD Conference Proceedings*, OECD, Paris, 89-110
Simon, H.A. (1985), What We Know about the Creative Process, in Kuhn, R.L. (1985) (Ed.), *Frontiers in Creative and Innovative Management*, Ballinger, Cambridge, 3-20
Sinha, D.K, & M.A. Cusumano (1991), Complementary Resources and Cooperative Research: A Model of Research Joint Ventures among Competitors, *Management Science 37*, 1091-1106
Singh, J. (2004), Multinational Firms and Knowledge Diffusion: Evidence Using Patent Citation Data, Working Paper, INSEAD
Sjöholm, F. (1999a), Technology Gap, Competition and Spillovers from Foreign Investment: Evidence from Establishment Data, *Journal of Development Studies 36*, 55-73
Sjöholm, F. (1999b), Productivity Growth in Indonesia: The Role of Regional Characteristics and Foreign Direct Investment, *Economic Development and Cultural Change 47*, 559-584
Smarzynska Javorcik, B. (2004), Does Foreign Direct Investment Increase the Productivity of Domestic Firms? In Search of Spillovers through Backward Linkages, *American Economic Review 94*, 605-627
Smarzynska Javorcik, B. & M. Spatareanu (2008), To Share or Not To Share: Does Local Participation Matter for Spillovers from Foreign Direct Investment?, *Journal of Development Economics 85*, 194-217
Smith, M. (1958), The Trend toward Multiple Authorship in Psychology, *American Psychologist 13*, 596-599
Smith, M. P. & Favell, A. (2006), *The human face of global mobility*. New Brunswick, N.J.: Transaction Publishers.
Soete, L. (1981), A General Test of the Technological Gap Trade Theory, *Weltwirtschaftliches Archiv 117*, 638-660
Soete, L. (1987), The Impact of Technological Innovation on International Trade Patterns, *Research Policy 16*, 101-130
Suarez-Villa, L. (2000), *Invention and the Rise of Techno-Capitalism*, Rowman & Littlefield, Lanham
Taylor, M.Z. (2009), International Linkages and National Innovation Rates: An Exploratory Probe, *Review of Policy Research 26*, 127-149

Teece, D.J. (1977), Technology Transfer by Multinational Firms: The Resource Cost of Transferring Technological Know-How, *Economic Journal 87*, 242-261

Teece, D. (2000), *Measuring Intellectual Capital: Organizational Strategic and Policy Dimensions*, Oxford University Press, New York

Thursby, J. & M. Thursby (2006), *Here or There? A Survey of Factors in Multinational R&D Location*, The National Academic Press, Washington, D.C.

Tijssen, R.J.W. (2001), Global and Domestic Utilization of Industrial Relevant Science: Patent Citation Analysis of Science-Technology Interactions and Knowledge Flows, *Research Policy 30*, 35-54

UN Comtrade (2010) *United Nations Commodity Trade Statistics Database.* United Nations

UNCTAD (2000), *World Investment Report 2000: Cross-Border Mergers and Acquisitions and Development*, No. 92-1-112490-5, United Nations Conference on Trade and Development, New York

UNCTAD (2005), *World Investment Report 2000: Transnational Companies and the Internationalization of R&D*, United Nations Conference on Trade and Development, Geneva

UNCTAD (2010), *UNCTADStat,* (database). (Accessed January 2011)

UNESCO (2010), *UNESCO Science Report 2010,* UNESCO Publishing.

US MPI (2010), *2009 American Community Survey and Census Data on the Foreign Born by State*, US Migration Policy Institute, Washington, DC.

van Zeebroeck, at al., (2008), Patent Inflation in Europe, *World Patent Information 30*, 43-52

Verbeek, A., K. Debackere & M. Luwel (2003), Science Cited in Patents: A Geographic “Flow” Analysis of Bibliometric Citation Patterns in Patents, *Scientometrics 58*, 241-263

Vernon, R. (1966), International Investment and International Trade in the Product Cycle, *Quarterly Journal of Economics 80*, 190-207

Vernon, R. (1979), The Product Cycle Hypothesis in the New International Environment, *Oxford Bulletin of Economics and Statistics 41*, 255-267

Verspagen, B. (1994), Technology and Growth: The Complex Dynamics of Convergence and Divergence, in Silverberg, G. & L. Soete (1994) (Eds.), *The Economics of Growth and Technical Change: Technologies, Nations, Agents*, Edward Elgar, Aldershot, ?-?

Verspagen B. & W. Schoenemakers (2000), The Spatial Dimension of Knowledge Spillovers in Europe, Paper Presented on the AEA Conference on IP Econometrics

Veugelers, R. (2010), Towards a Multipolar Science World: Trends and Impact, *Scientometrics 82*, 439-456

von Zedtwitz, M. & O. Gassman (2002), Market versus Technology Drive in R&D Internationalisation: Four Different Patterns of managing Research and Development, *Research Policy 31*, ?-?

Wagner, C.S. (2005), Six Case Studies of International Collaboration in Science, *Scientometrics 62*, 3-26

Wakelin, K. (1997), *Trade and Innovation. Theory and Evidence,* Edward Elgar, Cheltenham

Wakelin, K. (1998a), The Role of Innovation in Bilateral OECD Trade Performance, *Applied Economics 30*, 1335-1346

Wakelin, K. (1998b), Innovation and Export Behaviour at the Firm Level, *Research Policy 26*, 829-841

Wamsley, D.J., Epps, W.R. & Duncan, C.J. (1998), Migration to the New South Wales North Coast 1986-1991: lifestyle motivated counterurbanisation" *Geoforum 29,* 105-118.

White, S. (2005), Cooperation Costs, Governance Choice and Alliance Evolution, *Journal of Management Studies 42*, 1383-1412

Williamson, O.E. (1996), *The Mechanisms of Governance*, Oxford University Press, Oxford

Winter, S. (1987), Knowledge and Competence as Strategic Assets, in Teece, D. (1987) (Ed.), *The Competitive Challenge: Strategies for Industrial Innovation and Renewal*, Ballinger, Cambridge, MA, ?-?

World Bank (2010a), *World Development Indicators 2010*, (database). (Accessed January 2011)

World Bank (2010b), *Knowledge Assessment Methodology 2010*, (database). (Accessed January 2011)

Yoshino, M.Y. & U.S. Rangan (1995), *Strategic Alliances*, Harvard Business School Press, Boston, MA

Yu, C.-M.J. & M.-J. Tang (1992), International Joint Ventures: Theoretical Considerations, *Managerial and Decision Economics 13*, 331-342

Zanfei, A. (2000), Transnational Firms and the Changing Organization of Innovative Activities, *Cambridge Journal of Economics 24*, 515-542

Zitt, M., E. Bassecoulard & Y. Okubo (2000), Shadows of the past in International Cooperation: Collaboration Profiles of the Top Five Producers of Science, *Scientometrics 47*, 627-657

Zucker, I. & M. Darby (2006), Movement of Star Scientists and Engineers and High-Tech Firm Entry, *NBER Working Paper No.12172*, National Bureau of Economic Research, Cambridge, MA

13 Appendix

Table 13-1 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		

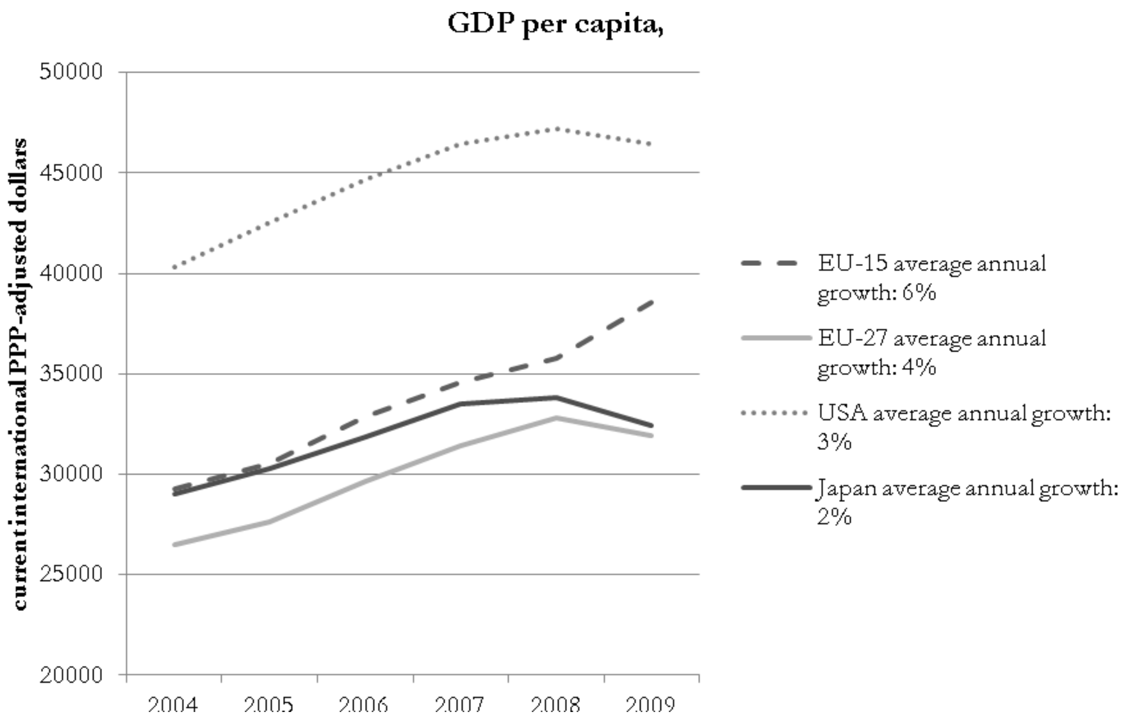

Figure 13-1 Development of GDP per capita (PPP adjusted current international dollars) in the triad region: 2004-2009

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

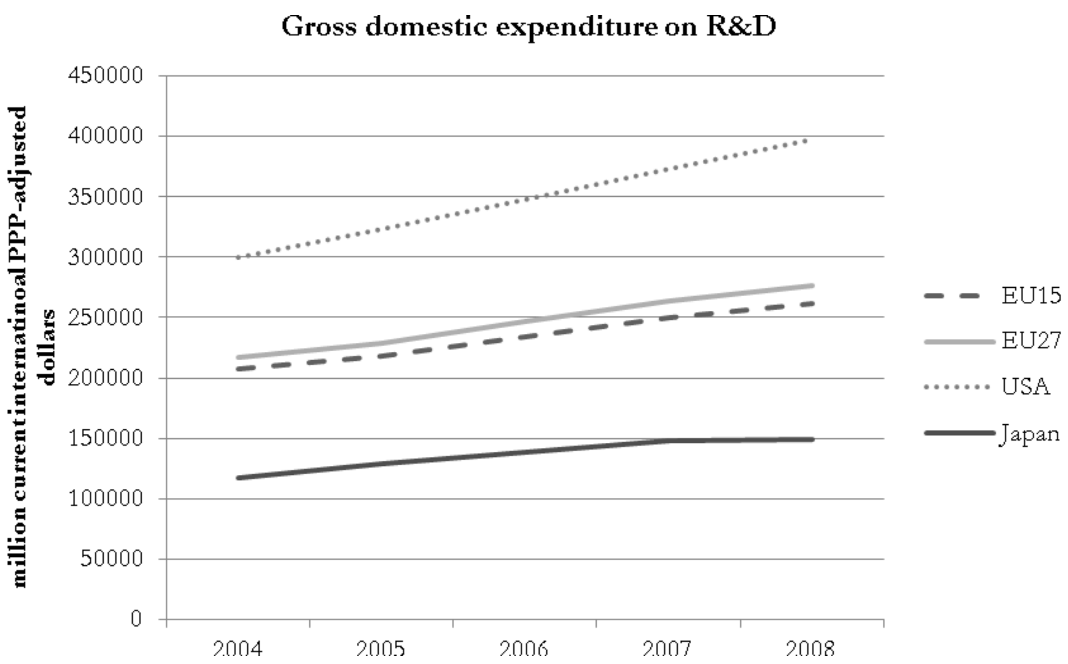

Figure 13-2 Development of gross domestic expenditure on R&D in the triad region: 2004-2008

Source: OECD (2010a)

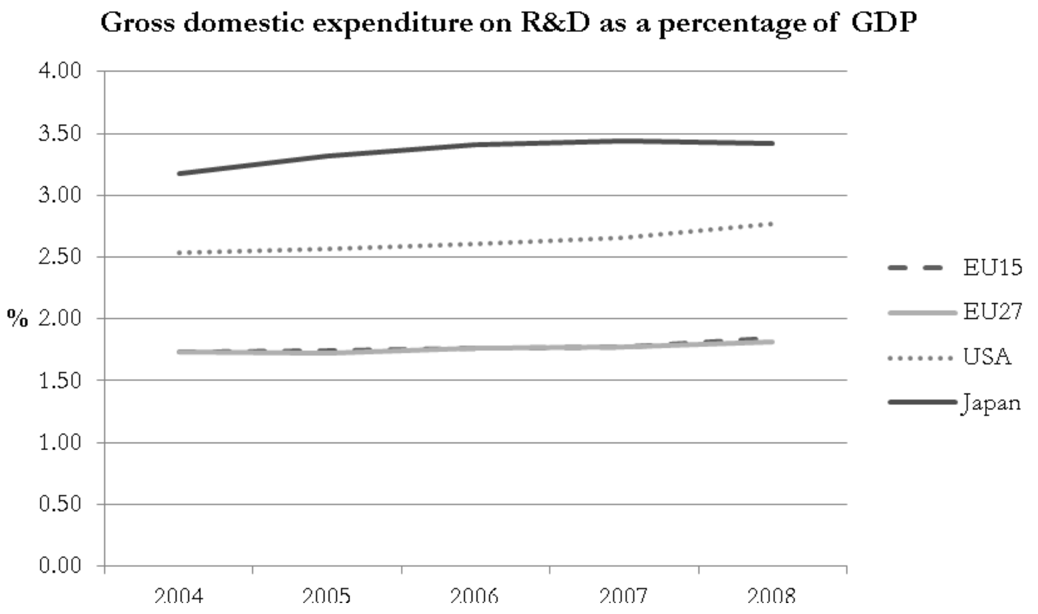

Figure 13-3 Development of GERD as a percentage of GDP
Source: OECD (2010a)

Table 13-2 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 13-3 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 13-4 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 13-5 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 13-6 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)