Centre of Excellence for Science and Innovation Studies

CESIS Electronic Working Paper Series

Paper No. 323

Intra-triad Knowledge Flows

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August, 2013

The Royal Institute of technology
Centre of Excellence for Science and Innovation Studies (CESIS)
http://www.cesis.se

Intra-triad Knowledge Flows[1]

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Abstract:
In this paper we point out a gap in the EU 2020 strategy to deliver growth that is *smart*, through more effective investments in education, research and innovation. The gap in the strategy is that in addition to investing in its own R&D, the EU must take advantage of knowledge created in the rest of the world. Even if EU is a major generator of new knowledge and will become even more so when the strategy is implemented, more new knowledge is (and will be) generated outside than inside the EU. New knowledge developed in other parts of the world are not flowing immediately, automatically and without costs to the relevant actors within the EU. It is critical for the EU to develop efficient channels for the imports of knowledge from other parts of the world. We analyze EU's capacity to absorb knowledge created in the other Triad nations (United States and Japan) through the following channels for international knowledge flows: academic knowledge channels, patents as a knowledge channel, technology trade, strategic R&D cooperation, trade networks, foreign direct investments, and high-skilled migration. The indicators show that there are certain types of knowledge channels that Europe must try to use much more extensively in order to become a leading knowledge economy.

Key words: knowledge flows, knowledge channels, knowledge absorption, EU2020.

JEL codes: O30, F69

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[1] **Summary of working paper 11, workpackage 2.3.3 'Knowledge Flows' of the ESPON Applied Research Project 2013/1/14, TIGER: Territorial Impact of Globalization for Europe and its Regions**

Preface

The current era of globalization started around four decades ago and manifested itself at almost the same time in a number of knowledge-intensive urban regions. It is based on a rapid expansion of the networks of motorways and air connections and on an increased capacity and speed of information processing and transmission. It is characterized by a rapid knowledge-intensification that manifests itself through strongly increased R&D investments and a rapid increase of the share of knowledge-handlers in the labor force in the Western countries but increasingly so also in newly industrialized countries. Thus, the generation of knowledge is widely dispersed and takes place in regions all over the world. Any country or region that wants to preserve or increase its international competitiveness must have enough efficient knowledge channels to be able to tap the latest relevant knowledge wherever it is generated. This new knowledge is used as an input in product development as well as knowledge generation in the region. In the current era of globalization the diffusion of knowledge has been facilitated by the decreasing costs for transportation of goods, people, and information, deregulation, liberalization, and lowered barriers for international trade and foreign direct investments. However, there are no guarantees that a more rapid diffusion will benefit all nations and regions, since the value of the knowledge for the receiver is dependent upon his/her absorptive capacity. Furthermore, since there are increasing returns in knowledge production there are strong forces stimulating the spatial agglomeration of knowledge production. The spatial extent of knowledge spillovers and knowledge flows more generally is a critical factor for the territorial development in Europe.

The general objective of this WP is to measure and understand the growing knowledge flows across the world and within Europe. More targeted objectives have nevertheless been redefined after coordination with the KIT project on innovation which mainly deals with the regional scale. We will focus here on the position of EU as a whole in the knowledge flows and through specific analyses not implemented in the KIT project. These include between countries' trade on high value goods products and meta-analysis on spillover effects in Europe.

Background and Trends in the European Knowledge Economy

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.[2] The purpose of this paper is to assess the capacity of the European Union to absorb new knowledge created in the other triad regions through different channels of knowledge flows. Furthermore, the position of Europe as a leading knowledge-based economy is analyzed in relation to the United States and Japan. The 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.

In line with earlier research, this paper focuses on the triad EU-USA-Japan to make it possible to make comparisons with previous research. In addition to this, the analysis is extended to include knowledge flows to the EU from other parts of the world such as Australia, Canada and the BRIC[3] countries for some of the indicators as well as knowledge flows from the triad to specific European countries. Although the triad regions' share of the worldwide exports of, for example R&D-intensive goods, declined from 82 percent in 1993 to 69 percent in 2004, the triad regions are still major players in the global economy (Gehrke, Krawczyk & Legler, 2007).

The background to our report has been the prominent concern for many years within the European Union (EU); how to strengthen its innovative capability since it is becoming 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.[4]

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

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

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

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

knowledge and technology, in particular from the two other triad regions. Thus, it was not surprising that the Lisbon strategy to a large extent failed.

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).[5] This is from one perspective very remarkable, since Europe is a major player in the generation of scientific and technological knowledge. 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.

The literature and the summarized data in the report indicate that:

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

Europe still lacks an integrated R&D and innovation strategy with proper instruments to achieve the goals laid out by the Lisbon strategy. Europe lacks cohesion and central decision-making regarding R&D and innovation comparable to what exists in the US and Japan. The individual member states still have a substantial autonomy when it comes to R&D, innovation and higher education. It has been far beyond the scope of this paper to try to design a new R&D and innovation strategy for Europe. Instead, we have focused on one critical factor for a successful such strategy and that is the capacity of Europe to rapidly acquire knowledge developed in the two other triad regions.

The importance of such a capacity is well understood as soon as we realise that the gross domestic R&D expenditure in current USD (PPP-adjusted) in the US and Japan taken together is about double of that in the EU, and that researchers in the US and Japan produce approximately the same number of scientific and technical articles as the researchers within the EU (Archibugi & Coco, 2005). The underlying reason why such a capacity is so important is the role of diversity or 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 are assumed to emerge from the combination of existing knowledge bits.

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

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. 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 share 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.

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.[6] 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 (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. Knowledge flows, intentional as well as unintentional, are generally assumed to enable technological progress, to increase competitiveness and to support long-term economic growth and development in many different and complex ways (Cassiman & Veuglers, 2002). New knowledge is created on basis of the existing knowledge stock (Griliches, 1990) and to a high extent by combining existing knowledge pieces, i.e. novelty by combination (Schumpeter, 1934). Knowledge – codified knowledge as well as tacit knowledge embodied in human beings – is the most important input in the knowledge production process. 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.

In order to improve the production of new knowledge in Europe, Europe needs to enhance its potential to absorb new knowledge created in the other triad regions through different channels of knowledge flows.

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[6] 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).

Data and Indicators

In this paper, we broaden the scope and concentrate on channels for international knowledge flows and we identify and analyze the following channels for international knowledge flows:

1. Academic channels

    Sources

    Academic co-authorship: NSF (2000); NSF (2010); UNESCO (2010)
    Citations of scientific articles: NSF (2010); World Bank (2010b)
    Mobility of academic researchers and scientists: OECD (2010b)
    Student exchange: OECD (2010b)

2. Patent

    Sources

    Patent citations: OECD REGPAT database (2011); OECD Citations database (2011); Eurostat (2010); Mancusi (2008)
    Science cited in patents: Verbeek, Debackere & Luwel (2003)
    Cross-border patenting: OECD (2010a)

3. Technology trade (including international consulting)

    Sources

    Royalty and licence fees: World Bank (2010a); World Bank (2010b)

4. Strategic R&D cooperation

    Sources

    Strategic R&D alliances: MERIT-CATI database (accessed 2011); NSF (2002); OECD (2010); NSF (2010)

5. Trade networks

    Sources

    Imports of goods: NSF (2010); EC (2007); Eurostat (2010)
    Imports of services: Havlik, P., R. Stollinger, O. Pindyuk & G. Hunya (2009)
    Unit value of imports: Comtrade (2010)

6. Foreign direct investments (FDIs)

    Sources

    Intra-MNF networks: Chaloff & Lemaître (2009)
    Inward FDI: OECD (2010d)
    Outward FDI: OECD (2010d)

7. International migration

    Sources

    Demand for skilled migration: Chaloff, & Lemaître (2009); OECD (2010c)
    Europe's position and capacity of attracting high-skilled migrants: Chaloff & Lemaître (2009); Japanese Statistics Bureau (2010); OECD (2010c); Eurostat (2010); US MPI (2010)

Summary of results

Academic knowledge flows

In terms of academic knowledge flows, cooperation at both the individual level and the organizational level offers a potential for knowledge exchange. Knowledge is transferred when researchers and scientists study the publications of other researchers and scientists. Such knowledge flows are normally documented by citations of earlier contributions in the field. In addition, the mobility of students and researchers provides knowledge flows to both the home country and the host country.

It can be observed in Table 1 that European scientists are deeply engaged in international co-authorships. This might be an effect of, among other things, EU's framework programs[7] 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.

Table 1 Scientific publications in international collaboration, 2008

Region	*Co-authored articles between EU-19 and the triad (% of world's internationally co-authored articles)*		*Number of internationally co-authored articles per million people*	*International researchers enrolled in advanced research programs as a % of all researchers*	*International students enrolled in tertiary education as a % of all students*	*Share of cited papers in the Top 1 percentile[B] (%)*
	1998	**2008**	**2008**	**2008**	**2008**	**2008**
EU-27	-	-	429[A]	14.9[C]	5.9[C]	29.6
USA	28,714 (28.0)	53,406 (29.0)	275	28.1	3.4	51.6
Japan	4,622 (4.5)	8,243 (4.5)	142	16.2	2.9	4.5
World	102,438[A]	184,394[A]	-	-	-	-

Source: UNESCO (2010); NSF (2010); OECD (2010)
[A] Includes articles produced in collaboration with other EU countries.
[B] More than 21 citations.
[C] EU-19 average, includes students moving within EU.

[7] 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

Furthermore, 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. 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).

As Table 2 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). Evidently, Japanese foreign students are more common in the US than in Europe.

In 2008, more than a third of the world's foreign students study in Europe. 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).

Table 2 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 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. 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.

A few interesting observations can be made regarding academic knowledge flows from Australia, Canada and the BRIC countries to the EU. In 2008, EU-19 co-authored the largest number of articles with Canada followed by Russia and Australia (and then Japan). These countries as well as Brazil and India also co-author above 60 percent out of all their internationally co-authored articles with EU-19. China only co-authors 39 percent of its internationally produced articles with European researchers. 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.

Table 5.13 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. 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 (not in table). Chinese foreign students contribute to the largest share (8.5 percent) of all foreign students in the EU-19.

Table 3 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.

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. France, Germany, Italy, the Netherlands, Spain and the UK produce most of the internationally co-authored articles in Europe in absolute figures. 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 academic community in Europe is a valuable asset for acquisition of knowledge and expertise beyond the borders of the countries (Archibugi & Coco, 2005). Academic knowledge flows from the triad to specific European countries, differ substantially between the member states. The Scandinavian countries, including Finland, as well as the Netherlands, exploit co-authorships as a knowledge source to a much larger extent than the other nations as Table 4 shows. 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.

Table 4 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)

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.

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

Table 5 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.

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 in terms of patent citations. The opposite pattern is occurring in both the US and Japan since they cite their own patents increasingly more.

Table 5 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 REGPAT and OECD Citations Database.
EU: EU-25 excluding Cyprus, Lithuania and Luxembourg.

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.

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). 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).

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? 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. The statistics also show that the knowledge flows differ between different knowledge fields.

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). European inventors co-patent with inventors from the US to a larger extent with reference to USPTO patent grants than US inventors co-patent with inventors from the EU. The reverse is true with reference to patent applications to the EPO, although the gap is much smaller.

Table 6 Geographic distribution of citation flows to published literature (percent) and of international cooperation in patents present in triad USPTO patents and EPO patents (percent of total patents)

Triad relation	*Citation flows to published literature, 1992-1996*		*International cooperation in patents, 2007*	
	USPTO patents	EPO patents	USPTO patents (grants)	EPO patents (applications)
EU-15 to US	30	23	21.1	4.5
US to EU-15	36	45	2.2	8.4
EU-15 to Japan	9	6	1.0	0.5
Japan to EU-15	33	38	0.6	1.4

Source: Verbeek, Debackere & Luwel (2003); OECD (2010)

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. 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. In terms of knowledge flows, it is positive that European inventors have taken advantage of the development of the research performed in China.

Table 7 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)

Statistics of citations in patents applied at the EPO by selected European countries to Japanese, US, and EU patent publications demonstrates that there has been an increase in knowledge transfers 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. It seems that Europe is not as Europeanized when it comes to exploiting knowledge from abroad through patent citations as it used to be. 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.

The European countries (except Sweden) 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 an Europeanization of cooperation in patents, which is negative as regards to the ability of European countries to acquire knowledge from the other triads.

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. 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.

The interpretation of the technology balance of payments of various regions and countries is somewhat ambiguous. 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.

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 can be observed between 2002 and 2008 (World Bank, 2010a). EU imports much more than the USA and Japan together. Figure 7 shows that 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.

Table 8 Royalty and License Fees 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. Unfortunately, we cannot say anything about the origin and the destination of the technology flows, although it is rather safe to assume that most of the imported technology trade to Europe originates from the triad regions.

Knowledge flows through 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[8]. 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[9]: 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.

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). Recent data on strategic R&D alliances confirms the upward trend towards more international cooperation when measured by the number of total new alliances in the world. Table 9 shows

[8] 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).

[9] 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.

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 one 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 extent 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 9 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
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. 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. 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. 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. Since both the US and Japan spend a considerable larger share of their GDP on R&D investment, Europe should continue to be open to R&D cooperation with third countries.

Table 10 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. 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 10 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: MERIT-CATI Database

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 11. However, the number of new alliances formed between the triad and these countries has decreased between 1993-1999 and 2000-2006. Instead Denmark seems to be cooperating more intensively with firms from the US. Also Belgium, Finland and Italy have increased their cooperation with US firms.

Table 11 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: MERIT-CATI Database

Knowledge flows via trade networks

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. 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[10], which can contribute to faster technological progress and higher rates of productivity growth (Helpman, 1997).

The imports per capita of high-tech products in Europe are lower than in Japan and substantially lower than in the US (NSF, 2010). 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.

Unit values can be used in order to measure the quality of imports of goods. 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). 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 case.

The unit value of imported high-technology products is much higher for the US than for the other two triad regions. This can either imply that the US imports more high-quality, sophisticated high-technological products than the other two regions, or that the US pays more for identical products due to successful marketing campaigns in the US. It seems that EU fails to import the most advanced high-tech products, i.e. the high-tech products with the highest knowledge content from the world. However, the EU imports high-technology products with a much higher unit value from the US than from Japan as well as from the world. Does this imply 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?

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

Table 12 Unit Values of Imports of High-technology Products during the Last Decade (2000-2009)

Classification according to OECD	Unit value
EU-27 –World	**22.8**
USA – World	**36.5**
Japan - World	**25.4**
EU-27 - USA	**41.5**
EU-27 – Japan	**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 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 (own compilation of UN Comtrade statistics, 2010). Canada remains the largest provider of high-technology goods out of the six countries. India surpassed both Australia and China during the last decade 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.

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 13 Unit Values of Imports to EU-27 of High-technology Products from the Australia, Canada and BRIC countries during the last decade (2000-2009)

Classification according to OECD	Australia	Canada	Brazil	Russia	India	China*
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

Knowledge flows via foreign direct investments

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).

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).

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?

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. 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.

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.

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. Since 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 appears to take advantages of the high-level R&D capabilities in the US to a larger extent than in Japan.

Furthering the analysis to knowledge flows via FDIs to Europe from Australia, Canada and the BRIC countries, one can see in Table 14 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 is from China and India. EU-19 performs FDI in Australia, Canada and the BRIC countries to a larger degree then it receives in inward investments from these countries.

Table 14 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)

Among the European countries, 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.

Knowledge flows via international migration

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.

Demographic changes such as the current aging population in Europe, the United States and Japan underlines the need for migration of highly skilled personnel. The dependency ratio of Japan has been increasing since 2000 and is anticipated to accelerate in the next decade due to a shrinking working-age population. The result of this pattern is much higher educational and social expenditures per person in the working-age population. The average EU-15 country is anticipated to face similar problems as Japan in the long term. Also the United States is projected to experience an increasing dependency ratio as their population of not working-age continues 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.

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. When the growing need for human resource in science and technology (HRST) cannot be met by domestic supplies, the ability to attract HRST from abroad becomes a key factor for the region's future competitiveness. A highly skilled and innovative human resource in science and technology, which initiate R&D advances and knowledge-based product development, will be a decisive factor in order for Europe to remain a competitive knowledge-based economy (Delanghe, Muldur, Soete, 2009). With the internationalization of 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. 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.

There has been a substantial increase of immigrants in total to the EU between 1995 and 2006, although the share of highly skilled immigrants as opposed to all immigrants has stayed roughly the same (Chaloff & Lemaître, 2009). This signifies that low skilled immigration has been as common, or even more common, than high skilled migration. 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 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. According to Table 15, 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. Europe does not take fully advantage of highly skilled migrants as a knowledge source beyond the borders of the union.

Table 15 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)

It becomes evident from Table 16 that the triad is not the greatest 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 16 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)

In Table 17, the UK is the European country that receives the largest number of immigrants with tertiary education from the world (excluding Europe) in 2000, then 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.

Table 17 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)

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.

Conclusion

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. The EU receives large amounts of FDI and technology licenses from the triad, a fact that enables the EU to absorb new knowledge through these channels. Although still behind the other triad regions, Europe is rapidly increasing its imports of high-technology goods, however, in comparison to imports to the US these are not of the most advanced quality. Imports of high-technology goods from the US, Australia, Canada and China are the most advanced, whereas the massive imports of high-technology goods from India especially, are of much lower quality.

Europe seems to be behind in attracting knowledge flows via academic channels in comparison to the US. Similarly, 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. This might be due to the large amount of high-skilled immigrants arriving to Europe from Australia, Canada and the BRIC countries. These countries also provide a relatively larger amount of foreign students in Europe than what is provided by both the US and Japan. In contrast to the academic- and migration patterns, the European business community shows a high propensity to collaborate with the other triad regions as well as with the rest of the world through strategic R&D projects and the use of international prior knowledge through patent citations.

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 when spillovers due to geographical proximity is not possible. The extent to which economic agents are invited to participate in collaborative ventures will ultimately depend on the attractiveness of the knowledge base of the region. After careful analysis of EU's knowledge base and potential to absorb new knowledge from the rest of the world we have been able to identify several suggestions for future EU policies.

1. Open up EU-financed R&D projects so that they also can finance the participation of researchers from non-EU countries
2. Develop generous support systems for researchers and PhD students from EU countries to be guest researchers in non-EU countries.
3. Develop generous support systems for researchers and PhD students from non-EU countries to be guest researchers in EU countries.
4. Competitive salaries and working condition (labs, data, resources to hire assistants, researchers, PhD students)
5. It is important for the EU to develop a number of elite universities that are competitive with the best in the rest of the world
6. Create clear, simple and general rules for experts from non-EU countries to work in EU countries.
7. Make it easier for highly educated non-EU citizens to migrate to EU countries.
8. Improve the training in particular in English, Chinese and Japanese within EU to improve international interaction and in particular the imports of new knowledge, new ideas, new technology to the EU.
9. If the EU seeks to encourage knowledge absorption through foreign firm expansion, it should examine potential barriers to FDI. Policies that are highly correlated with high

inward FDI flows are policies aiming to improve financial and infrastructure services, including telecommunication, power and transport. These policies should be implemented in some of the Union members. Furthermore, since a firm's capacity to absorb knowledge and benefit from FDI depends on the skills and training of the workforce, the EU should make sure that the investments in worker-training is adequate.

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 on 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.