EUROPEAN COMMISSION

Brussels, 8.6.2011
SEC(2011) 739 final

Part 7/41

COMMISSION STAFF WORKING PAPER

Innovation Union Competitiveness report 2011

5. Mobility of researchers and human resources

Highlights

An effective European Research Area will contribute to an internal market for knowledge in Europe, where researchers, science and technologies can circulate freely, thereby optimising knowledge spillovers. To this end, it is not sufficient to enhance the system - research performers and users also need to be stimulated to take up the opportunities offered to them and use the changing structures in view of collaborative knowledge production. An enhanced mobility of students and researchers is crucial in this respect.

The Erasmus and Marie Curie schemes have stimulated the development of mobility within Europe. However, the mobility of researchers across Europe is still limited. Around 7% of all doctoral candidates in the EU are studying in another EU country. 76% are EU nationals studying in their own country while the remaining 17% are citizens from outside the EU.

Moreover, the mobility of researchers is not equally spread over Europe. If flows of students under Erasmus are relatively balanced, this is not so when it comes to researchers. The most important net receiver of doctoral candidates in both absolute and relative terms is the United Kingdom, with a net gain of almost 15 000 doctoral candidates of EU nationality. The other Members States with a net gain are France, Spain, Austria, the Czech Republic, Sweden, Finland and Belgium. On the other end, Italy (3 600), Portugal (2 500) and Romania (1 700) register the largest net-losses in absolute terms in intra-EU exchanges of doctoral candidates.

Europe is opening up in terms of international mobility of researchers. The overall pattern is an inflow of researchers from Asia and an outflow of researchers to the United States. Asia, the Middle East and Oceania are the largest ‘senders’ of doctoral candidates to the EU with 5.8% of doctoral candidates in the EU coming from this broad geographical region.

Among countries outside Europe, China was the most important sender of doctoral candidates to the EU with around 6 500 doctoral candidates in 2007. Three large EU Member States stand out as recipient of doctoral candidates: the UK (with more than 35% of its students coming from outside the EU), France (31%) and Spain (nearly 17%)

In the other direction, the number of doctoral graduates in Science and Engineering in the United States with European citizenship increased from around 1 300 in 1996 to around 1 800 in 2007 (an increase of approximately 38.6%). Among the EU Member States, Germany, Italy, France, Romania, Spain, the United Kingdom, Greece and Bulgaria belong to the top 30 countries with doctorates awarded in the United States. However, the share of overall European doctoral graduates receiving their doctoral degree in the United States remains low (2-3%).

5.1. Are students and doctoral candidates studying in European countries other than their own?

Participation in student-exchange programmes is a major predictor of the future mobility pattern of researchers: according to the MORE survey, 32 % of mobile researchers had previously taken part in a student exchange programme like Erasmus, compared to only 15 % of non-mobile researchers[147]. Put differently — the experience of a stay abroad as a student significantly increases the likelihood of becoming mobile later as a researcher. The Erasmus programme prepares the ground for the mobility dimension of the ERA.

The mobility of Erasmus Programme students in humanities and social sciences tends to have a north–south movement, while students in science, technology and math have a tendency of south–north movement

From the perspective of the European Research Area, the mobility pattern of students is interesting for two reasons: firstly one can use the mobility pattern of students as an indictor of the relative attractiveness of universities. Secondly, the mobility pattern giver a very general indication of the geographical and institutional preferences of future researchers within Europe.

Figure II.5.1.and figure II.5.2. show that there is a tendency of north–south movement of students in the social sciences and humanities but a tendency of south–north movements in the MTS subjects. The previous chapter on universities and public research-performing organisations presented the location of major research-intensive universities in Europe.[148] The Erasmus student population cannot be seen as a representative sample of all student mobility in Europe. Nevertheless, making the cross-analysis with the Erasmus student mobility pattern, there seems to be an overall correlation between the location of Europe's top research universities and the mobility of Erasmus students in maths, technology and sciences.[149]

[147] See the Intra-Mobility study of MORE.
[148] See Part II, chapter 1.1.3.
[149] However, this overall observation is still to be confirmed. The data on ERASMUS student mobility are at country level and not at institutional level, so a strict correlation can not be established.

Figure II.5.1. Erasmus student mobility in humanities and social sciences, 2007-2008

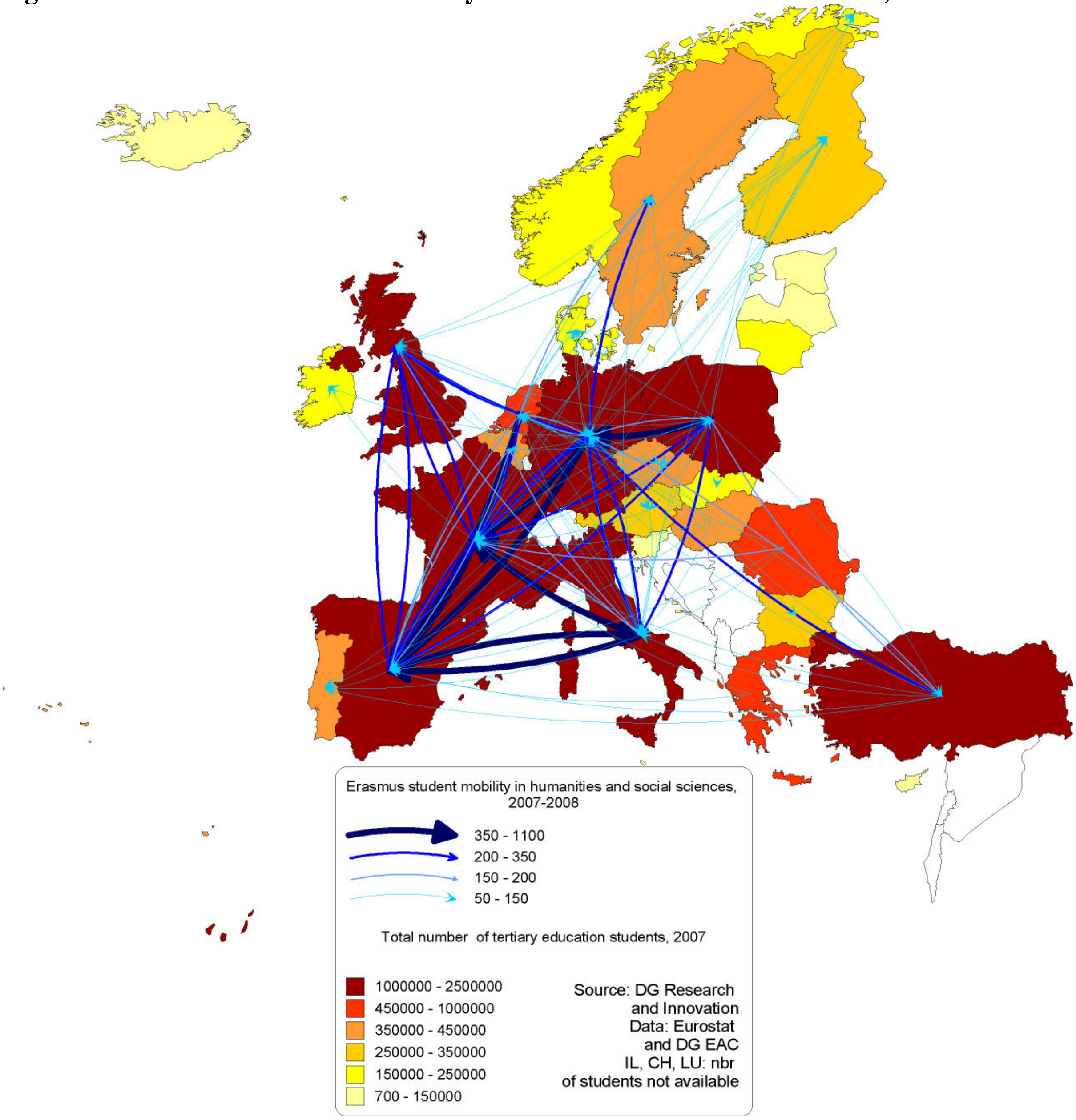
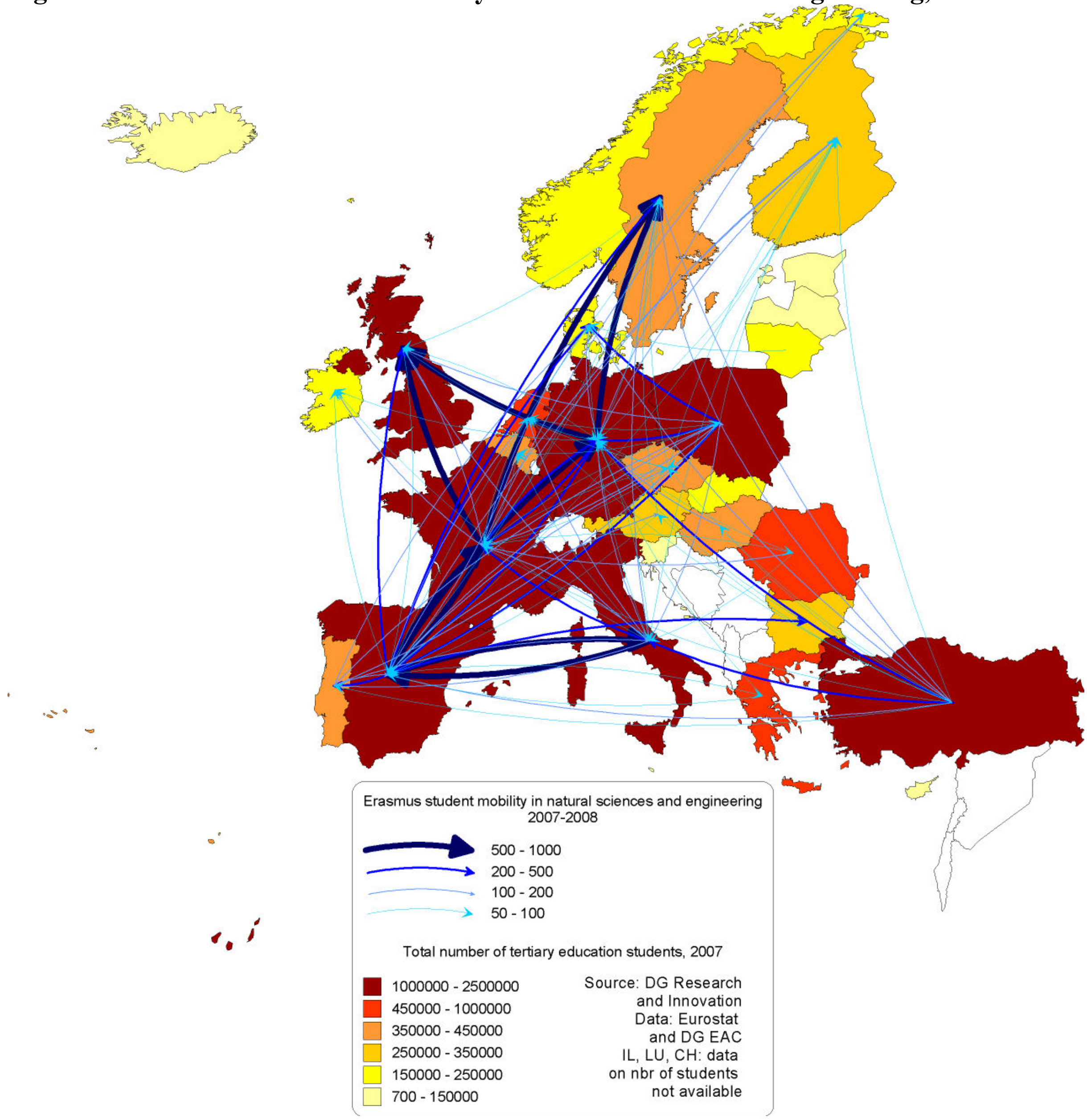


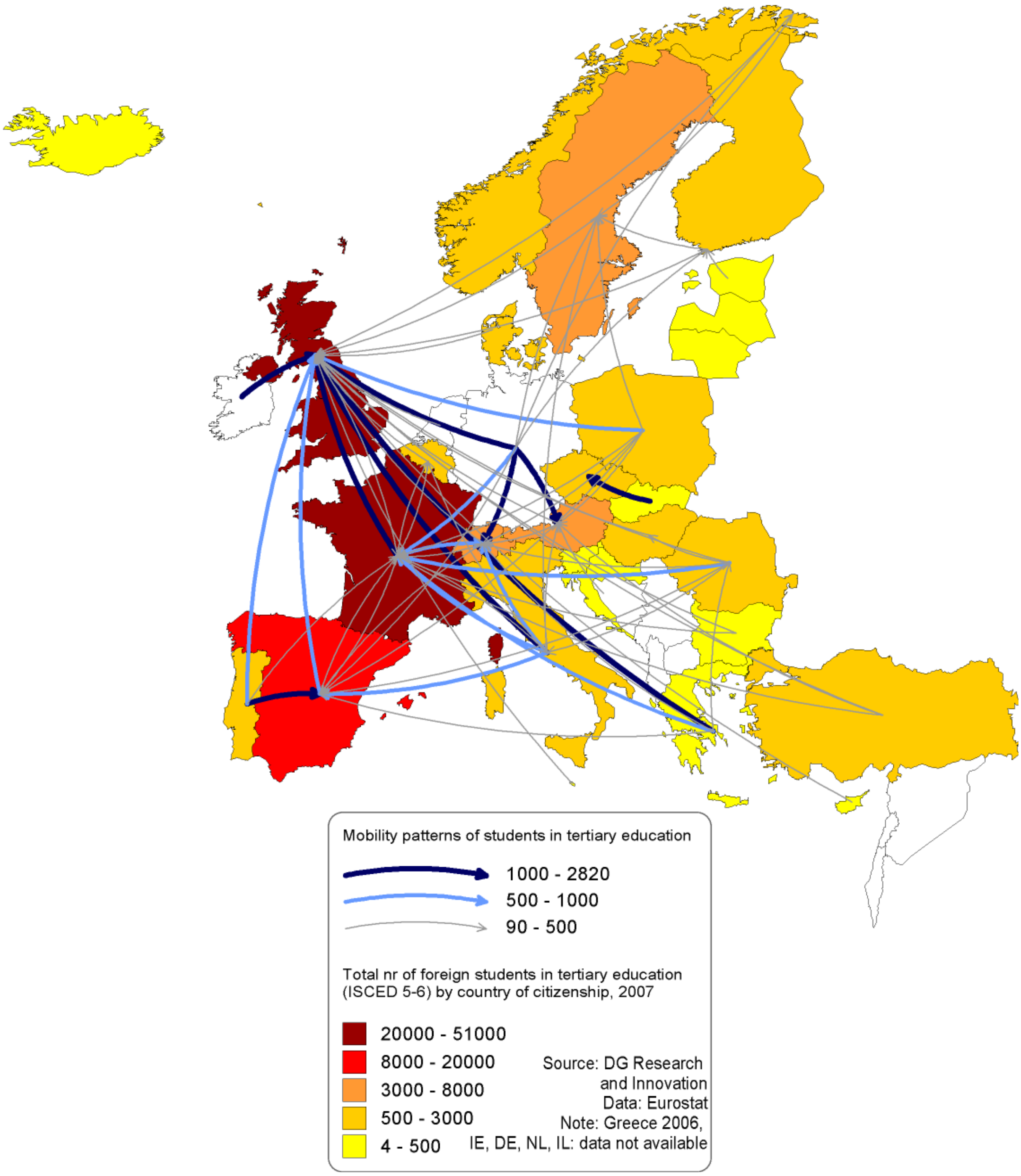
Figure II.5.2. Erasmus student mobility in natural sciences and engineering, 2007-2008



Student mobility financed by the Erasmus Programme presents a more balanced mobility flow than overall student mobility

By design, the flow of students within the Erasmus Programme is more or less balanced, as it was originally set up as a student-exchange programme between universities. This becomes clearer when comparing to the total flow of students in tertiary education across Europe, as presented in figure II.5.3. Overall, the United Kingdom is clearly the major attractor within Europe, in particular German, Italian and Greek students are moving to the United Kingdom. Spain attracts a larger number of Portuguese students, Switzerland and Austria observe a massive influx of students from Germany, and the Czech Republic hosts many Slovakian students. In 2008, the Eastern European countries were less integrated in the intra-European flows of students in absolute numbers. Given the importance of experiences of mobility as a student for mobility later on in life, this lower integration may hamper the extent to which future researchers of the EU-12 Member States will participate in the opportunities offered by the European Research Area.

Figure II.5.3. Mobility of students in tertiary education

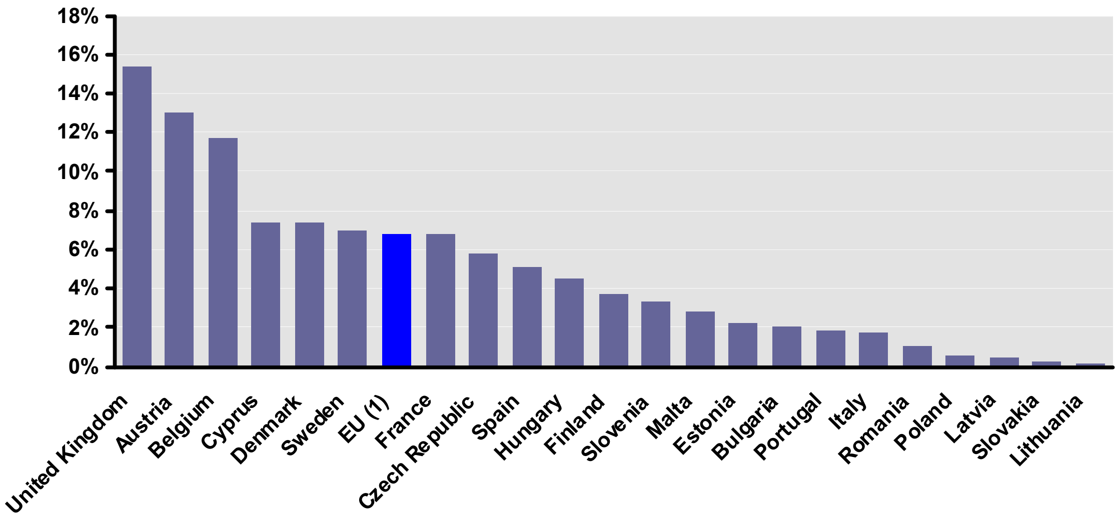


Notes: (1) Mobility patterns are based on the country of citizenship of foreign students in countries; (2) Data for doctoral candidates by citizenship are not available for Germany, Ireland, Greece, Luxembourg and the Netherlands.

The United Kingdom, Austria and Belgium host the highest percentage of doctoral candidates from other EU Member States. Lithuania, Slovakia and Latvia have the lowest share of doctoral candidates from EU Member States

The quality of education and research at the host institution is decisive for the future career and job prospects of a doctoral candidate. Doctoral candidates will try to get the best quality working conditions and move, if necessary, to another Member State for their research. Hence, the patterns of movements of young researchers are therefore indicative about the relative quality of working conditions in research within the European Research Area, although language and cultural factors also influence the mobility patterns. Figure II.5.4. shows the share of doctoral candidates in the EU Member States with citizenship from another Member State. Of the 22 countries reporting data, the United Kingdom receives the larger number of doctoral candidates from other Member States as a share of the total number of doctoral candidates in the country: 15% of doctoral candidates in the United Kingdom are citizens of another Member State. Austria and Belgium follow with 13% and 12% respectively. The EU-27 average is 6%. The countries with the lowest inflows of doctoral candidates from other Member States are primarily the new Member States (Lithuania, Slovakia, Latvia, Poland, Romania, Bulgaria and Estonia) and some of the Southern European countries (Italy, Portugal).

Figure II.5.4 Doctoral candidates (ISCED 6) with the citizenship of another EU Member State as % of total doctoral candidates in the reporting Member State, 2007



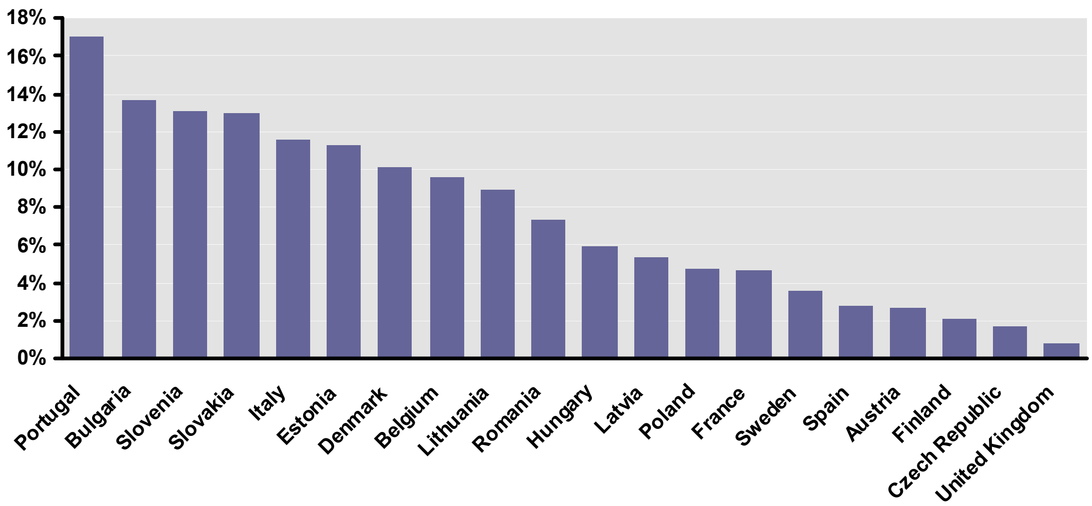
Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat, MORE Study
Note: (1) EU does not include DE, IE, EL, LU, NL - data for these Member States are not available.

In relative terms Portugal, Bulgaria and Slovenia are the biggest exporters of doctoral candidates to other EU Member States, while the United Kingdom exports the lowest share of doctoral candidates

Figure II.5.5. provides a picture of the intra-EU outflows of doctoral researchers in relative terms, but for a different set of countries. The figure shows the percentage of doctoral candidates of each EU nationality in another EU Member State compared with the total number of doctoral candidates in the country with the reporting country's nationality.

Portugal presents the highest share of doctoral candidates in another EU Member State as percentage of doctoral candidates with Portuguese citizenship studying/working in Portugal (17%). Bulgaria follows with 14% and Slovenia and Slovakia with 13% for each. As mentioned above, although the United Kingdom tops the list of countries with the highest share of doctoral candidates from another Member State, Figure II.5.5. shows that relatively low shares of doctoral candidates with UK citizenship study/work in other EU Member States. The differences between these two indicators may be explained by many factors, e.g. the quality of the education system in the United Kingdom, or the perceptions of foreign students/researchers about the quality of this system. It may also point to the relatively lower language barriers for students/researchers coming into the United Kingdom.

Figure II.5.5 EU doctoral candidates (ISCED 6) in EU Member States of which they are not citizens as % of total doctoral candidates of their citizenship in their home Member State, 2007



Source: DG Research and Innovation
Data: Eurostat, MORE Study

Innovation Union Competitiveness Report 2011

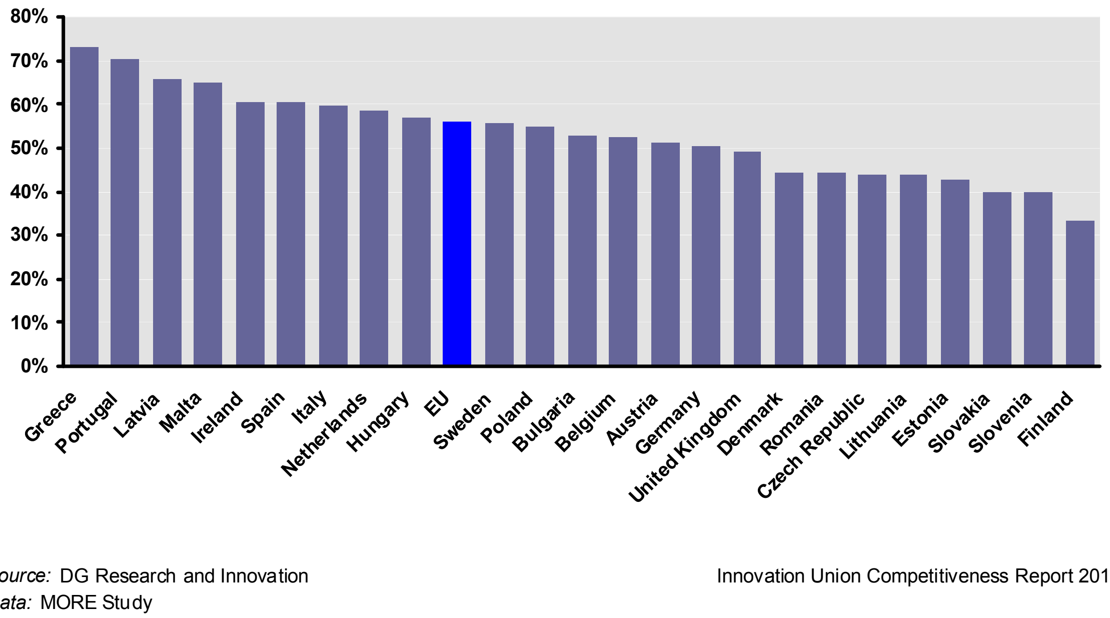
5.2. Are researchers moving about Europe as part of their career?

The MORE study on mobility patterns and career paths of EU researchers[150], carried out on behalf of the Commission in 2009–2010, was the first attempt at a comprehensive, pan-European study focussing on researchers international mobility. The study included surveys of researchers in Higher Education Institutions, Public Research-performing Organisations and industry as well as a pilot survey of EU–US researcher mobility.

Researchers in the Southern European countries are more likely to have been internationally mobile at least once in their career

MORE revealed that EU-wide, 56% of researchers have been internationally mobile[151] at least once in their careers. Of these researchers, more than half (that is 29% of all EU27 HEI researchers) have experienced international mobility during the last three years. Figure II.5.6. shows a clear north–south split with researchers in Greece, Portugal, Spain and Italy reporting the highest levels of mobility. Among those researchers who had been internationally mobile, 80% believed that their mobility experience had had a positive impact upon their career. Moreover, 64% had 'actively considered' further mobility in the future. The survey also looked at the extent to which researchers are currently engaged in 'formal collaboration' with researchers from other countries. Although no cause and effect was identified, it is interesting to note that 65% of the researchers who had been internationally mobile reported ongoing collaboration with colleagues in other countries, compared with 54% of non-mobile researchers.

Figure II.5.6 Share of researchers in the higher education sector with international mobility experience (of at least three months duration), 2009



Source: DG Research and Innovation
Data: MORE Study

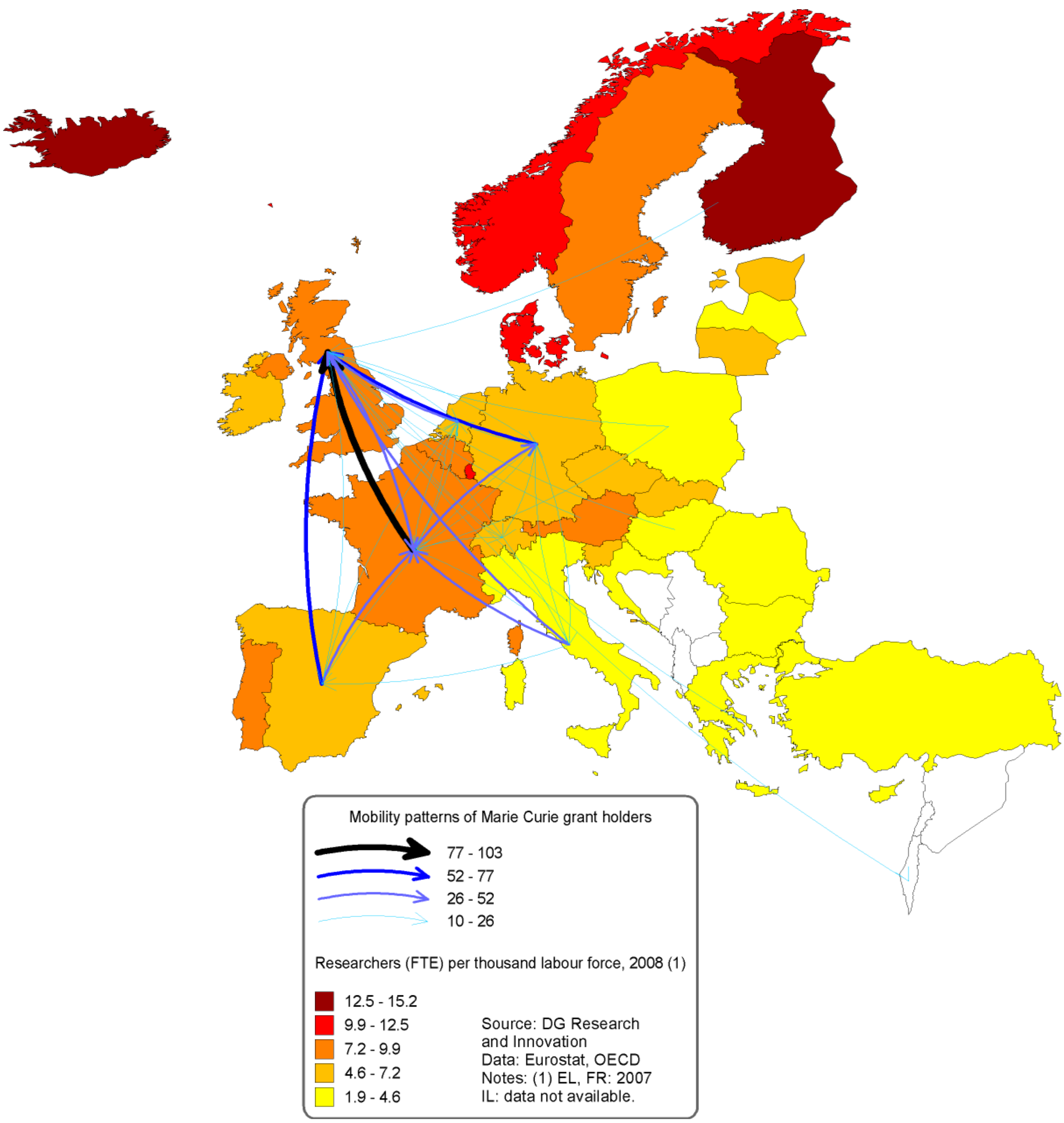
Innovation Union Competitiveness Report 2011

[150] http://ec.europa.eu/euraxess/index.cfm/general/researchPolicies.
[151] International mobility was defined as having worked in a country other than the country in which the researcher attained his/her highest educational degree. It includes research visits of three months or more.

The United Kingdom is the main attractor of Marie Curie Fellows

Applications for Marie Curie Fellowships are evaluated according to the quality of the applicant and of his/her research project (50 %) and the quality of the host institution (50 %). Hence the movement of Marie Curie Fellows is an indicator of the relative attractiveness of research conditions, including the possibility of learning languages commonly used in sciences and engineering. As Figure II.5.7. clearly indicates, the United Kingdom is the main attractor of Marie Curie Fellowships.

Figure II.5.7. Mobility patterns of Marie Curie grant holders



The share of the participation of women in the framework programme has been quite constant during the last decade

The framework programme provides interesting insights into the dynamics of women's participation in research. Taking the available data on percentage of women's participation in actions supported by the 'People' Specific Programme of the Seventh Research Framework Programme, we see by and large a constant rate of participation, ranging from 38 % in 2003 to 39 % in 2009.[152]

The MORE survey of researchers in higher education institutions[153] in 2009 showed that male researchers (60 %) are more likely than female researchers (51 %) to have been internationally mobile. This holds true across all broad scientific domains, but the difference was most marked in the social sciences and humanities (64 % versus just over 50 %). However, data for international mobility over the last three years suggested that the gap between the sexes had been reduced (31% of males against 28% of females).

5.3. Is there a growing mobility of researchers between Europe and the rest of the world?

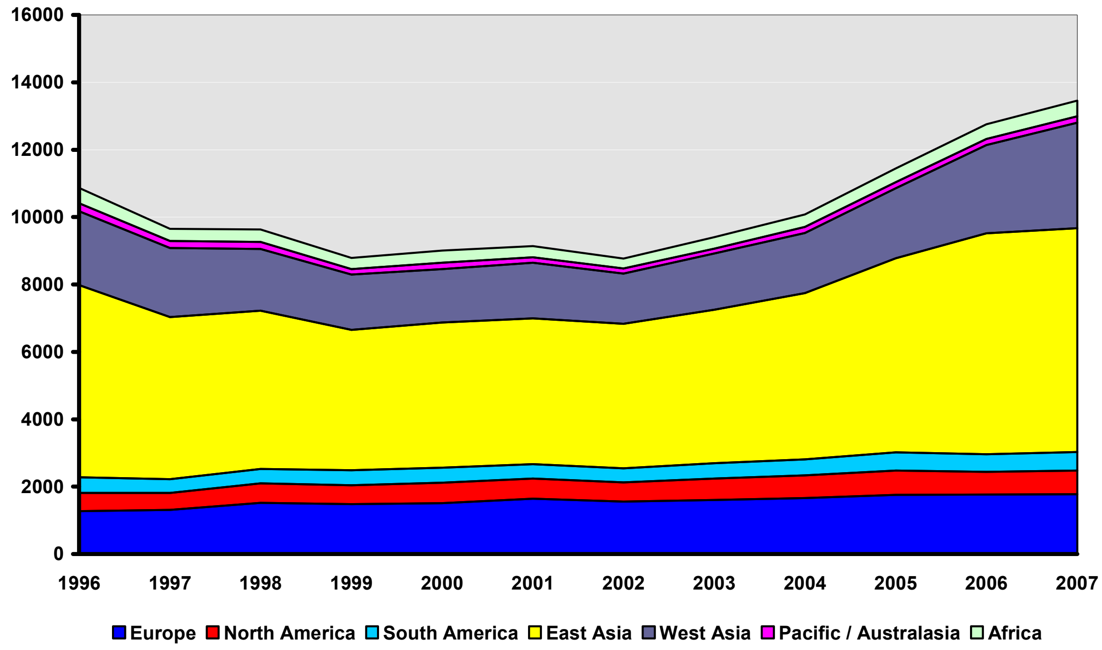
This section analyses existing data on the EU's world attractiveness for researchers. Unfortunately, data are still not sufficient to draw any firm conclusions. The section starts with the number of doctoral graduates of European origin in the United States. The United States is the benchmark as the major pool of international talent used to study the relative attractiveness of the European system for researchers. The section continues with data on specific framework conditions, such as salary levels and research conditions visible in data on potential return rates. The last part of the section reviews incoming mobility to Europe from other parts of the world.

The number of European citizens receiving their doctoral degree in the United States increased by almost 40 % between 1996 and 2007 but they still represent a relatively low share (2–3 %) of total doctoral degrees awarded in Europe

Figure II.5.8. presents the number of non-US doctoral graduates by main region of origin in science and engineering over time. The number of doctoral graduates in the United States with European citizenship has increased from about 1 300 in 1996 to about 1 800 in 2007, an increase of 38.5 %. The number of doctoral graduates in the United States from East Asia is the highest, and equals approximately 6 600 doctorates in 2007.

[152] For a more detailed gender analysis in research and innovation, including the EU research Framework Programme, see Part II, chapter 3.
[153] http://ec.europa.eu/euraxess/pdf/research_policies/MORE_HEI_report_final_version.pdf.

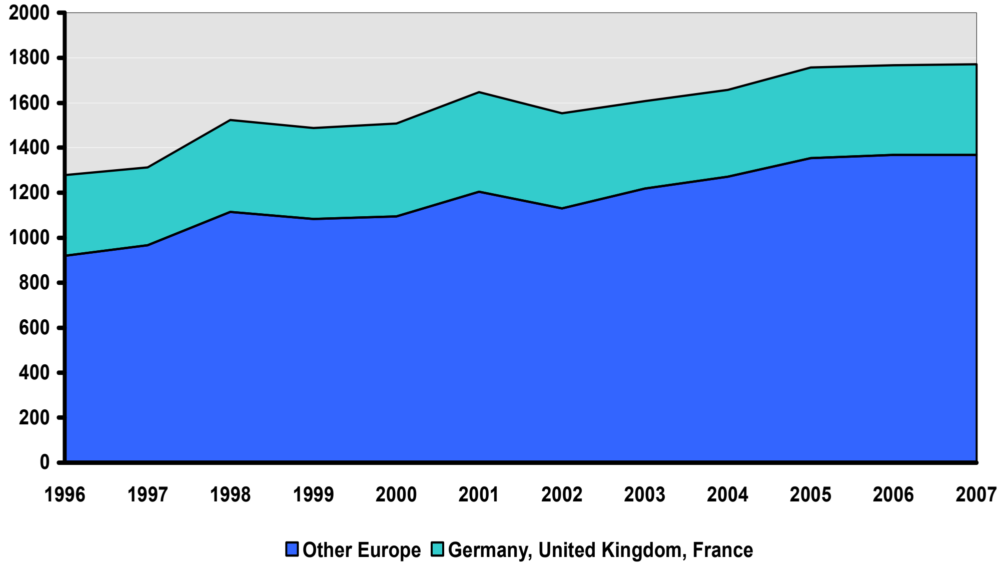
Figure II.5.8 Non-US citizens doctoral graduates in science and engineering in the United States by main region of origin, 1996-2007



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: MORE Study, www.census.gov/compendia/statab/2010/tables/10s0787.xls

Figure II.5.9. shows the number of doctoral graduates in science and engineering in the United States holding citizenship of European countries over time, separating Germany, the United Kingdom and France from the rest of Europe. The number of doctoral graduates in the United States originating from Germany, the United Kingdom and France represents 23 % of all doctorate graduates in the United States from Europe. The number of doctoral graduates from Germany, United Kingdom and France has increased by 12 % from 359 in 1996 to 403 in 2007. For the rest of Europe, the number of doctoral graduates in the United States has increased more strongly from about 919 in 1996 to 1 368 in 2007 (by 49 %).

Figure II.5.9 European citizen doctoral graduates in science and engineering in the United States, 1996-2007

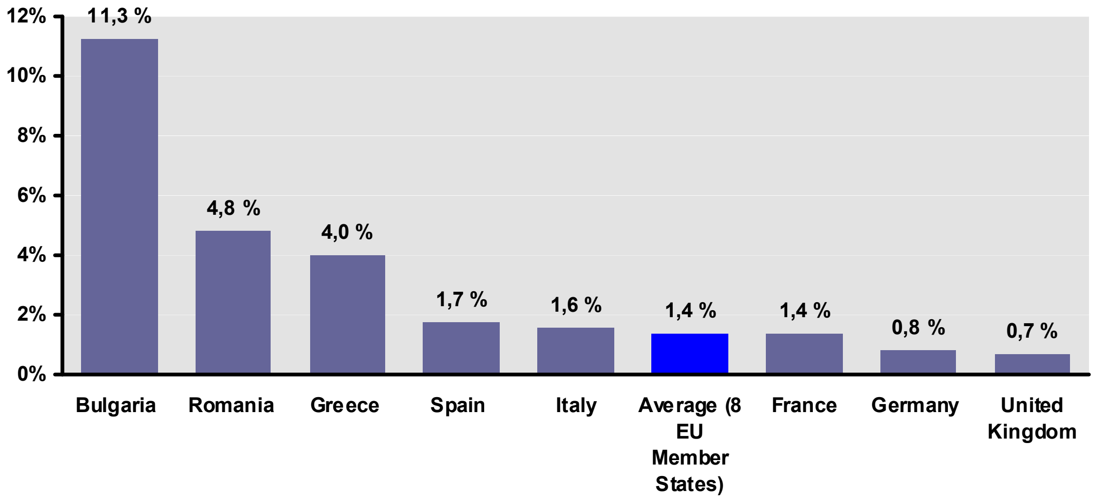


Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: MORE Study, www.census.gov/compendia/statab/2010/tables/10s0787.xls

Bulgaria, Romania and Greece are the Member States with the highest share of doctoral students having finalised their doctoral degree in the United States

Figure II.5.10. presents the ratio of non-US citizens earning doctorates in the United States to the number of doctoral degrees earned at home for the eight EU Member States on the top-thirty list (see also the top-forty list in Table 13). The average for these 8 EU countries is 1.4%: on average 1.4 doctorates are awarded to citizens of these 8 countries from US institutions for every 100 doctorates awarded at home. Bulgaria appears to be an outlier with a ratio of 11.3%.

Figure II.5.10 Number of EU citizens earning doctorates at universities and colleges in the United States (1) as % of total doctoral degrees awarded at home, 2007



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat, NSF/NIH/USED/USDA/NEH/NASA, 2008 Survey of Earned Doctorates
Note : (1) Only the eight Member States on the top 40 list of countries are included on the graph.

US academic research institutions can offer significantly higher remuneration schemes for researchers in specific competitive fields than European academic research institutions

Researchers, particularly in the fields of natural sciences and engineering, encounter international competition for their talent and skills. An outstanding researcher can be choosy about where he/she wants to work. To estimate the relative attractiveness of European non-private research institution one can use average remunerations as a proper proxy. A survey among researchers in natural sciences in Europe and the United States was made to 6254 respondents mostly from established research institutions in the north and west of Europe with only few respondents from the new Member States (where remuneration levels are significantly lower than in the other Member States). Interestingly, remuneration levels are similar at the level of postdoctoral fellows. When it comes to an advanced academic career, salary levels are significantly higher in the United States than in Europe. The average values hide the way that remuneration can reach extreme levels in the United States when the competition concerns outstanding talents. In contrast, remuneration schemes in Europe tend to be more homogeneous, making it difficult to come up with attractive offers for outstanding talents.[154]

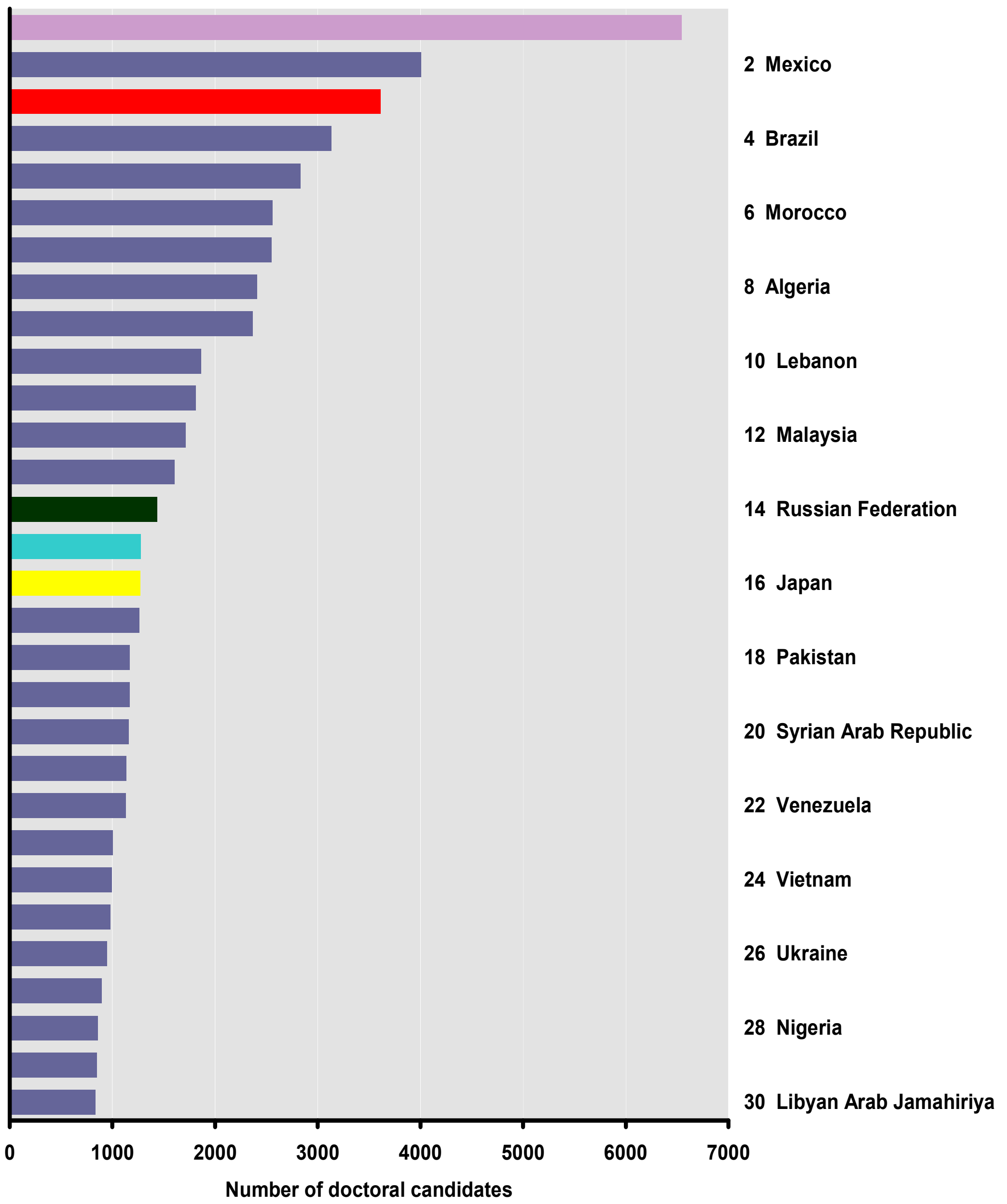
Chinese students are the most important non-European pool of doctoral candidates in Europe

Overall, around 17% of doctoral candidates in the EU are citizens from non-EU countries. As Figure II.5.11 shows, among non-European countries, China was the most important sender of

[154] Survey of Naturejobs. See http://www.nature.com/naturejobs/salary/survey/2010/index.html

doctoral candidates to the EU with around 6 500 doctoral candidates in 2007. Mexico and the United States followed with 4 000 and 3 600 doctoral candidates, respectively.

Figure II.5.11 Foreign (non-EU) doctoral candidates (ISCED 6) in the EU (1) - the top 30 countries of origin, 2007



Source: DG Research and Innovation

Innovation Union Competitiveness Report 2011

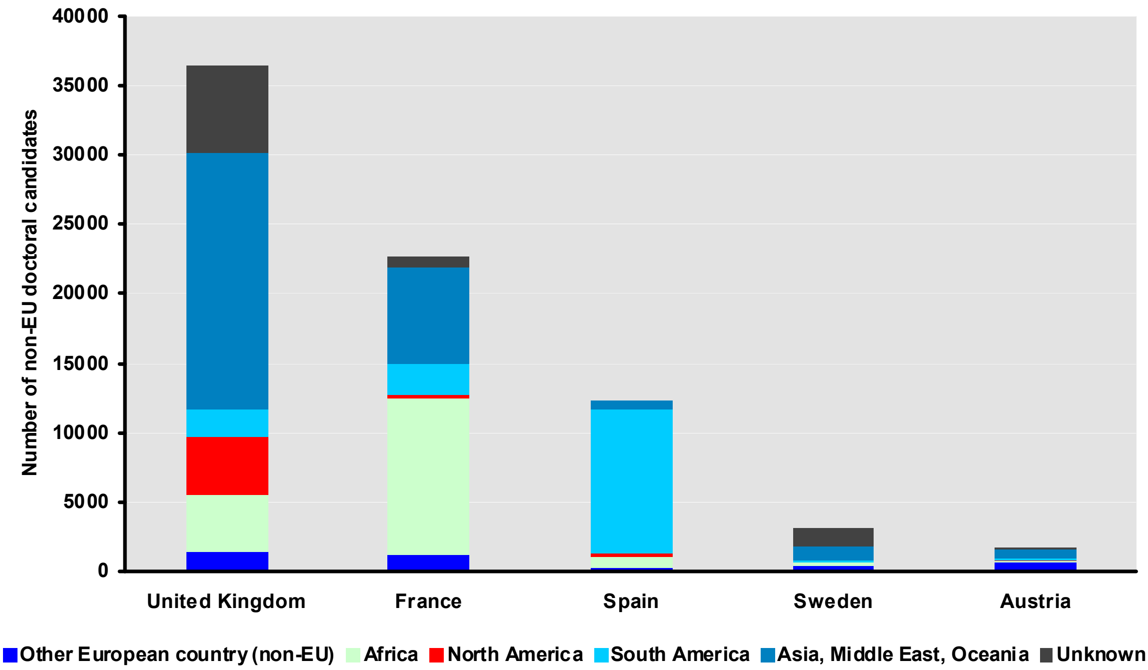
Data: Eurostat, MORE Study

Note : (1) DE, IE, EL, LU, NL were not included in the calculation as data for these Member States are not available.

The inflow of doctoral candidates to the EU tends to be linked to language and historical factors

Figure II.5.12. shows that the Member States which received most foreign (non-EU) doctoral candidates are the United Kingdom, France and Spain, all three receiving around 71 000 doctoral candidates from non-European countries (36 000, 23 000 and 12 000, respectively) in 2007. Citizens of countries in Asia, the Middle East and Oceania combined accounted for 51 % of foreign doctoral candidates to the United Kingdom. Knowledge of the local language and historical ties seem to be important factors: in Spain, 85 % of doctoral candidates from non-European countries come from South America; in France almost one in two doctoral candidates from non-European countries comes from African countries (49 %).

Figure II.5.12 Number of non-EU doctoral candidates (ISCED 6) by region of citizenship - the five Member States receiving the most candidates [(1)], 2007



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat, MORE Study
Note : (1) DE, IE, EL, LU, NL were not included in the calculation as data for these Member States are not available.

6. Free movement of science and technology across Europe and beyond

Highlights

An effective European Research Area will contribute to a single market for knowledge in Europe. To this end, it is not sufficient to enhance the system — research performers and users also need to be stimulated to take up the opportunities offered to them and use the system for collaborative knowledge production. Knowledge circulates between the public and private sector (see chapter II.2), across Europe and between Europe and other parts of the world. Knowledge flows can take different forms: exchange of informal knowledge and information, knowledge embodied in persons (see chapter II.4), concrete cooperation in producing science, and cooperation in the development and ownership of technologies. Evidence shows an increasing integration of science and technology production in Europe. However, this knowledge circulates predominantly within Western Europe, leaving countries in Eastern Europe, and some of the Southern European countries, outside the dominant knowledge flows.

Evidence of electronic infrastructures indicates an increasing flow of informal scientific knowledge. The strong increase in Open Access repositories, journals and articles testify similar trends towards knowledge sharing driven by mutual benefit. However, much progress remains to be made. Only 20 % of the total number of peer-reviewed journals worldwide offer open access to the reader. Scientific integration and cooperation can also be measured by the number of co-publications. In absolute numbers, European researchers co-publish mainly with colleagues from other European countries, and this intra-European co-publication has increased by almost 10 % between 2003 and 2008. However, a divide appears between an increasingly integrated Western Europe and an Eastern Europe suffering from a lower level of trans-European scientific cooperation — a picture also emerging from data on the mobility of researchers. At the same time, European scientists increasingly co-publish with colleagues from non-European countries: a growth of 8 % over the period 2000–2008. The largest growth has taken place in the co-publications with researchers from the most research-intensive Asian countries. However, the EU still lags behind the United States in scientific cooperation with these Asian countries.

Contrary to scientific cooperation, technological cooperation is closely linked to market exploitation and application of knowledge. Worldwide, co-patenting has more than tripled since the early 1990s, with a major role played by the United States. At EU level, the four strongest countries in terms of patent applications (France, the United Kingdom, Germany and Italy) account for 75 % of all EU patent applications. However, all Member States increased their co-patenting both within the country and with European or third-country partners. Co-patents with third countries increased more than those within the EU, showing the international and open character of innovation systems but also the need to consolidate the internal market for knowledge.Networks organised around co-patenting collaborations have been growing, usually around a core of key linkages, reinforcing the regions with higher degrees of patenting, which become the regions with stronger co-patenting activities. Germany has been playing a bridge role in this networking. Smaller countries show less integration in the networks. Europe's scientific cooperation divide seems to be visible also in technological collaboration, with an additional peripheral role for some Southern European countries as Portugal, Greece, and to a certain extent, Spain.

6. Free movement of science and technology across Europe and beyond

A higher integration of EU Member States' research systems is an essential prerequisite of the realisation of the ERA, with the view of avoiding duplication of research results obtained in various Member States, and maximising knowledge spillover. The Innovation Union Initiative emphasises the need to remove obstacles to flows of knowledge and a single market for knowledge. Knowledge flows in transnational collaboration which are disseminated through open access to scientific products also contribute to raising the quality of European science and technology.

This chapter presents cooperation and knowledge flows for the production of science and technology, spanning from information- and knowledge-sharing using information and communication technologies (measured by Webometrics, e-infrastructures and open access to scientific articles), transnational cooperation in the production of knowledge (measured by collaborative links and international cooperation funded through the EU framework programme), cooperation in producing scientific knowledge (co-publications), and cooperation in technology development (co-patenting).

6.1. Is there an expansion in electronic infrastructures and open access to scientific articles?

The capacity of European e-infrastructures has largely expanded over the last five years

Normalised networks, the Central Processing Unit (CPU)[155] and computing capacities used in European e-infrastructures and accessible from any country[156] have been multiplied by more than 17 between 2005 and 2010. This network capacity is mainly provided by GEANT, DANTE, CPU and computing capacity by EGI and PRACE. These infrastructures are essential in supporting the exchange of data and information between researchers, universities and research organisations throughout Europe.

Table II.6.1 Normalised network, CPU and computing capacities[(1)], 2005-2010 (reference: 100 in 2005)

2005	100
2006	158
2007	363
2008	482
2009	908
2010	1751

Innovation Union Competitiveness Report 2011
Source: DG Research and Innovation
Data: DG Information Society
Note: (1) 1/3 (netcap) + 1/3 (cpucap) + 1/3 (compcap)

[155] Central Processing Unit.
[156] Purely national resources are excluded.

The use of European e-infrastructures has increased by over three times over the last five years

Cross-country network traffic represents actual knowledge circulation between researchers, universities and research organisations within the EU and between the EU and the rest of the world. This cross-country traffic has been multiplied by more than three between 2005 and 2010.

Table II.6.2 Cross-country network traffic [(1)], 2005-2009 (reference: 100 in 2005)

2005	100
2006	161
2007	222
2008	274
2009	327

Innovation Union Competitiveness Report 2011
Source: DG Research and Innovation
Data: DG Information Society
Note: (1) 1/2 (traffic EU) + 1/2 (traffic beyond EU)

This considerable expansion of the capacity and actual use of e-infrastructure is partly due to EU funding, but mostly to national funding. In fact, 1.13% of EU FP-7 budget is devoted to e-infrastructures. EU funding to European e-infrastructures represents 5% to 10% of total funding to these infrastructures. The rest is financed by national investments.

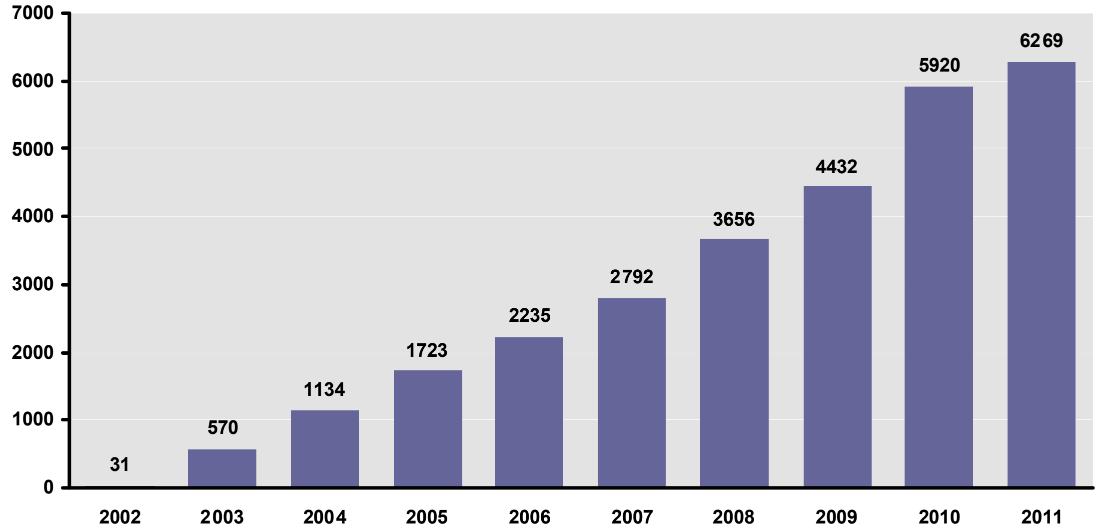
Dissemination of science through Open Access

In recent years Open Access (OA) has become an increasingly important tool for the dissemination of knowledge from research to society as shown by the growing number of OA Journals and repositories. OA journals do not differ from the traditional journals in their commitment to peer review or their way of conducting it, but only in their cost-recovery model. The funding model used by OA journals does not charge readers or their institutions for access.

The number of Open Access journals and open-access repositories increased substantially since 2002, with the highest numbers being recorded in European countries

According to the Directory of Open Access Journals, which covers free, full-text, quality-controlled scientific and scholarly journals, there are 6269 OA journals in March 2011 (Figure II.6.1.).The highest number of Open Access journals can be found in the EU, followed by the United States, Brazil, India, Japan and China.

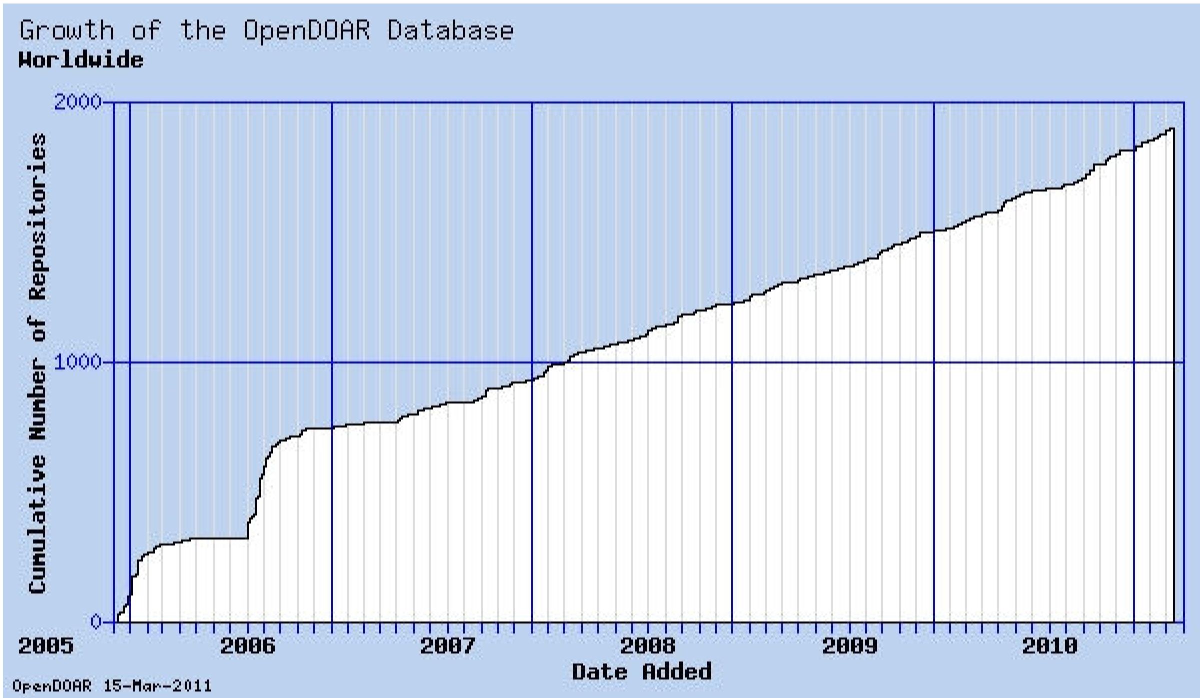
Figure II.6.1 Number of Open Access journals, 2002-2011



Source: DG Research and Innovation
Data: Directory of Open Access Journals

Innovation Union Competitiveness Report 2011

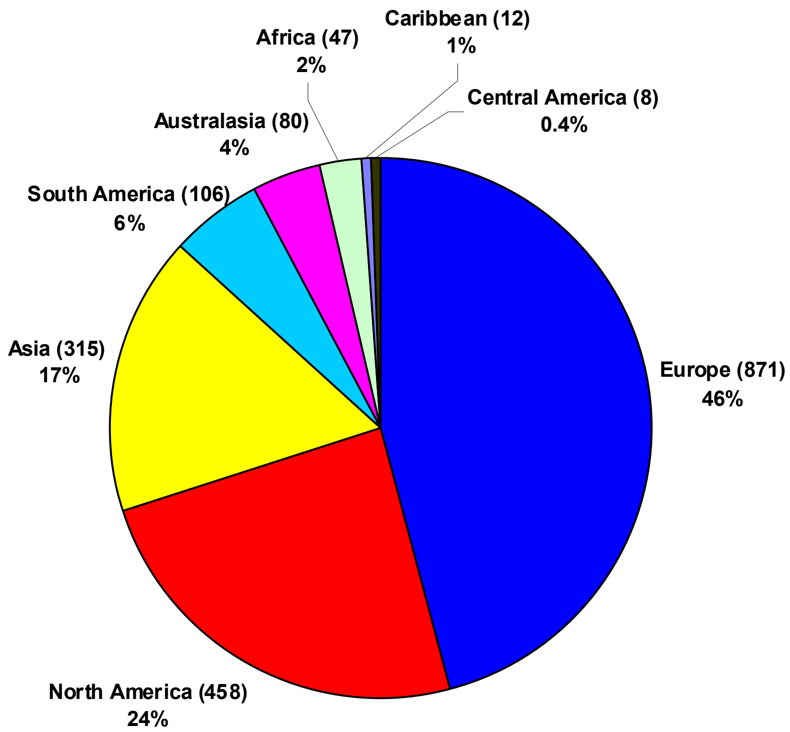
The increase of OA practice can also be noticed by the growth of the number of repositories (Figure II.6.2.) — the online locus for collecting, preserving, and disseminating the publications in digital form — used for Open Access Self-Archiving.



Source: DG Research and Innovation
http://www.opendoar.org

Yet again the highest number of Open Access repositories can be found in the EU, followed by North America and Asian countries.

Figure II.6.3 Repositories by world region (total = 1897)



Source: DG Research and Innovation
Data: www.opendoar.org

Innovation Union Competitiveness Report 2011

In 2008, about 20% of peer-reviewed journals worldwide offered Open Access to the reader, a slight increase compared to 2006

Although these indicators show the important growth of OA over last years, they cannot individually make a comprehensive estimation of the penetration ratio of both OA publishing and Self-Archiving practices. To this end, a more significant indicator of the overall growth of the phenomenon could be the proportion of research literature (articles) available in OA form in OA journals and repositories.

Estimations[157] show a share of OA in the total number of articles published in peer-reviewed scientific journal articles published worldwide in 2006 (approximately 1 350 000) of 19.4%, subdivided as follows: 4.6% immediately openly available, 3.5% available after a one-year embargo period, and 11.3% available in subject-specific or institutional repositories or on authors' home pages.

[157] Bo-Christer Bjork et al, Information Research vol. 14 no. 1, March, 2009, 'Scientific journal publishing: yearly volume and open access availability'. http://informationr.net/ir/14-1/paper391.html .

In 2008[158], the overall share of OA literature was 20.4 %, of which:

- 8.5 % free at the publishers' sites (62 % in full OA journals, 14 % in subscription journals which make their electronic versions free after a delay, and 24 % as individually open articles against payment in otherwise subscription journals).

- 11.9 % free in either subject-based repositories (43 %), institutional repositories (24 %) or on the home pages of the authors or their departments (33 %).

6.2. Is transnational scientific cooperation growing both within Europe and beyond?

In 2008, almost half of world publications were made in transnational cooperation. Intra-EU co-publications have increased by almost 10 % between 2003 and 2008.

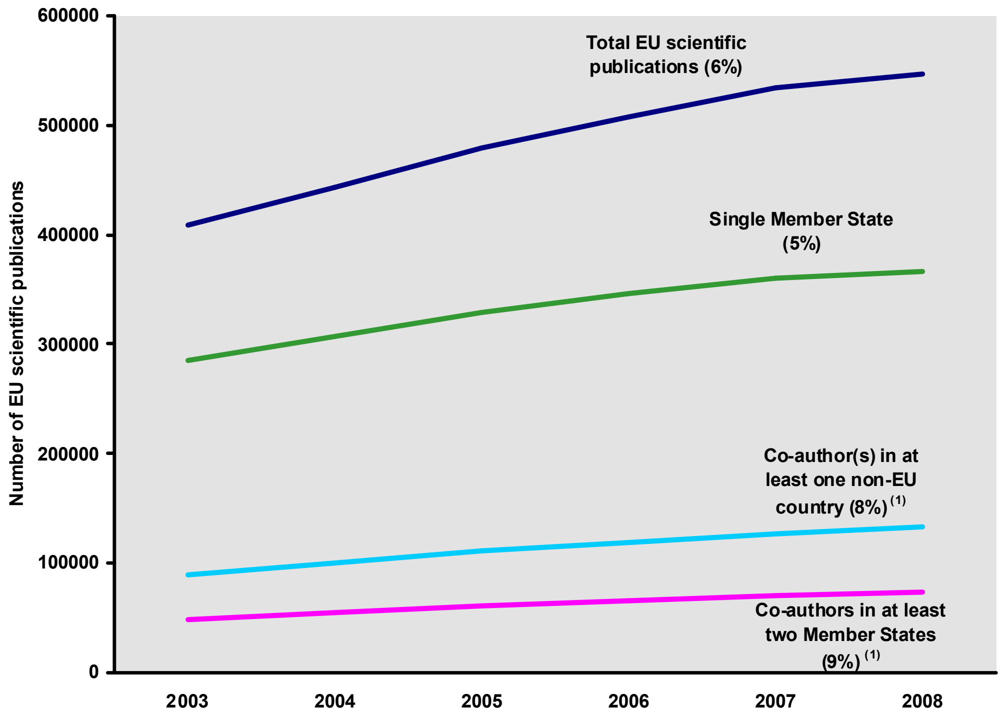
Figure II.6.4. shows the total number of scientific peer-reviewed publications in the EU, the number of scientific publications in each country (single author and domestic co-publications), the number of scientific publications involving authors in at least two EU Member States, and the number of scientific publications in the EU where at least one author is based outside the EU.

Researchers based in the EU are increasingly integrated in transnational networks, as reflected by the higher growth of the number of transnational co-publications (within EU and with non-EU countries) compared to the growth of scientific publications within single Member States over the period 2003–2008: in total, EU transnational co-publications represented 33.5 % of all EU publications in 2008, against 30.5 % in 2003, which represents a growth of 9.8 %. A similar trend is visible in the opening up of the EU, with an 8 % increase of co-publications including authors from at least one non-EU Member State. The figures show therefore both a greater EU integration in recent years and an increasing openness of EU research towards the rest of the world.

However, with an average annual growth rate of 8 % since 2003, collaboration with non-EU countries has progressed less rapidly than intra-EU cross-border collaboration (average annual growth rate of 9.8 %), a sign of a slightly faster integration of scientific activities within the EU than with the rest of the world. Additionally, extra-EU collaboration also involves some intra-European collaboration, namely collaboration with European non-EU countries.

[158] Bo-Christer Bjork, Patrik Welling, Peter Majlender, Turid Hedlund, Mikael Laakso, and Gudni Gudnasson, *Open Access to the Scientific Journal Literature: Situation 2009.*

Figure II.6.4 EU collaboration in scientific publications, 2003-2008; in brackets: average annual growth rate 2003-2008



Source: DG Research and Innovation   Innovation Union Competitiveness Report 2011
Data: Science Metrix / Scopus (Elsevier)
Note: (1) 'EU scientifc publications with co-authors in several Member States and in at least one non-EU country' are included in both of these categories.

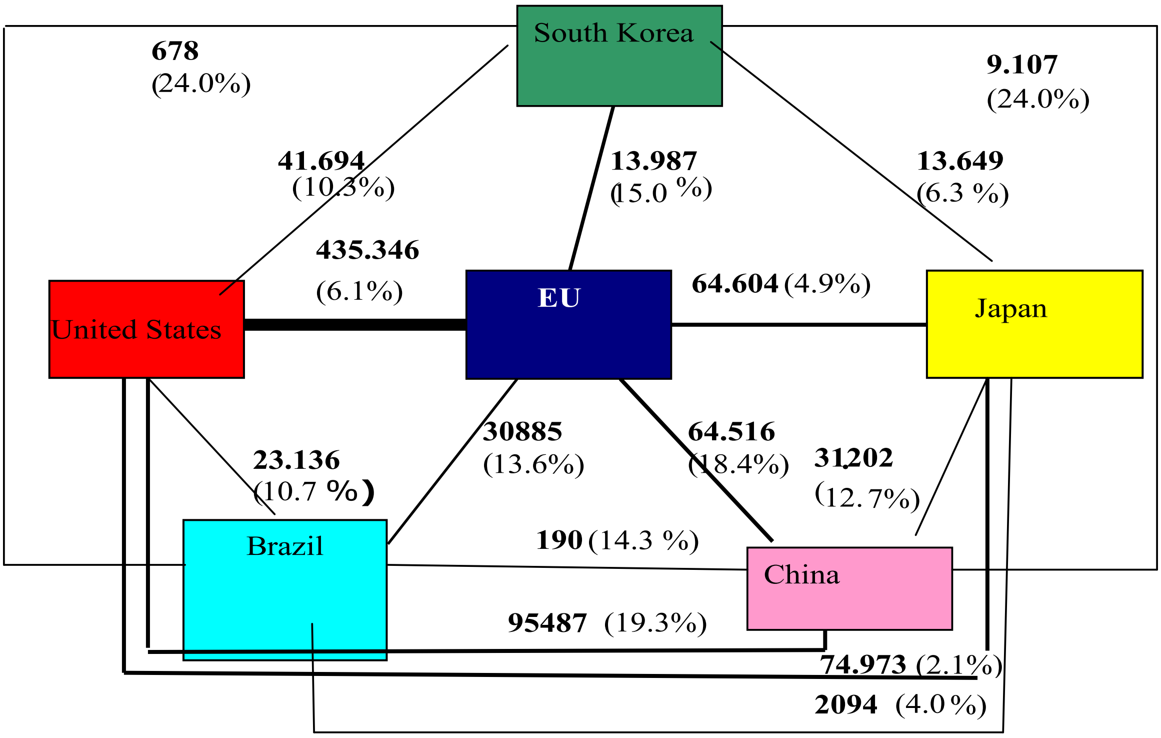
Major world scientific cooperation still takes place between the EU and the United States. However, the United States has developed a larger scientific cooperation than the EU with all major Asian research-intensive countries. The EU is catching up.

Figure II.6.5.shows that transnational activity is increasing between all world regions. In absolute terms, the highest level of scientific collaboration by far takes place between the EU and the United States, with over 435 000 joint publications between 2000 and 2009. Far behind, but growing three times faster, the second strongest collaboration links take place between the United States and China (about 95 000 between 2000 and 2009). US scientific collaborations with Japan and South Korea are also more extensive than those of the EU Member States.

Since 2000, China has increased its scientific collaboration with every country at a very rapid pace. China is therefore becoming an international partner of primary importance for scientific collaboration. Although counting 17% fewer scientific publications than the EU in total in 2000–2009, the United States has had about 46% more co-publications with China (95 000) than the EU has with China (75 000) since 2000. China is therefore a more important partner for the United States than for the EU. However, the collaboration of the EU and the United States with China has progressed at a similar pace (respectively 18.4% and 19.3% per year on average). In addition, European countries are rapidly reinforcing their collaboration also with other countries in the world, such as Japan, South Korea and Brazil. Over the period

2000–2009, the EU has increased its scientific cooperation with the research-intensive Asian countries (Japan, South Korea and China) at, on average, 12.8 %, while the United States expanded its scientific cooperation with the same countries by 10.6 % over the same period.

Figure II.6.5. Scientific co-publications between the EU, the United States, Japan, South Korea, China and Brazil, 2000–2009 (figures on the links: average annual growth rates (%), 2000–2009)



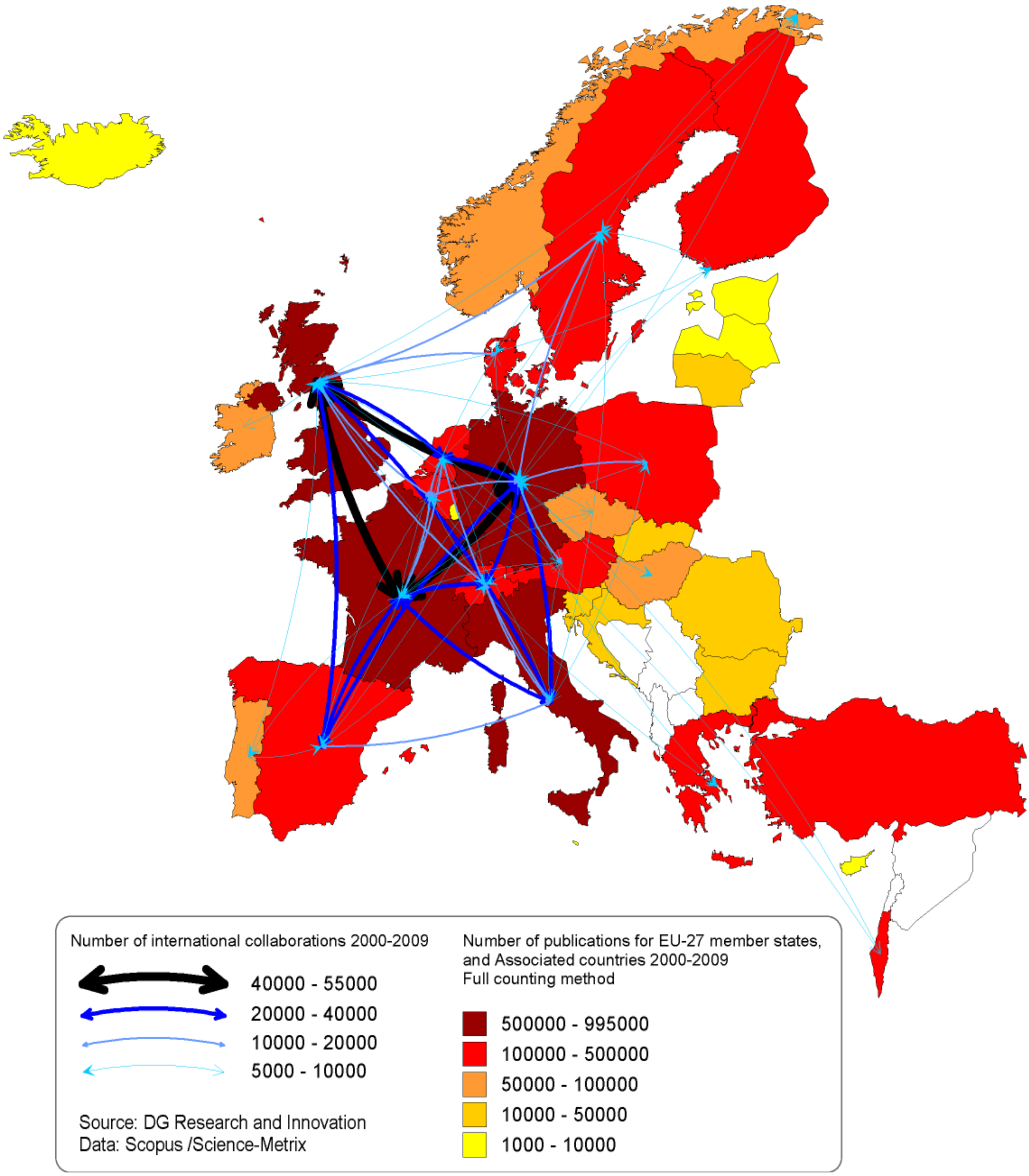
Source: DG Research and Innovation
Data: Science Matrix / Scopus (Elsevier)
Note: The thickness of a link between two countries is proportional to the number of co-publications between these two countries between 2000 and 2009.

EU Scientific collaboration seems to be centred among Western European countries, both in scale and scope, with a divide between Eastern and Western Europe.

Within Europe the highest number of cross-border co-publications is registered, as expected, between countries with the highest number of overall publications, namely the United Kingdom, France, Germany and Italy. The collaboration is also generally more intense among

Western European countries, where yet again both the number of publications and co-publications is highest. In terms of volume of scientific co-publications, the map below shows a relatively weak link between EU-15 and EU-12.[159]

Figure II.6.6. Co-publications(1) between European countries, 2000–2009



Notes: (1) Threshold for a link between two countries: 6 000 co-publications over 2000–2009

[159] These findings from co-publication data are confirmed by the analysis of intra-European mobility flows of researchers and of skilled human resources (see chapter II.4).

The colour of the country indicates its total number of publications over 2000–2009.

As expected, the largest countries have the highest number of cross-border scientific co-publications: the United Kingdom, Germany, France, Italy and Spain. In terms of annual average growth rate between 2000 and 2008, beside small countries (Luxembourg, Malta and Cyprus), the highest growth rates are recorded for Portugal (16.3%), Ireland (16.2%), Spain and Slovenia (13.4% each), Greece (12.8%), Romania (12.5%) and Austria (12.1%).

Table II.6.3 International scientific co-publications

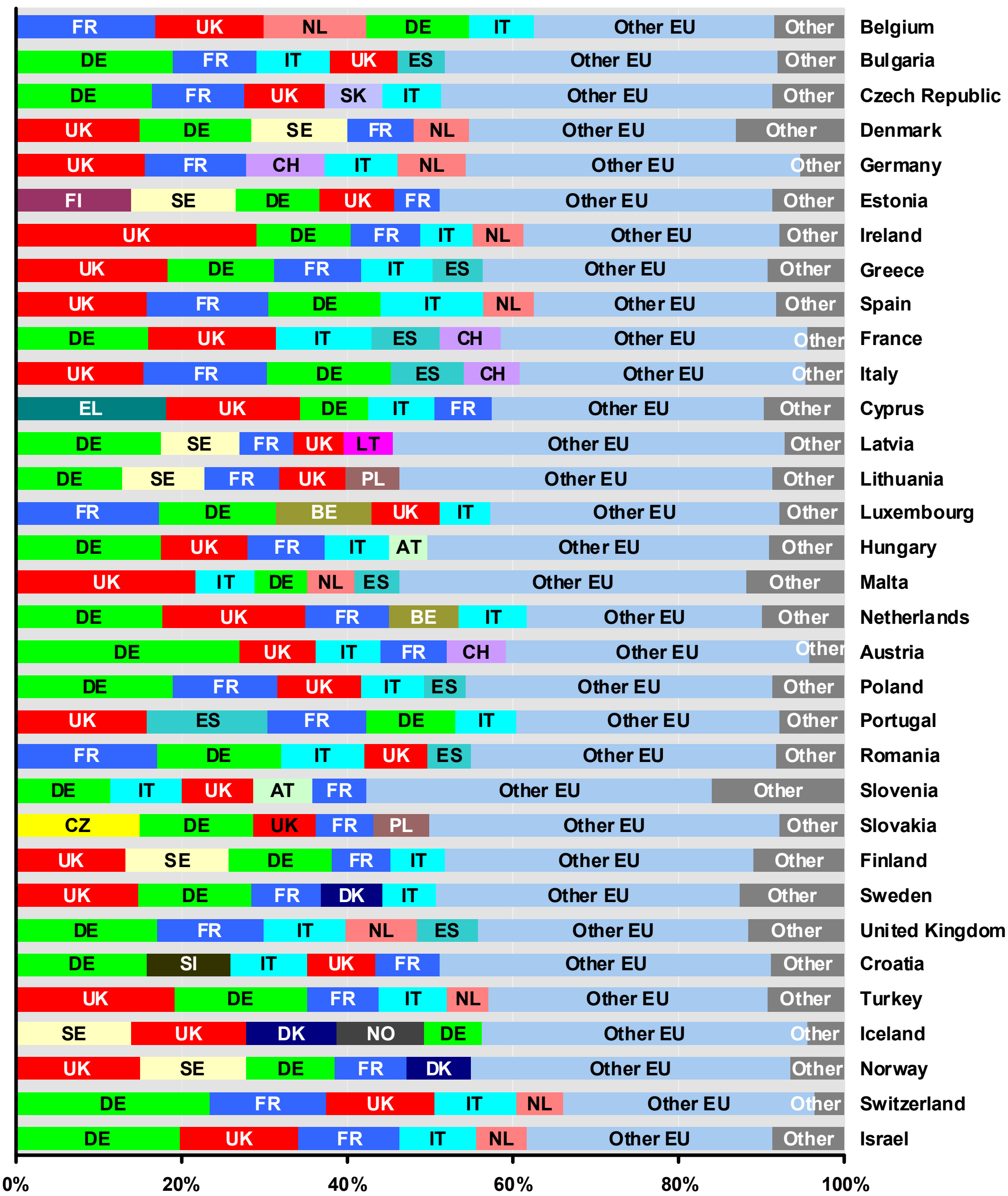
	2000	2008	Average annual growth (%) 2000-2008
Belgium	4784	11071	11,1
Bulgaria	734	1452	8,9
Czech Republic	1928	4440	11,0
Denmark	3573	7126	9,0
Germany	24477	48290	8,9
Estonia	268	659	11,9
Ireland	1183	3937	16,2
Greece	1881	4924	12,8
Spain	7303	19927	13,4
France	18622	36857	8,9
Italy	10889	24692	10,8
Cyprus	96	533	23,9
Latvia	175	299	6,9
Lithuania	274	669	11,8
Luxembourg	52	366	27,6
Hungary	2148	3298	5,5
Malta	21	99	21,4
Netherlands	8020	17372	10,1
Austria	3123	7787	12,1
Poland	3970	7075	7,5
Portugal	1539	5153	16,3
Romania	987	2540	12,5
Slovenia	550	1507	13,4
Slovakia	856	1798	9,7
Finland	2888	5902	9,3
Sweden	6434	11993	8,1
United Kingdom	24188	51458	9,9

Source: DG Research and Innovation
Data: Science Metrix / Scopus (Elsevier)
Innovation Union Competitiveness Report 2011

Researchers from European countries cooperate most frequently with colleagues from large countries, i.e. the United Kingdom, Germany, France, Italy, Spain, and from countries in geographical proximity

Within Europe, researchers from most EU and Associated Countries collaborate intensively with colleagues from large countries, i.e. the United Kingdom, Germany and France, followed by Italy and Spain. The large countries collaborate in absolute terms mostly among themselves, but also with Switzerland (consistently the preferred partner for Germany, France and Italy) and the Netherlands (for Germany, the United Kingdom and Italy). Geographical proximity plays a significant role: for instance there is a preferential collaboration between Belgium and the Netherlands, the Czech Republic and Slovakia. Some countries prefer co-publications with colleagues from bigger-performing (or larger) neighbours: Lithuania is a preferred partner of Latvia, whereas Poland is a preferred partner for Lithuania and Slovakia.

Figure II.6.7 The five main co-publication partners of EU Member States and associated countries (1), 2000-2009



Source: DG Research and Innovation
Data: Science Metrix / Scopus (Elsevier)
Note: (1) All EU Member States and IS, NO, CH, HR, TR, IL are covered.

Innovation Union Competitiveness Report 2011

6.3. Is technological cooperation increasing both within Europe and beyond?

International co-patents are increasing — but remain at a very low level

Contrary to the scientific cooperation analysed above, technological cooperation is more closely linked to market exploitation and application of knowledge. During the past two decades, economic globalisation and technological internationalisation have strongly increased, backed up by the possibilities offered by information and telecommunication technologies. Both R&D and technology production are considered key elements in the movement towards opening up and collaborating externally. Collaboration patterns in patenting provide information on how and with whom the technology development process took place, on partnerships, actors and networking. Traditionally, patents are good indicators of the inventiveness of countries or regions, and can provide evidence on technological changes, degrees of specialisation and trends, as well as the role they play in the protection of intellectual assets. More recently, co-patents are being increasingly used either in the context of quantifying university–industry partnerships, or in econometric studies, to measure research and collaboration in the frame of regional innovation systems.

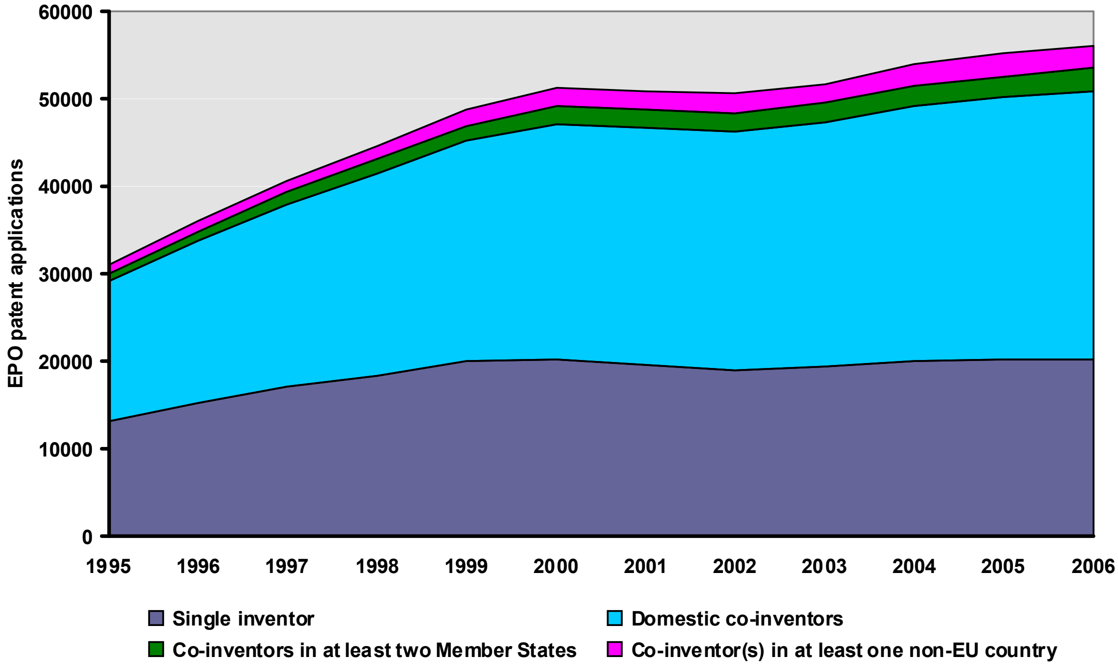
Different studies[160] suggest that co-patenting at country level is still dominated by multinational companies. However, many other factors also intervene. Smaller or less-developed countries appear more engaged in developing co-inventive activity than large industrialised countries. Cultural and geographical proximity are important factors for international collaboration in patenting, and countries appear to collaborate more in the technology areas in which they are less specialised.

The incidence of co-patenting is determined by a number of factors such as the environment of the researcher/inventor, the composition of his or her research team, the contractual context in which the research is being performed, the degree of internationalisation of the research institution, the region and country as well as the technological field. Patenting is considered to be associated more with certain sectors than others: the propensity of patenting is generally greater in science-based or high-tech areas.

Figure II.6.8. shows that over the period 1995–2006 the number of EPO patent applications in which EU inventors were involved has been increasing. Transnationally co-invented patents (covering both EU patents with co-inventors from at least two Member States and EU patents with co-inventors in at least one non-EU country) have been growing at a higher rate (average annual growth rate of 9.35%and 9.45% respectively) than the total number of patents (average annual growth rate of 5.5%). However, transnational technological collaboration remains relatively modest, and much smaller in size than transnational collaboration in science. **This domestic nature of patenting activity is partly linked to the confidentiality required in the invention process.**

[160] Study prepared for DG RTD by RINDICATE 'The Impact of Collaboration on Europe's Scientific and Technological Performance', Final Report, March 2009
http://ec.europa.eu/invest-in-research/pdf/download_en/final_report_spa2.pdf.

Figure II.6.8 Number of EPO patent applications with at least one inventor residing in the EU, 1995-2006



Source: DG Research and Innovation
Data: Eurostat

Innovation Union Competitiveness Report 2011

Number of EPO patent applications with at least one inventor residing in EU-27, 1995-2006, absolute figures

Table II.6.4 Number of EPO patent applications with at least one inventor residing in the EU, 1995-2006

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total	31123	36142	40746	44712	48822	51371	50905	50648	51817	54095	55287	*56196*
Single inventor	13145	15194	17166	18354	20019	20245	19568	19012	19475	20143	20389	*20356*
Domestic co-inventors	16050	18607	20855	23128	25157	26889	27110	27278	27871	29072	29826	*30661*
Co-inventors in at least two Member States	961	1164	1314	1617	1770	2106	2144	2166	2319	2378	2461	*2569*
Co-inventor(s) in at least one non-EU country	967	1177	1411	1613	1876	2131	2083	2192	2152	2502	2611	*2610*

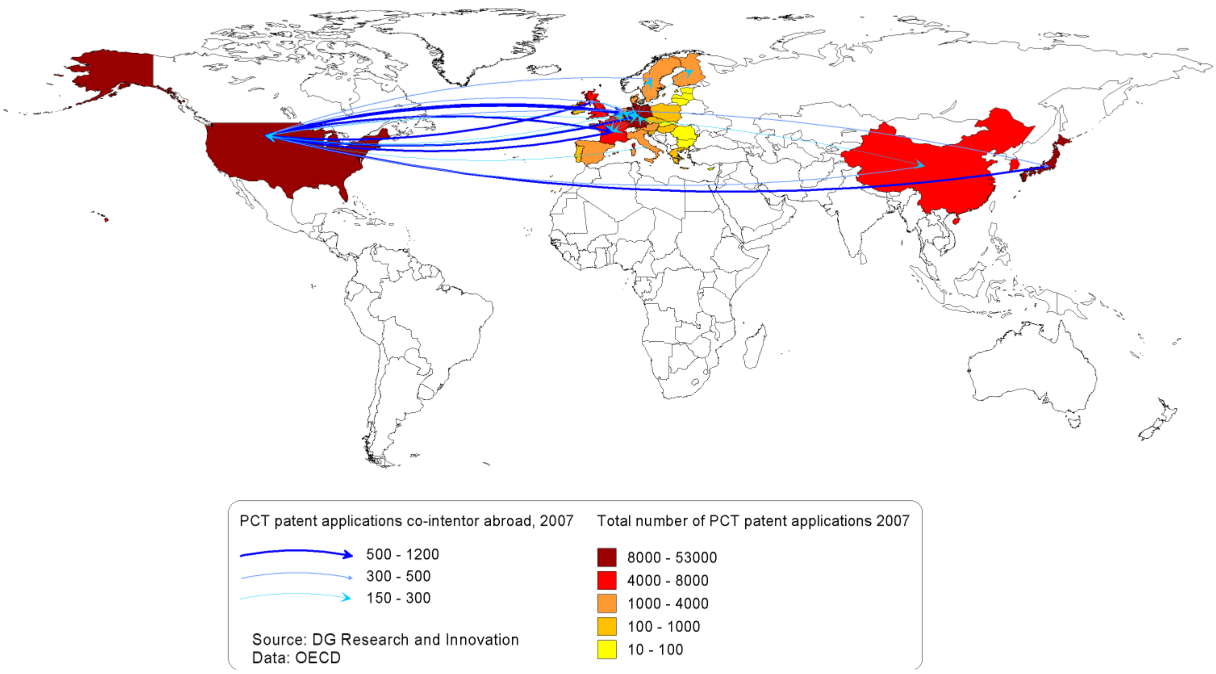
Source: DG Research and Innovation
Data: Eurostat
Note: (1) Values in italics are provisional.

Innovation Union Competitiveness Report 2011

The United States remains the main technological partner for Europe, but closer linkages are being established, both with Asia and with other countries

From the map below we can see that the United States is the main partner country of the EU in the co-invention of PCT patent applications. Japan and China follow. In 2006, the last year of available data, 2 684 PCT patent applications were invented in the EU with at least one co-inventor based in the United States; the figures are clearly more modest for Japan (247) and China (210). Among the European countries, Switzerland plays a special role in technology collaboration with 1 156 PCT patent applications with co-inventors based in the EU.

Figure II.6.9. PCT patent applications[161] co-inventor abroad, 2007

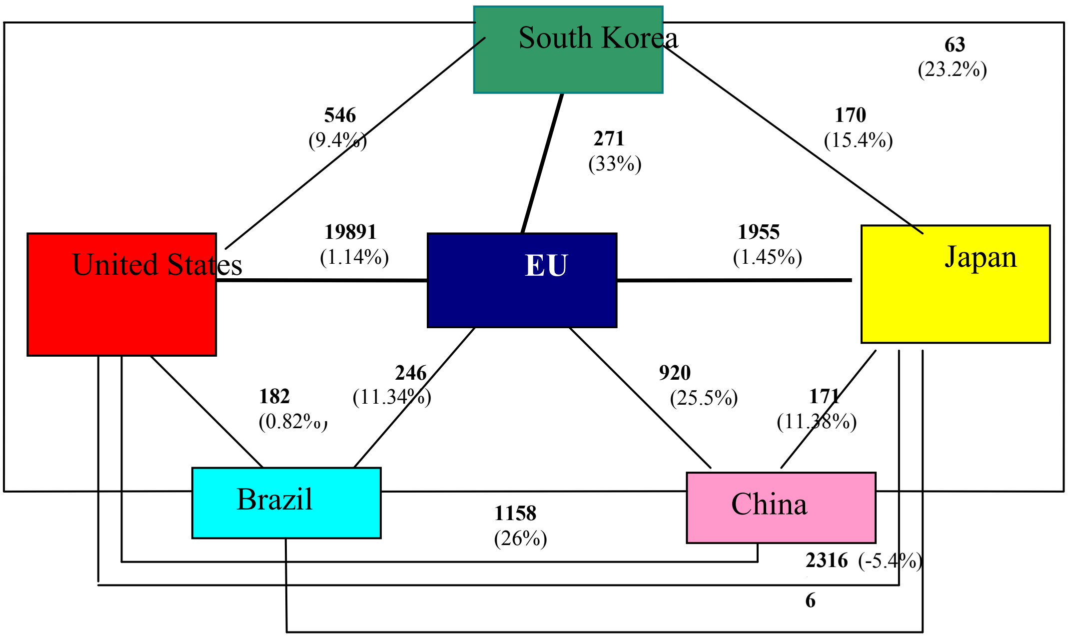


The EU, the United States and Japan are reinforcing their technological cooperation links among themselves but also with emerging economies

Transnational technological research cooperation through co-patenting is also an indicator of the degree of international networking giving evidence to the ability of different economies to develop links between themselves. The EU, United States and Japan are competing to increase their links with emerging economies, such as the case of China and Brazil. Figure II.6.10 illustrates that even if the United States is the main partner for the EU, with a total near 20 000 co-patents, collaboration with South Korea, Brazil and China has been increasing over the years.

[161] Note: Patent applications filed under the Patent Cooperation Treaty (PCT), by priority year and inventor's country of residence.

Figure II.6.10. Number of transnational co-patents for each pair of countries, 2000-2007; in brackets average annual growth rates (%) 2000-2006[162]



Source: DG Research and Innovation
Data: Eurostat
(1) Note: The average annual growth rates were calculated for the period 2000-2006, since the values for 2007 were not consolidated when the graph was produced

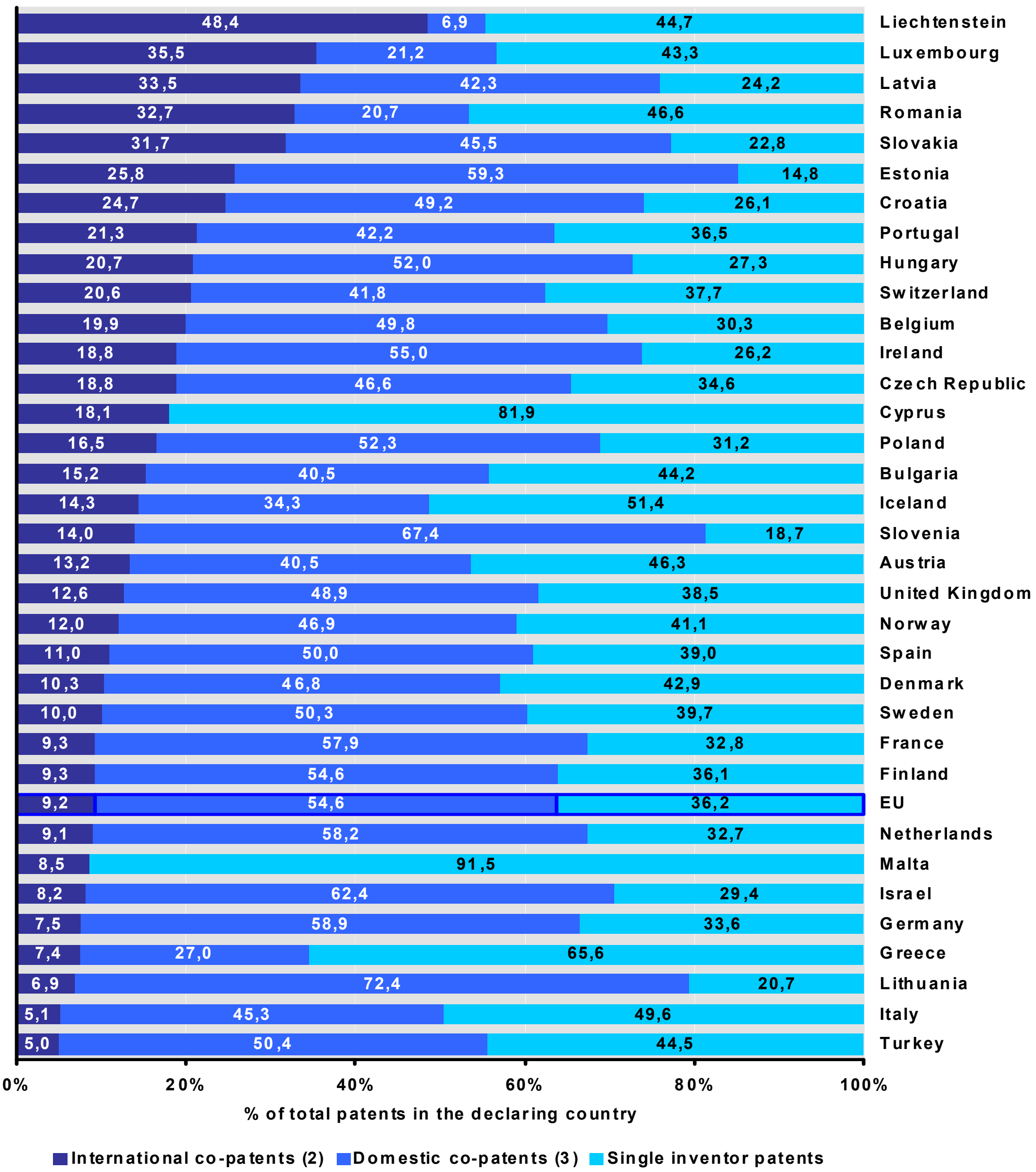
In most European countries, the majority of patents are invented in either domestic or international collaboration

The figure below illustrates that for most European countries, with the exception of Cyprus and Malta[163], the majority of patents are invented with collaboration, either inside the own country or with foreign partners. In most countries, domestic collaboration largely prevails over cross-border collaboration, which remains relatively limited on average in the EU (9.2 % of EPO patent applications were invented in the EU). As expected, cross-border collaboration is much more important in smaller countries and more generally in countries with lower levels of patent inventions in absolute terms. This aspect will be discussed further in this part, when showing how these collaborations are translated in networks and specific collaboration patterns.

[163] These exceptions are due to the dimension of the research systems and the lack of critical mass in these countries.

Of the four larger countries, Germany, France, Italy and the United Kingdom, which together account for more than 75 % of all the EPO patent applications invented in the EU in 2006, the United Kingdom is the most internationalised (12.6 % of the UK inventions applied to the EPO have a co-inventor abroad), followed by France (9.3 %) and Germany (7.5 %).

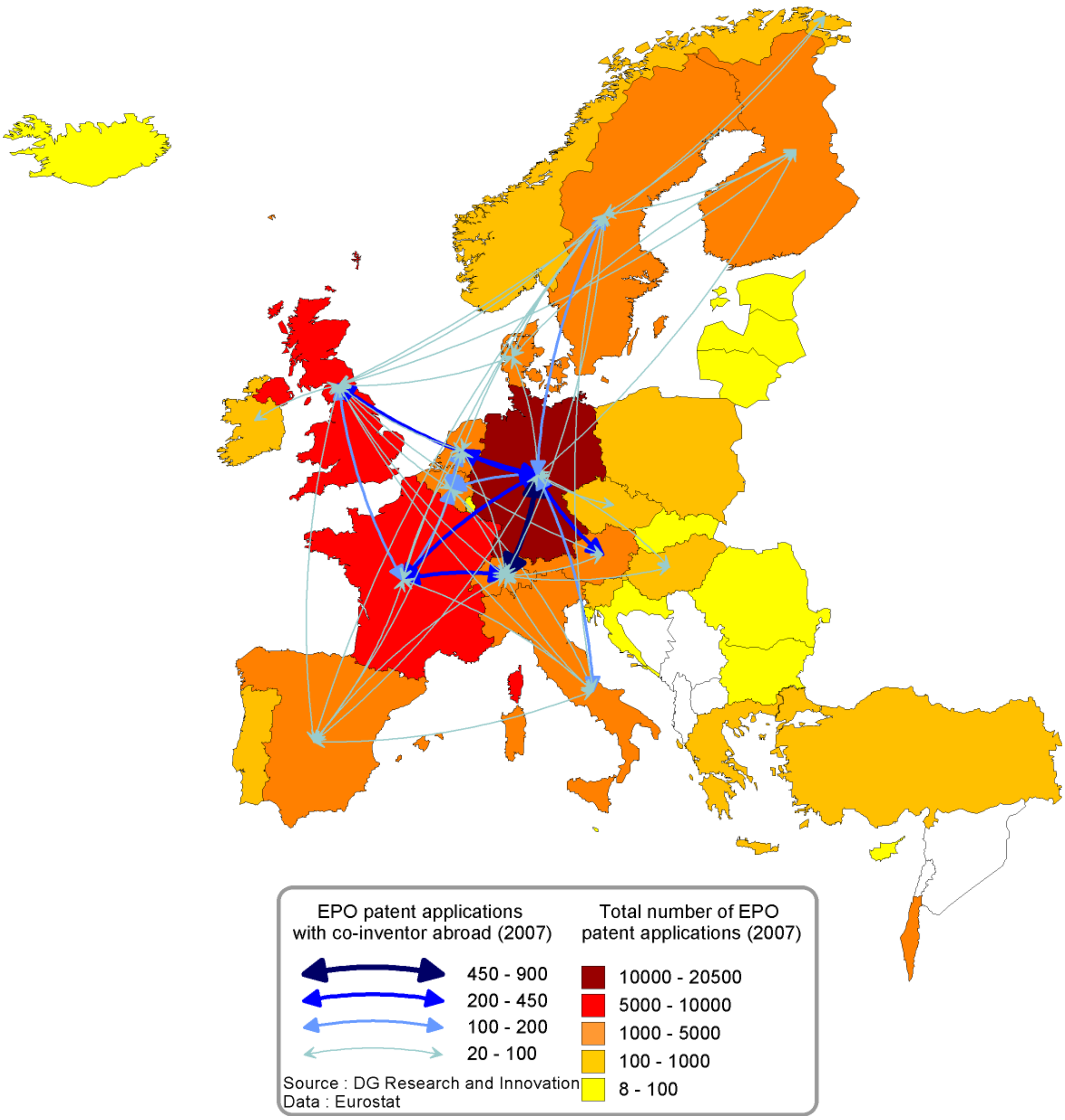
Figure II.6.11 International and domestic co-patents [(1)], 2006



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat
Notes: (1) EPO patent applications by country of residence of the inventor(s).
(2) International co-patents are co-patents with at least one inventor based in another country.
(3) Domestic co-patents are co-patents only involving inventor(s) based in the declaring country.

The analysis of data on co-invented patents can improve the understanding of transnational knowledge flows, especially if we consider the overall specialisation of the different countries in some sectors and technology areas. Despite the relatively small size of Switzerland, this country appears as the first partner in absolute terms for Germany and France, ahead of larger countries like the United Kingdom or Italy. This may be due to the intensive cross-border patenting activity of Swiss multi-national enterprises but also of Swiss higher education institutions. The map below shows that two dimensions have a strong influence on the level of inter-country technology collaboration: the size of the country and its technology development. However, innovation leadership is not particularly related to its propensity to collaborate. Smaller or less-developed countries appear to cooperate relatively more in technology development than large research-intensive countries.

Figure II.6.12. Co-inventions of EPO patent applications(1) between European countries, 2007

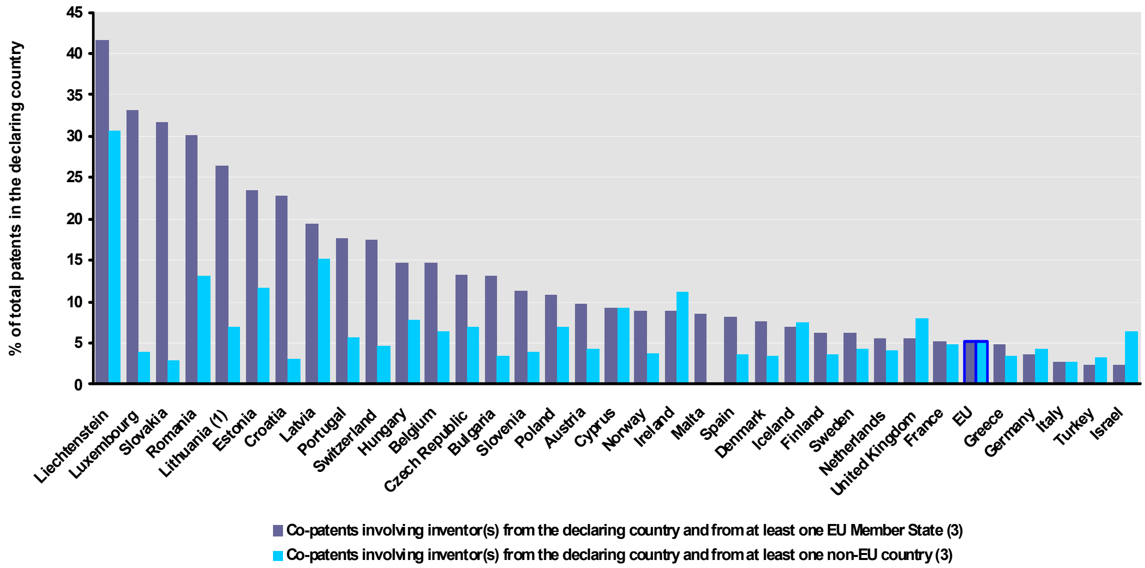


For the majority of EU Member States, the transnational co-invention of patents is made predominantly with other EU partners

Figure II.6.13. shows the predominance of EU co-inventors for the majority of the EU Member States, in particular smaller countries. Only Ireland and the United Kingdom (as well as Iceland and Israel) show an opposite pattern, giving preference to technology collaboration with partners located in countries outside of the EU. It is worth noting that among the non-EU partners for EU Member States, Switzerland is one of the prominent partners for joint technology development besides the United States. It is also worth mentioning that, according to different studies[164], collaboration in the co-invention of patents is based on intensive, consolidated, face-to-face and long-lasting relationships.

A high relevance of intra-EU co-patenting is only observed in a few Member States, occurring more frequently in border areas. Extra-EU co-patenting is not a dominant feature in most countries, with the exception of the United Kingdom and Ireland, due to their links with the United States, and Latvia and Poland for the same reason in relation with Russia.

Figure II.6.13 Co-patents (1) involving EU and non-EU countries, 2006 (2)



Source: DG Research and Innovation | Innovation Union Competitiveness Report 2011
Data: Eurostat
Notes: (1) EPO patent applications by country of residence of the inventor(s).
(2) LT: 2005.
(3) The two categories are not mutually exclusive.

6.4. Are European countries absorbing technologies produced abroad?

As knowledge production becomes more distributed in the growing multi-polar world of science and technology, international trade in technologies expands. Knowledge produced in one country is increasingly used and commercialised in another country. Given Europe's

164 See for example 'The Impact of Collaboration on Europe's Scientific and Technological Performance', Final Report, March 2009 http://ec.europa.eu/invest-in-research/pdf/download_en/final_report_spa2.pdf.

shrinking share of world science and technology production, transnational spillover and absorption of knowledge produced outside Europe becomes more important. This is also an important dimension of a European single market for knowledge.

Cross border ownership of patents is increasing

Another indicator on international flows of patents and technologies is based on the distinction between the inventor of a patent and the owner/applicant of a patent. The globalisation of the production of knowledge is reflected in an increasing share of patent applications owned or co-owned by applicants whose country of residence is different from the country of residence of the inventors.[165] Cross-border ownership is often not linked to international cooperation between firms situated in different countries. It is mainly the result of the activities of multinationals: the applicant is a conglomerate and the inventors are employees of a foreign subsidiary. Nevertheless, patent data provide a proxy to track the international flow from 'inventor' countries to 'applicant' countries. This analysis concerns patent applications to the EPO. In 2006, on average 17.6 % of all inventions filed at the EPO were owned or co-owned by a foreign resident, compared to 16.3 % in 2000 and 10 % in 1990.

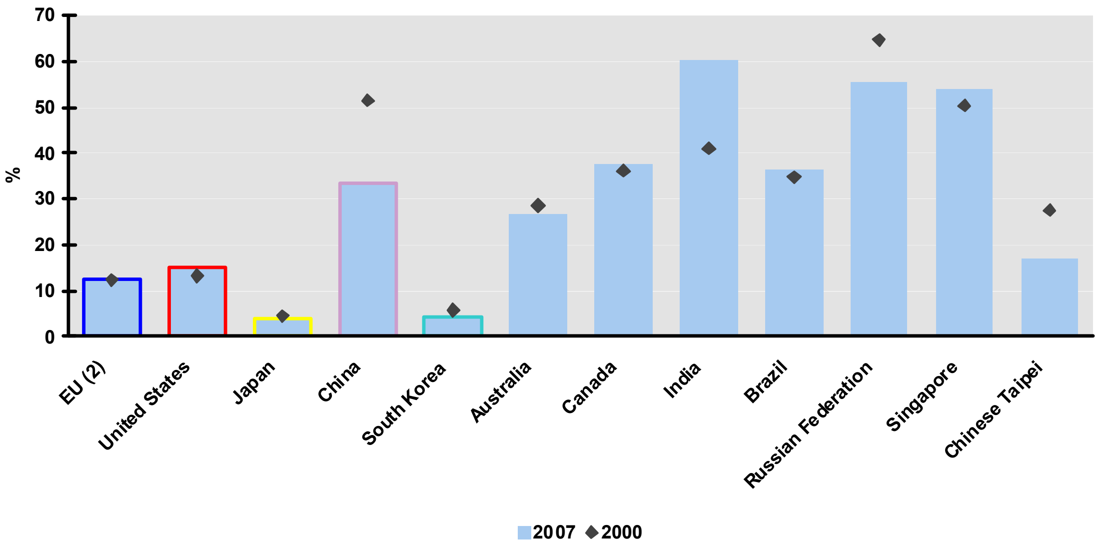
Patents invented in the EU are increasingly owned by non-EU firms

Given that the share of world patents invented in the EU has been decreasing over the years, it is important for EU companies to be able to absorb inventions made abroad and to take part in the expanding transnational knowledge-development chains. However, evidence shows the reverse trend. EU ownership of non-EU inventions is less frequent than the ownership of EU inventions by non-residents, and the gap is growing.

Comparing the two graphs below, we see that of all the patents invented in the EU, the share of patents owned *outside* the EU (12.4 % in 2007, compared with 12.3 % in 2000), is higher than the share of non-EU-invented patents which are owned *in* the EU (9.5 % in 2007 compared with 8.7 % in 2000). The same situation can be observed in countries like Australia, Canada, India and the Russian Federation. On the contrary, foreign inventions represent a bigger share of the total number of US-owned patents than in EU-owned patents. In 2007, 18.6 % of all US-owned patents were inventions made abroad (a slight increase compared to 2000), which is more than the share of US inventions owned outside the United States. Japan and South Korea are good examples of the opposite situation: both are countries in which residents rarely own foreign inventions. The situation in China is particular but interesting, illustrating its economic consolidation. China changes from having a large share of patents invented abroad to having a growing capacity of domestic inventions: in 2000, 29.1 % of all domestically owned patents were invented abroad, changing to only 11.8 % in 2007. China also seems able to absorb a larger part of its domestic inventions, shifting over the six-year period from over 50 % to less than 35 % of domestic inventions being owned by foreign firms.

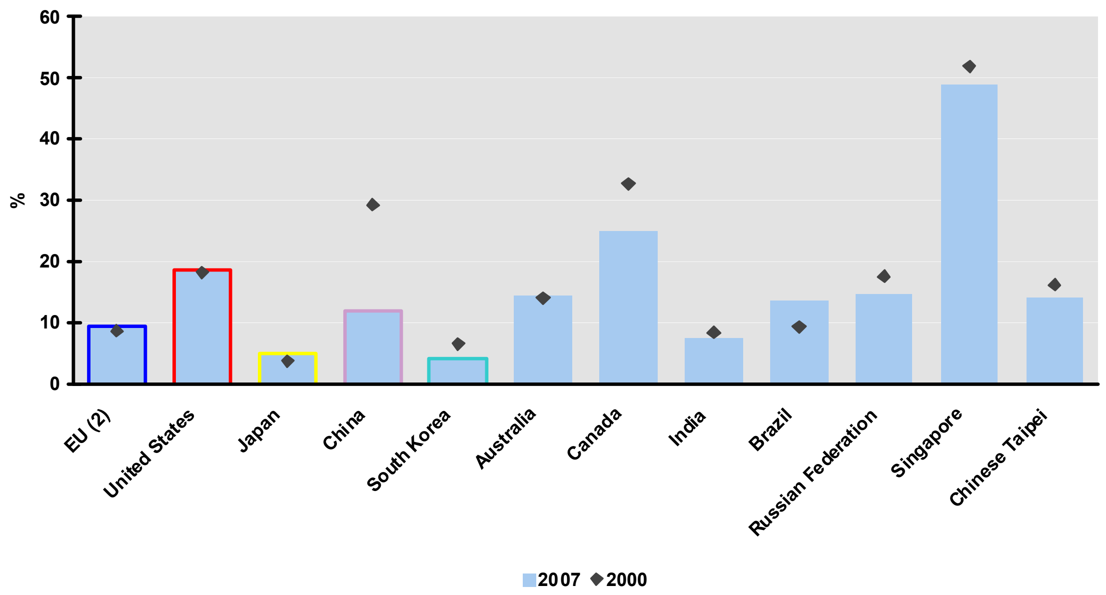
[165] Patent documents specify the inventor(s) and the applicant(s) — the owner of the patent at the time of application — together with their country (or countries) of residence. In most cases the applicant is an institution (either a firm, university, public laboratory) but can also be an individual.

Figure II.6.14 Foreign ownership (%) of domestic inventions [1], 2007



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data : OECD
Notes: (1) The share of domestic EPO patent applications owned by foreign residents.
The patents count is based on the priority date and the inventor's country of residence.
(2) The EU is treated as one entity.

Figure II.6.15 Domestic ownership (%) of foreign inventions (1), 2007



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: OECD
Notes: (1) The number of EPO patent applications owned by country residents but invented abroad as % of total EPO patent applications owned by country residents.
The patents count is based on the priority date and the inventor's country of residence.
(2) The EU is treated as one entity.

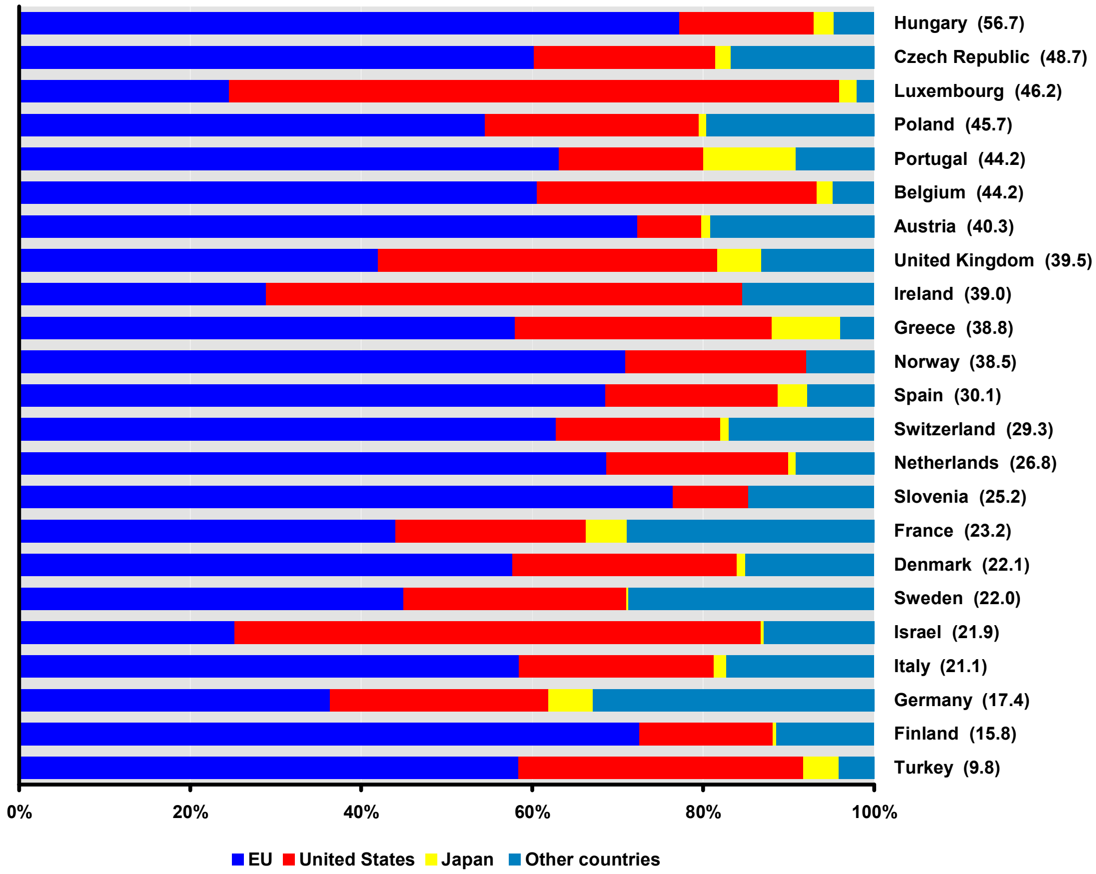
The flow of patents and inventions is more intense within Europe, indicating the existence of a European area for technology development

The figures below confirm the trend already observed for the period 1998–2003[166]: European inventions and patents flow predominantly within Europe. Foreign ownership of inventions in EU countries is largely intra-European and more evident in smaller countries, like Hungary, Portugal, Austria, Finland or Slovenia; ownership of US inventions is more frequent for Luxembourg, Ireland, Turkey and Israel, and in a lesser degree, also for the United Kingdom.

Similar findings can be seen for the domestic ownership of foreign inventions. For a majority of the European countries, foreign inventions originated in another EU country are registered in over 60 % of cases.

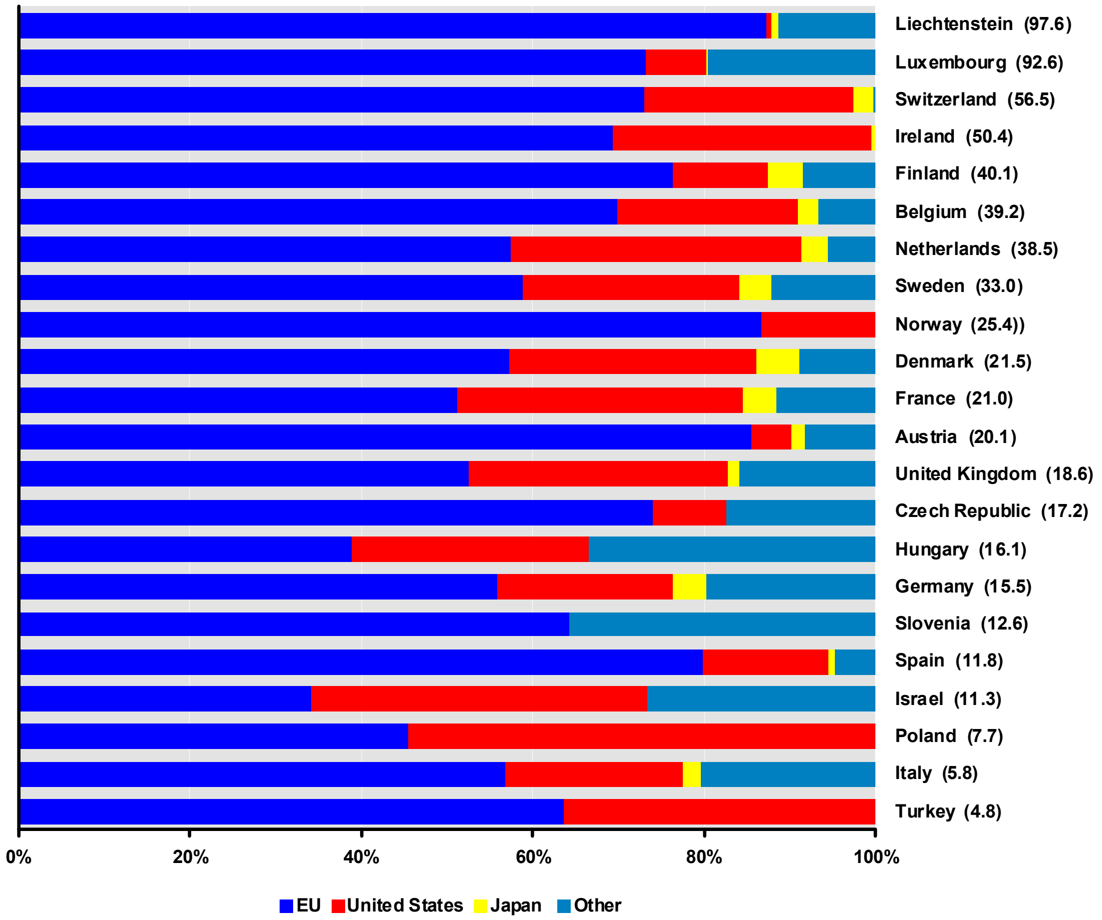
[166] See European Science, Technology and Competitiveness report 2008/2009.

Figure II.6.16 Foreign ownership of domestic inventions [1], 2007; in brackets: the share (%) of domestic patent applications owned by foreign residents



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data : OECD
Notes: (1) Domestic EPO patent applications owned by foreign residents.
The patents count is based on the priority date and the inventor's country of residence.
(2) In the cases of EU Member States, EU refers to all Member States except the Member State under consideration.

Figure II.6.17 Domestic ownership of foreign inventions [1], 2007; in brackets: the share (%) of domestic patent applications invented abroad

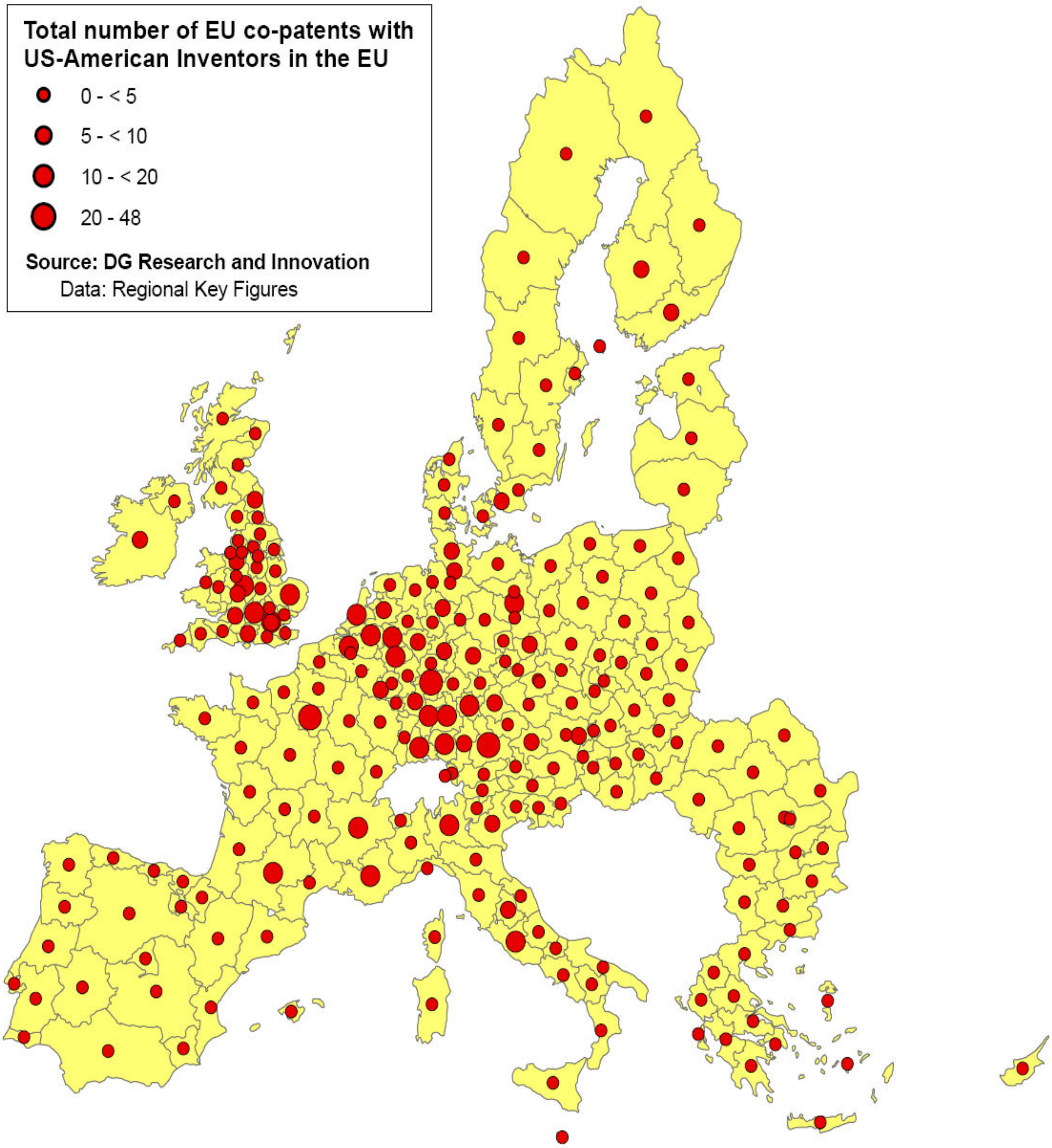


Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: OECD
Notes: (1) The number of EPO patent applications owned by country residents but invented abroad as % of total EPO patent applications owned by country residents.
The patents count is based on the priority date and the inventor's country of residence.
(2) In the cases of EU Member States, EU refers to all Member States except the Member State under consideration.

The capacity to absorb technologies produced outside the EU is concentrated in a few regions

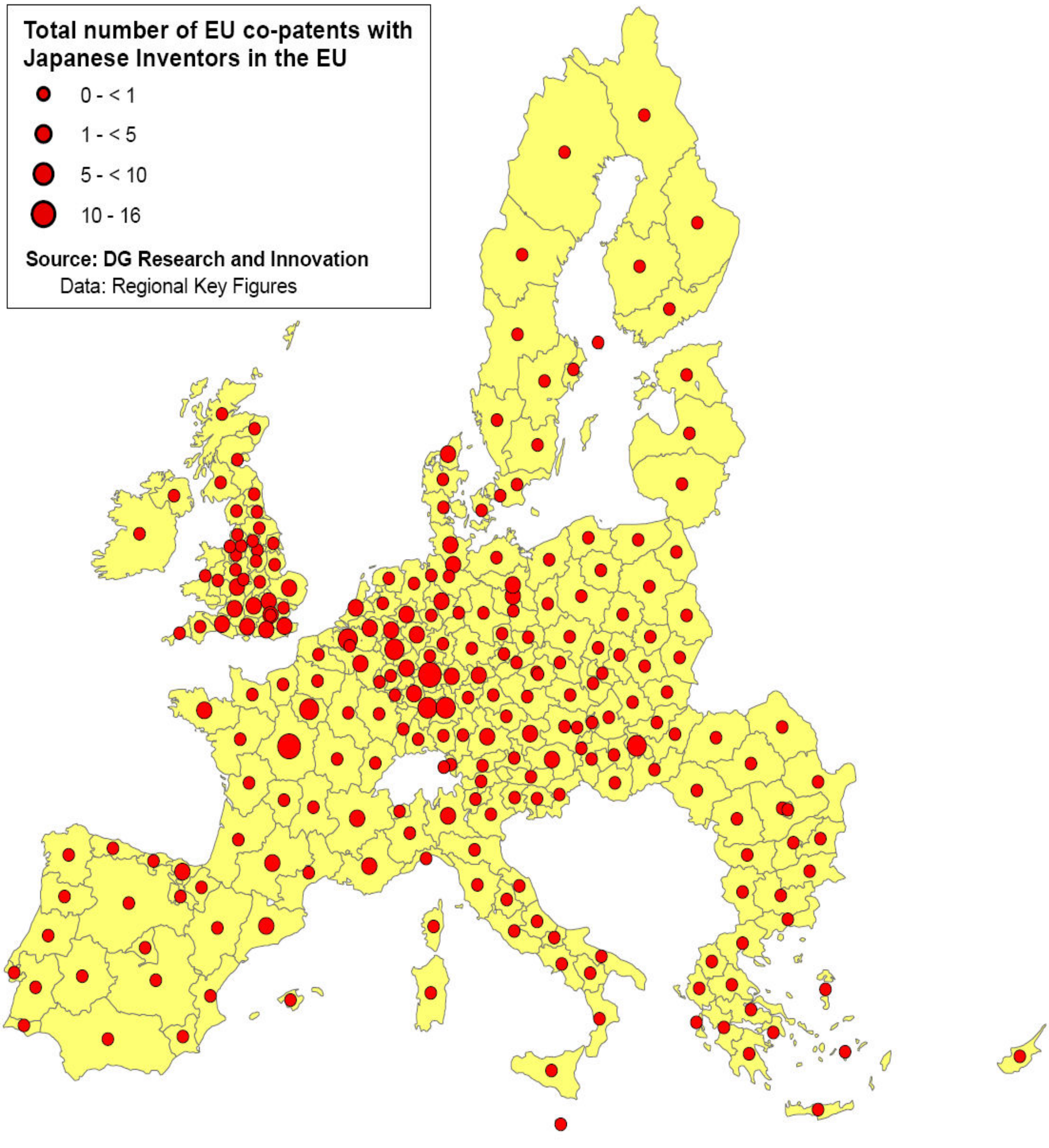
Co-patenting with third countries can also be a measured at the regional level as an indicator of the technology absorption capacity of a region. The following two maps show the total number of co-patents among EU regions with inventors from the United States or Japan. The maps illustrate that it is broadly the same regions that absorb technologies from the United States and from Japan, even though the total number of co-patents with US inventors is higher. Patterns of regional knowledge-absorption coincide mainly with the capacity of the regions to produce knowledge, with the exception of some regions in Sweden, Finland and Italy. Regions in the United Kingdom, Belgium, the Netherlands and western Germany are the largest technology absorbers in technology collaboration with co-inventors from the United States and Japan.

Figure II.6.17 Total Number of EU Co-patents with US Inventors



Note: 'Co-patents' refers to Patent Applications at the EPO, localised by residence of inventor
Source: Regional Key Figures, based on EPO Worldwide Patent Statistical Database (PATSTAT); regionalisation by means of OECD REGPAT; Map Basis Eurostat

Figure II.6.18 Total Number of EU Co-patents with Japanese Inventors in the EU

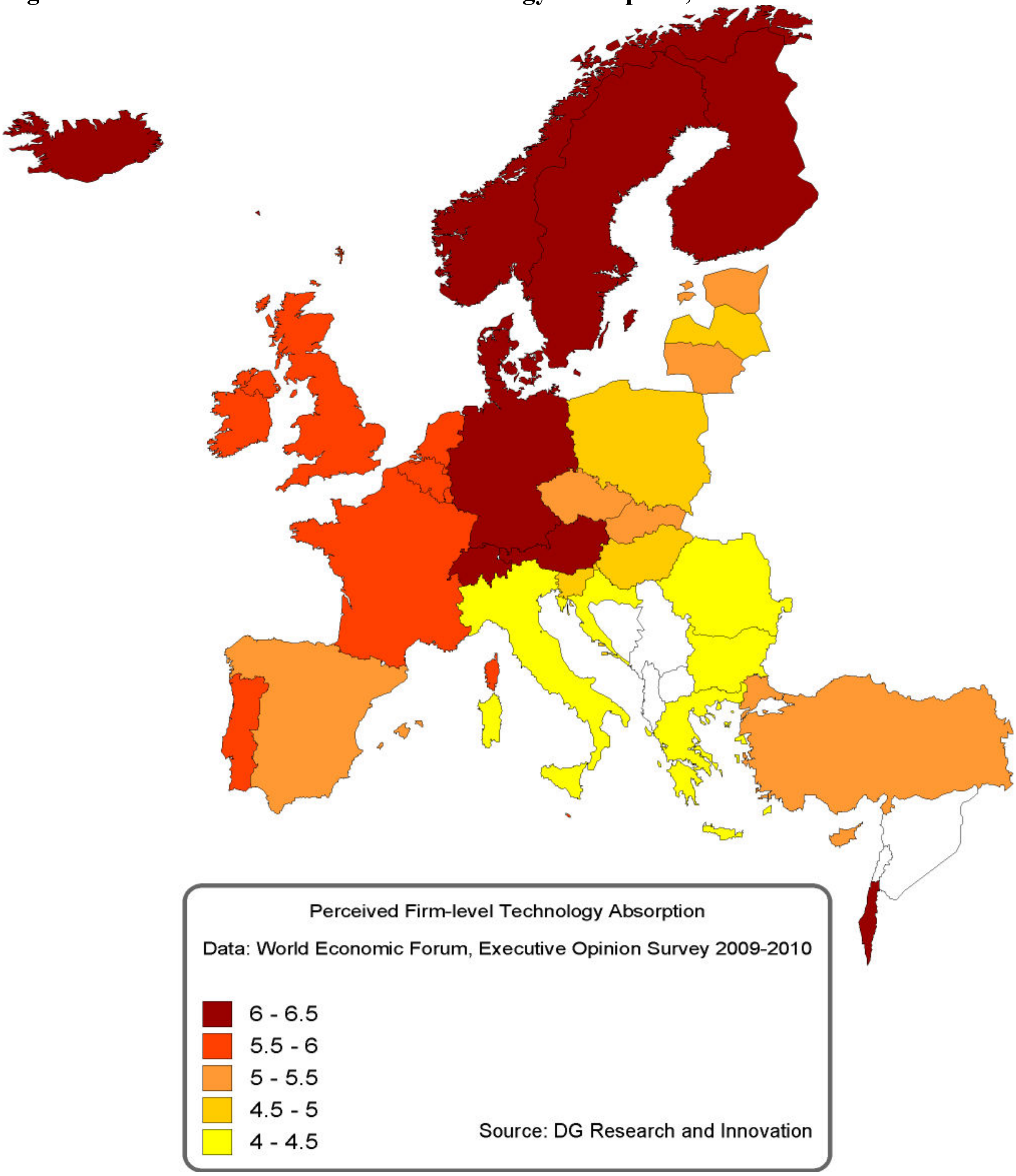


Note: 'Co-patents' refers to Patent Applications at the EPO, localised by residence of inventor
Source: Regional Key Figures, based on EPO Worldwide Patent Statistical Database (PATSTAT); regionalisation by means of OECD REGPAT; Map Basis Eurostat

The perception of firm-level technology absorption is highest among firms in the Nordic countries, Austria and Germany

The indicator on the perception of technology absorption by firms gives an estimation of the ease with which companies in a given country incorporate new technologies. Evidence shows that firms perceive highest technology absorption in strong technology producers.

Figure II.6.19. Perceived Firm-level Technology Absorption, 2009



Note: Averages; Question: Companies in your country are (1= not able to absorb new technologies; 7 = aggressive in absorbing new technologies)