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Trans-nationalizing innovation systems[1]: Defining, measuring and building framework for interconnected "silicon valleys"

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[1] This paper is an outcome of an ongoing research program "Trans-nationalizing innovation systems: channels and platforms for innovation and competence building" (CHAPS); Unit for Science, Technology and Innovation Studies (TaSTI), University of Tampere, Finland (www.chaps.fi)

1. Introduction

Innovation activities are not evenly distributed over the globe – instead they have concentrated to a number of locations and this tendency may remain although some of the strong present-day locations may change to some new ones as a part of the evolving change in the global division of labour. What has rarely been studied so far are the linkages, institutions and interconnectedness between these locations of intense innovation activities which cross the national borderlines and reach in many cases to other continents facilitated by foreign direct investments, collaborative networks or mobility of educated and entrepreneurial people. Even less than empirical studies there are contributions to conceptual and methodological aspects on this phenomenon we refer to as trans-nationalizing innovation systems. These issues are our interest in this paper.

This phenomenon was anticipated by Freeman (2002) who stated that the *national* level was the major phenomena of forging ahead, catch-up and falling behind processes in the 19th and the 20th centuries but all this may change in the 21st century due to an increasing capacity to use information and communication technology. This is related to a growing dominance of firms and networks with capability in *service* activities. The models which economists have used have largely been based on *manufacturing* activities, but manufacturing employment has declined substantially and although remaining important, financial, marketing, software, design and R&D services predominate in the portfolio of large MNCs. Competitive power will increasingly depend on the capability to manage international networks in production and marketing, with the core activities of research, design and development of software and hardware. Power in these networks will depend on a variety of information services and knowledge-based activities, but as they are embedded in social systems, political and cultural changes may then take precedence in the complex interactions between the various sub-systems of society at all levels of the global system. (Freeman 2002: 202; 209-210) As we now live 21st century, and Freeman's vision has manifested itself, we find it important to focus on this issue.

The paper will first discuss some key concepts that are necessary to make sense in measuring globalization of innovation (section 2). This is followed by a section (3) in which issues related to measurement and data are dealt with, after which some theoretical categorization is been presented. This categorization is then deployed in the subsequent analysis of some statistical data. The findings of this analysis indicate, among other things, that the process of trans-nationalization of innovation is more relevant in the context of such countries that can be characterized as small economies whereas the larger economies are yet less inclined to rely on external linkages (at least on average at a national level). It also seems evident that the regional level (or labour market area) would be a more appropriate spatial level of analysis than national. Thus, after preparing the grounds for its arguments, the paper then (in section 4) moves to discuss its key point which is that the trans-nationalizing to a great extent is a process involving especially those knowledge-intensive and innovation-driven geographical agglomerations, or "hotspots", and connects and builds interdependence between them. Innovation systems, then, co-evolve with these processes by their diverse formal and informal institutions and organizational settings. Next, we proceed to briefly outline the emerging framework aimed to capture the essence of the drivers, formation and impacts of trans-nationalizing innovation systems. This is followed by a short conclusive section (5).

2. From national to trans-national

As our focus in this paper is usually not that of nation-states and national innovation systems, we have found it important to clarify some of the key concepts. Portes (2001) distinguish cross-border organizational structures and activities to international, multinational and transnational. His definitions are based on sources and scales of activity as follows: international refers to programs and activities of nation-states, multinational refers to large-scale institutions like corporations or religions having activities in multiple countries and trans-national refers to border-crossing activities initiated and maintained by organized groups or networks of individuals and other "non-institutional actors" (ibid.). The following definitions are used in this paper:

- **Trans-national**[2] in this context comprise two latter definitions – multinational and trans-national – since the main point is to distinguish the activities that are clearly based on the activities of non-governmental actors of nation state from those who have no strong spatial obligations for their activities. It is well recognized, that both individuals and firms are connected with their surrounding environment with multiple ties and bonds, but they nevertheless have opportunities to conduct their innovation-related actions and steer the possible output to any location that seems the best to fit for their activities. Important difference is that nation state, or any other geographically defined regional authority, do not have this opportunity, but their goals have to be to enhance the activities in this certain spatially defined area. Trans-national is not totally free from the spatial bonds, but in that context it is recognized that within the real-life phenomena in which significant and long-term interactions are conducted, these tend to occur mostly between the limited amount of locations rather than everywhere, globally. Key agents are firms and individuals.
- **International** is then very similar concept with Portes (2001); i.e. agreements and activities between the nation states. In case of innovation activities, this refers to policies that aim to enhance the performance of the national innovation systems with activities and agreements crossing the national borders. Whereas transnational activities *transcends* the nation states and its spatial limits, international activities takes place and are organized between them to strengthen existing definition and specifically, to foster innovativeness of national economies. Key agents are national governments (or their ministries) and regional development agencies.
- **Globalization**, again, is a more macro level concept that refers to the overall interconnectedness of the economy and economic agents. Key agents are forums and institutional bodies mostly created by national governments, who are able to make global and supra national agreements, that have impact over several nation-states.

Bluntly, innovation related interaction and activities that take place at micro-level between the private agents (firms and individuals) crossing the national borders may be seen as *transnational activities*. They are not global in terms of multiple interconnections but rather build between two or limited number of agents (and regions) in most cases. Multinationals fit with this logic, and in fact, behind the emergence of concept of transnationalism were growing importance of multinational

[2] Transnational is rather trans-local or trans-regional in real-life, since it refers to actual interaction between the private actors (individuals, firms, organizations, etc.) that virtually always take place between certain localities or regions rather than nation states. Nation states however create significant borders for this interaction, and thus also trans-*national* connotation is well grounded.

corporations (MNCs) in 1980s (see Vertovec 2009). *Global policies* may be conducted by the global agents who have the authority (often given by national governments) to make globally binding agreements or recommendations. These agents refer to *"global policy makers"*, since their goals are mostly related to a creation of a more functional global economy instead of a success of any individual economies or firms (United Nations, World Bank, OECD, European Union, etc.).

Further, it may be reasonable to distinguish also *supranational policy* makers, which have authority to more limited geographical area but may possess capabilities, that used to belong to national governments, such as amending laws in case of the European Union. Two latter are quite overlapping in many terms (since global agreements rarely concern *all* the countries either) and they conduct policies that may benefit the global or supranational economy *at the expense of the single national economy*. Still, it may be feasible to distinguish between these two groups at least in definition because there is also an evident difference in their relation to socio-economic space.

3. Measuring globalization of innovation

3.1 Critical views to measures of innovation

While we extensively discuss about measuring the innovation in trans-national level in this paper, we are very well aware, that even national level measuring of innovation includes several short comings. To simplify the problems of measurement of innovation the following shortcomings are evident in all three major fields of measurement[3]; 1) R&D expenditures measure the input rather than output (innovations), 2) Patent data includes only those inventions, that new and worth patenting and still they may never turn out to be innovations, since they are not introduced in the market. 3) Innovation surveys may be partly subjective and lack time-series and international comparability

It may be relevant to start with the distinction between the inputs and outputs of innovation. Share of highly-skilled and educated labor force, for example, may be significant input for the innovation, especially in its more narrow sense as high-tech product, but it is not by means the measure for innovativeness or innovations, nor economic growth based on these innovations. Concrete examples to illustrate this are evident for example in Russia, where educational level is high, but innovativeness has remained low or case of brain drain from many developing countries, which clearly point out, how the value of highly trained human resources are almost completely depending on suitable socio-economic environment that provides opportunities to utilize the knowledge. This was pointed out already early economic analyses in context of human capital (Boulding 1968). The number of highly educated is a lot used measure however, not least because it is rather easy data to have. The interaction and its qualities between the individuals and their environments are much more difficult to measure.

[3] Following the idea of OECD's Frascati manual. Also bibliometric analysis is important tool in knowledge-based economy (although it includes several shortcomings as well), but it measures scientific work (output) rather than innovation and is not discussed here. (Smith 2010, 154)

More closely to innovation related R&D expenditures offer maybe better proxy to innovation and technological progress, but again, it is rather the input than output (innovation) of the process. To overcome input-output problem, for example expert questionnaires that aim to recognize key innovations from certain field, have been used. These questionnaires may be very informative, but it is difficult to form an overall picture according to these questionnaires and they are also somewhat subjective. (Nagaoka, Motohashi & Goto, 2010, 1085)

Critics below focus mostly on European Innovation Survey (CIS) that follow the ideas of Oslo manual and should be distinguished from more narrow surveys (like Yale Survey on Industrial Research and Development or Carnegie Mellon Universtiy R&D survey, etc.) Relate to CIS survey especially, following improvements should be considered:

- For cross-country comparisons, same questions, with same definitions and in same order should be asked and samples should be as similar as possible in each country. These similarities should be remained over time for time-series studies.
- Statistics should be collected from subsidiaries of multinationals and not just from activities executed and performed domestically, since increasingly R&D and innovation activities are conducted jointly by many multinational firms.
- While harmonizing of surveys is needed, in case of including more development countries, issues like capacity building, informal sectors, technology diffusion, etc. should be added to understand the processes in those countries better. (Mairesse & Mohnen 2010, 1147-1150.)

It should be noticed that the most important development in a survey-based innovation measurement has taken place in the case of CIS, and its basic format has diffused to Canada, Australia, Brazil, Argentina, China, and some other countries, which is very promising in terms of international comparisons. (Smith, 2010, 149.)

The increasing availability of (global) patent data[4] has made it more useful and valuable source for researchers of innovation and technological change also at international level. It is even said, that they are growing faster rate than patents themselves. Despite the clear advantages that patent data offers and improvements that have taken place recently, there are also serious shortcomings in this information when used as indicator or proxy to innovativeness**.** Although, patents are quite close to what one could say innovation, especially, in case of granted patents (instead of just applications) or citations of other inventors to certain patents, also this data has it shortcomings. Of these short comings at least following should be noticed according to Nagaoka, Motohashi & Goto (2010):

- There are differences in patent practices between the countries, for example co-ownership of patents is rarer in the USA due to different legal rights of the co-owners. In the USA, co-owner may use the invention to a third party, without consent of other co-owner, which is

[4] Patent data bases have been developed and maybe most important work in done by National Bureau of Economic Research (NEBR), but similar data bases have been developed OECD, European Patent Office (EPO) and Institute of Intellectual Property (IIP) in Japan. The problem is that databases are mostly targeted to firms, who may follow the development of their rivals, rather than form research purposes. Consequently, data bases are difficult (or even impossible) and time consuming to use for scientific statistical analysis due to their size and organization of the data. Emergence of suitable software, however, has made it easier to calculate analyses from NEBR data base, and partly explains the growing number of academic papers examining the patents. (Nagaoka, Motohashi & Goto, 2010, 1086)

not a case in Japan or Europe. Almost complete loss of control to invention understandably restricts the number of co-ownership patents in the USA.

- Only part of the patent applicants request the examination of patent application in Japan (66 %) and Europe (95 %) since there is not automatic examination like in the USA. Then, only part (about 30 % in Japan) of examined applications will be granted patents (1087)
- Patens are much more common in certain industries (chemicals, electronics) than others (services, textile) so industrial base of the region impact on the amount of the patents emerging from one region.
- Amount of needed patents is different and their efficiency is different depending on the line of business, so they do not directly tell which is more innovative, if compared without knowledge of sector in question. For example, in pharmaceutical industry patent is rather efficient way to appropriate rents from innovation, since new chemical entities in drug can be patented and it cannot be invented otherwise by someone else, while in electronics one product may require hundreds of patents and each of them may have many substituting technologies available.
- Citations to patents maybe better reflects their role in technological advancement, but often citations are done by those who examine the patents, not by other inventors.
- Not all patents will be innovations and there are significant differences between the patents. About 10 % of all patents account more that 80 % of the value of all patents in Germany (Scherer and Harhoff 2000) and in Japan more than 60 % of patents are not used internally or licensed out. Patents are often used just to stop other firms to enter the field.
- There are many inventions that are not patented if firms do think that they may maintain advantage otherwise. Especially process innovations are much more rarely patented than product innovations.
- Importantly, inventors address in application is often his or her business address and may even be the address of the headquarters instead of unit where inventor really works. Consequently, address does not give exact geographical location where inventor really is. (Nagaoka, Motohashi & Goto, 2010, 1086-1126)

In sum, as these problems indicate, there is lot of work to do especially at the international level, in order to produce more accurate data sets and tools to understand innovative activities and their relations to inputs and outputs of the process. Further, it clearly points out, that in-depth case studies to increase the understanding of the process and role of different environments have important role in this pursue. While we aim to collect and refine the statistical data analyses in the context of trans-nationalizing innovation systems approach, we hope to improve our understanding of the phenomenon by conducting in-depth case studies with conceptual tools of Channels and Platforms.

3.2 Taxonomy on cross-border innovation activities

There are many problems and obstacles related to the sources of statistical data on globalization and innovation. Smith (2010) has provided an assessment of data related to trans-nationalization (see a modified version of this in the Table 1). He points out (p. 76) that "…not all of the data is either as relevant or as high-quality as we might wish…" and that there are some indicators and statistics such as trade data that are "highly relevant for studying the growth of interdependent globalization when they focus on inter-industry trade, but of limited relevance when focused on arms-length transactions". Also Archibugi and Iammarino (2002, 105) state that the conceptual categories they

have developed do not match well with the statistical indicators: "Some indicators do not represent then totally (in the sense that they exclude significant parts of the phenomenon), others do not represent them exclusively (in the sense that they include phenomena that are not part of the object treated). There are further indicators that represent the phenomenon neither totally nor exclusively".

Table 1. Data on trans-nationalization of innovation (modified* from Smith 2010, 77)

Indicator	Definition	Data availability	Quality and relevance
R&D flows	BERD (Business Expenditure on R&D) investments by firms domiciled elsewhere	Questionable	'Arms-length' indicator of knowledge flows
R&D by affiliates	BERD by foreign-owned affiliates	Good	Highly relevant for interdependence
Patents by location of applicant	Patents by foreigners in domestic patent offices, or by domestic patent holders abroad	Excellent	Measure of invention; patents often unused
Technology balance of payments	Royalty payments and payments for patent licences	Poor	Relevant but limited by data quality
Migration, especially of the highly skilled	Cross-border movements of highly qualified people	Poor	Strongly relevant, with some signs of improvement in data quality

*Note: those indicators mentioned by Smith are omitted here that are not necessarily directly related to innovation activities (commodity trade, trade in services, foreign direct investment, foreign portfolio investment)

Archibugi and associates (e.g. Archibugi and Mitchie 1994, Archibugi and Iammarino 2002) have proposed a useful taxonomy on technological development and innovation activities that have a cross-border nature. The table (2) presents these three main categories and their main actors and forms. The first category ('international exploitation of nationally produced innovations') concerns the use by innovators to deploy their technological competences in markets other than the domestic one. Here, international trade is not the only option a firm may have: instead, it may find it more suitable to benefit from its competence by selling it disembodied (i.e. licensing it to foreign firms). A firm may also be interested in investing to another country to produce a particular innovative good there and thus maintaining the ownership of created intellectual properties. The authors' label the category 'international' in opposition to 'global' because innovations preserve their own national identity, even when they are diffused and marketed in more than one country.

In the second category ('global generation of innovation') the focus is on innovation generated on a global scale, usually by multinational enterprises (MNEs). Innovations here are based on inputs from multiple locations in different countries and these innovations are conceived on a global scale from the moment they are generated. This kind of operations is based on an internal network of an MNE and an efficient management of these geographically dispersed R&D units to combine their

competences and efforts. There are several ways how MNEs may organize their global innovation activities (see Bartlett & Ghoshal 1990).

A third category ('Global techno-scientific collaborations') consists of two types of actors (Archibugi & Iammarino 2002). Academic world has always transmitted knowledge from one scholar to another within a trans-national setting. Recently technological collaborations have increased also within the private sector. These are joint ventures in which two or more firms aim at developing new knowledge and/or products together. These joint ventures are often driven by a necessity to reduce the costs and risks of innovation and to cope with its increasing complexity. More and more these joint ventures take place between firms located in different countries.

Table 2. A modified taxonomy of the globalization of innovation, additions by the authors in italics (c.f. Archibugi & Michie 1995, Archibugi & Iammarino 2002, 101)

Categories	Actors	Forms
International exploitation of nationally produced innovations	Profit-seeking firms and individuals	Exports of innovative goods Cession of licenses and patents Foreign production of innovative goods internally designed and developed
	Public and non-profit organizations	*Transfer of good practices and social innovations (service models, operation practices, concepts, policies etc.)*
Global generation of innovations	Multinational firms	R&D and innovative activities both in the home and the host countries Acquisitions of existing R&D laboratories or greenfield R&D investment in host countries
	Supranational organizations	*Transfer of good practices and social innovations (service models, operation practices, concepts, policies etc.)*
	Individuals and firms	*Open Source Software projects based on development carried out in virtual communities (e.g. Linux)*
Global techno-scientific collaborations	Universities and public research centres	Joint scientific projects Scientific exchanges, sabbatical years International flows of students
	National and multinational firms	Joint ventures for specific innovative projects Productive agreements with exchange of technical information and/or equipment

In our view, the taxonomy seems to need some additions, because some important forms and processes of globalization of innovation are missing. First, there are many types of public and non-profit organizations that are interested in diffusing abroad their policies, service models or operational practices that have proven some merit, in order to create partnerships with similar

organizations in other countries or to attract new international clients and foreign direct investments, for example. There are, of course, supranational organizations such as WTO, WB, EU or OECD that play a role in creating and diffusing new policies but in addition, below the nation state level there are organizations that has a role here as well. Second, Internet has provided a new platform for virtual cooperation over long distances and has helped to create communities of specialists around, for example, Open Source Software (OSS) projects. These truly represent global generation of innovations. However, we cannot provide (at least yet) any statistical evidence of these additions.

The table 3 presents the categories by Archibugi and Iammarino (2002) with description of data used in this paper. As mentioned earlier, we will not concentrate here on the much studied phenomenon of the multinational firms and their efforts to globally generate innovations[5]. Instead we concentrate on the two other categories where other types of firms and organizations operate on a trans-national scale. Data is used to illustrate the trans-nationalization of innovation activities and to point out some tentative key points of the phenomenon. The data is acquired from the OECD (mostly from the recent report "Measuring Innovation – A New Perspective", online version, 2010) where a good deal of different perspectives has been combined to come up with a coherent picture of the recent developments at international level.

Table 3. Data on trans-nationalization of innovation

Categories	Actors	Forms	Data
International exploitation of nationally produced innovations	Profit-seeking firms and individuals	Exports of innovative goods Cession of licenses and patents Foreign production of innovative goods internally designed and developed	International technology flows (royalties and license fees) Firms with national / international collaboration on innovation*
Global techno-scientific collaborations	Universities and public research centres	Joint scientific projects Scientific exchanges, sabbatical years International flows of students	Trends in co-operation on scientific articles Highly cited (top 1%) scientific articles by type of collaboration Scientific publications and co-authored articles International students as a percentage of all tertiary enrolments
	National and multinational firms	Joint ventures for specific innovative projects Productive agreements with exchange of technical information and/or equipment	Regional average of PCT patents with co-inventor(s) by location Firms with national / international collaboration on innovation*
Global generation of innovations	Not applied in this paper		

*the same data because may be an indication of processes in both categories

[5] Nevertheless, we have to bear in mind that this third one is the one where probably the most extensive developments have so far taken place by the operations of multinational firms and foreign direct investments in terms of, for example, acquisitions of R&D laboratories and green-field investments on R&D facilities in host countries.

Nevertheless, as already discussed availability of good quality data of cross-border innovation activities is rather limited and, when available, tend to be biased towards research and patenting activities, and on public sector activities. Obviously, this kind of data is more easily tracked down than private sector's activities and national level analysis is often most interesting for supranational or global organizations like OECD. While this data is suitable to illustrate the phenomenon at rather general level, more detailed analysis to recognize the dynamics and interactions of trans-national innovation systems, will obviously need much more spatially (regional, trans-national) and functionally detailed data.

However, for the purposes of this paper, there is a good number (7) of indicators on "Global techno-scientific collaborations" whereas the other category, "International exploitation of nationally produced innovations", has only two indicators. All taken together, however, we believe they will indicate well the overall tendencies and offer adequate ground to make some tentative conclusions about the phenomenon.

3.3 International exploitation of nationally produced innovation

For the category of "International exploitation of nationally produced innovation", there are two available data sources that are "International technology flows (royalties and license fees)" and "Firms with national / international collaboration on innovation".

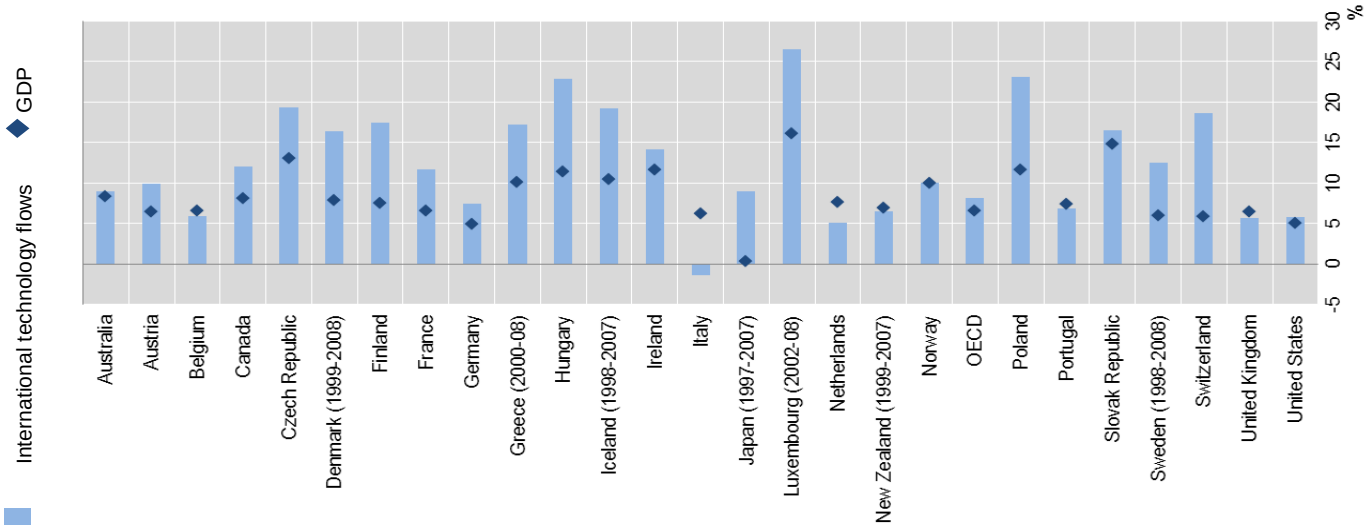

Figure 1. International technology flows (royalties and license fees), 1997-2008, average annual growth rate, based on USD, percentage (OECD, Technology Balance of Payments Database, December 2009; and OECD, Trade in Services Database, December 2009)

Figure 1 on international technology flows shows, first, that out of 26 countries with data 18 recorded higher percentage of growth in international technology flows than in their GDP, in seven countries GDP had grown more than these flows and in only one case (Italy) these flows showed a negative trend. On the average among the OECD countries, international technology flows have grown 8,1 per cent compared to the overall GDP growth of 6,5 per cent. Some of the large

economies are among those with rather slow or average growth of technology flows in relation to the GDP growth (e.g. UK, Australia, USA).

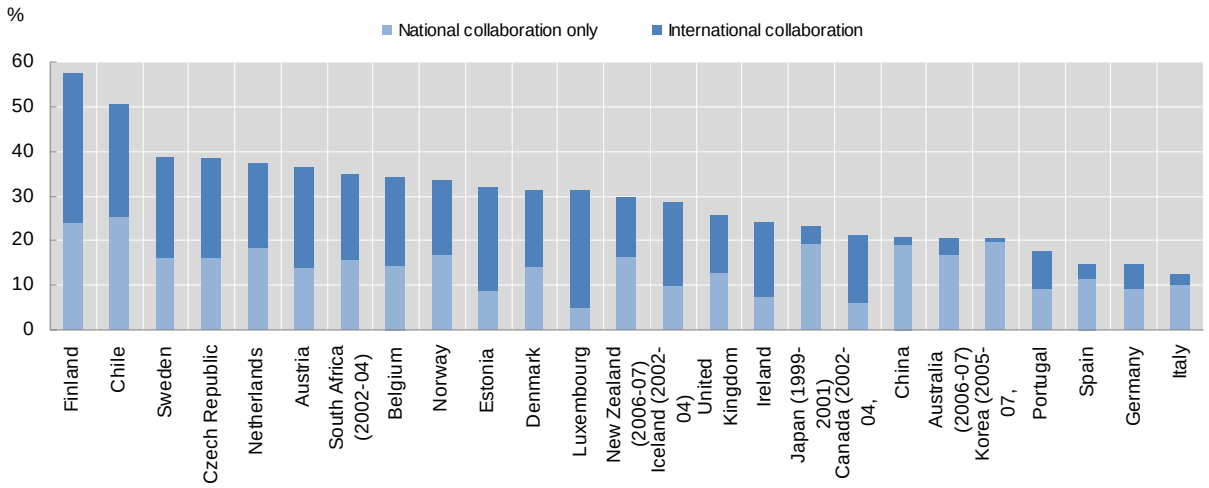

Figure 2. Firms with national/international collaboration on innovation, 2004-06, as a percentage of innovative firms (OECD, Innovation micro-data project based on CIS-2006, June 2009 and national data sources)

Regarding firms' international collaboration on innovation (Figure 2), out of 25 countries 14 reported higher shares of (also) international than national collaboration only. However, within the EU the countries with more tendencies to domestic collaborations included Germany, the UK, Spain and Italy. Outside the EU these countries include China, Australia and Japan. Concerning the international exploitation of nationally generated innovations, there is evidence that the countries most involved in this form of globalization are the smallest and the most technologically dynamic (c.f. Archibugi & Iammarino 2002, 111). This is to a great extent because of the limited size of their domestic market – a reason that has always induced firms to search for larger markets and especially so for products that require high investments (e.g. on R&D).

3.4 Global techno-scientific collaborations

As mentioned, there are many indicators on "Global techno-scientific collaborations" although a majority of these focus on universities' and other public research institutes' activities mostly. Thus, our indicators operate mostly in the development and interconnectedness of scientific and technological knowledge-bases.

Figure 3 shows that, overall, co-authorships in the fields of natural and medical sciences and in engineering representing two or more institutions have increased in importance over the period of 1985-2007 whereas single authorships have stagnated and single-institution co-authorships have remained on approximately same level.

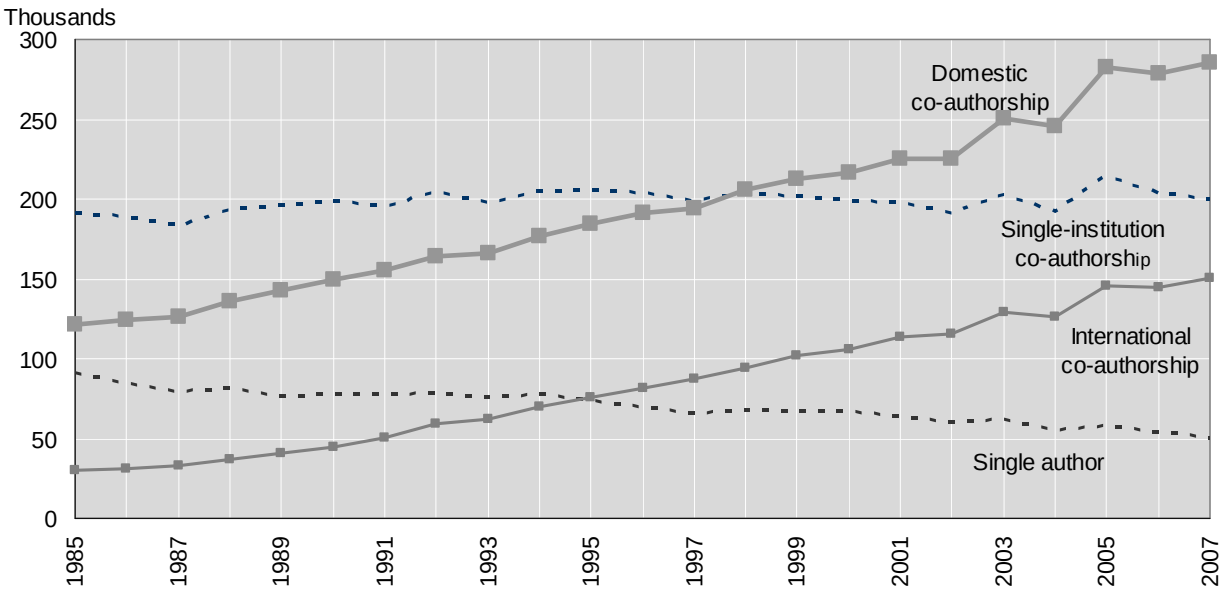

Figure 3. Trends in co-operation on scientific articles, 1985-2007 (the data is based on research articles in natural and medical sciences and engineering). (OECD Science, Technology and Industry Scoreboard 2009)

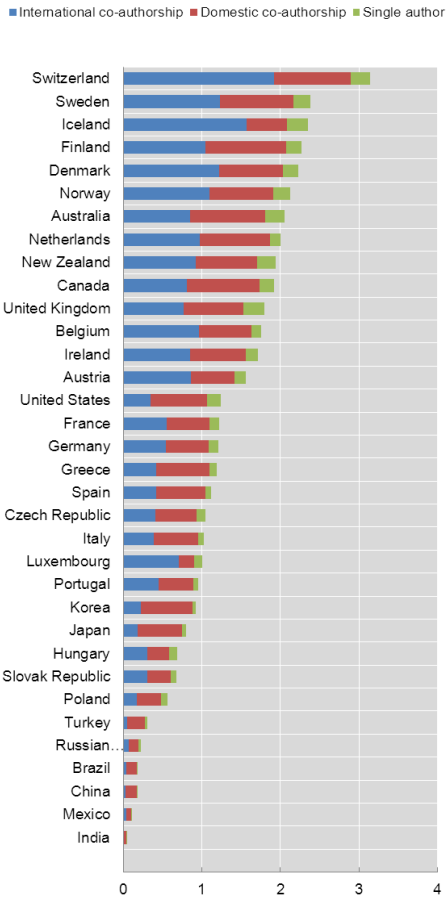

Figure 4. Scientific articles by type of collaboration, per capita, 2008 (Measuring Innovation: A New Perspective – OECD 2010)

If these authorships and collaboration of scientific articles are further studied by country in relative terms (Figure 4) it can be noted that among the top there are many small European countries that are also among the top performers in the Global Innovation Scoreboard (2009). Most of the large countries tend to have more domestic co-authorships. It is noteworthy also that the BRIC countries are, in relative terms, among the last countries.

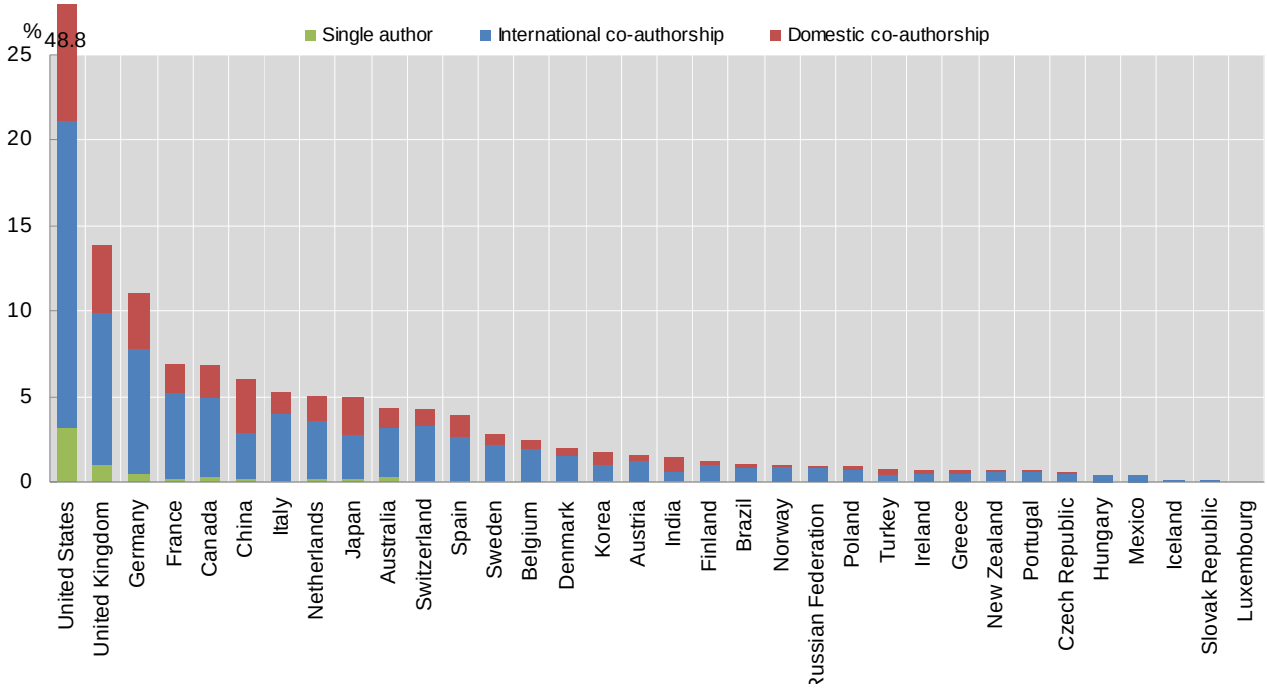

Figure 5. Highly cited (top 1%) scientific articles by type of collaboration, 2006-08, as a percentage of highly cited scientific articles worldwide (OECD calculations, based on Scopus Custom Data, Elsevier, December 2009)

Contrary to the earlier figure (4) on scientific articles in general, Figure 5 shows how the top one per cent of scientific articles measured by their citation rate are concentrated especially to the United States, and how this is combined with a high rate of almost 20 per cent of international co-authorships (and nevertheless, as well as almost 25 per cent of domestic co-authorships). Harshly, we may outline that the smaller the country, the more likely its top scientific articles are being written together with foreign collaborators, whereas in the cases of US, China, Japan and India about half of these are based on domestic collaboration.

Turning to the international mobility of higher education students, Figure 6 shows, first, that in general there are within the OECD and EU19 countries about seven percent average shares of international students and there have been slight increase in these shares between 2004 and 2007. Among the top-seven countries, six countries are English-speaking showing the advantage these countries have in this sense.

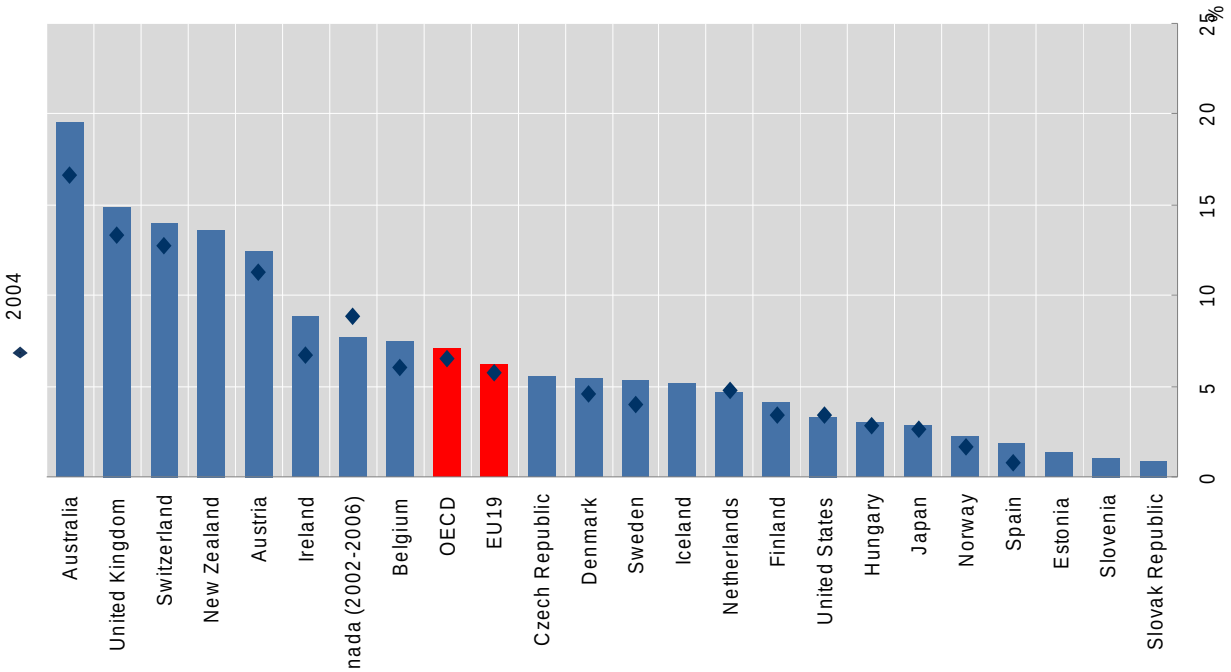

Figure 6. International students as a percentage of all tertiary enrolments, 2007 (Education at a Glance 2009: OECD Indicators)

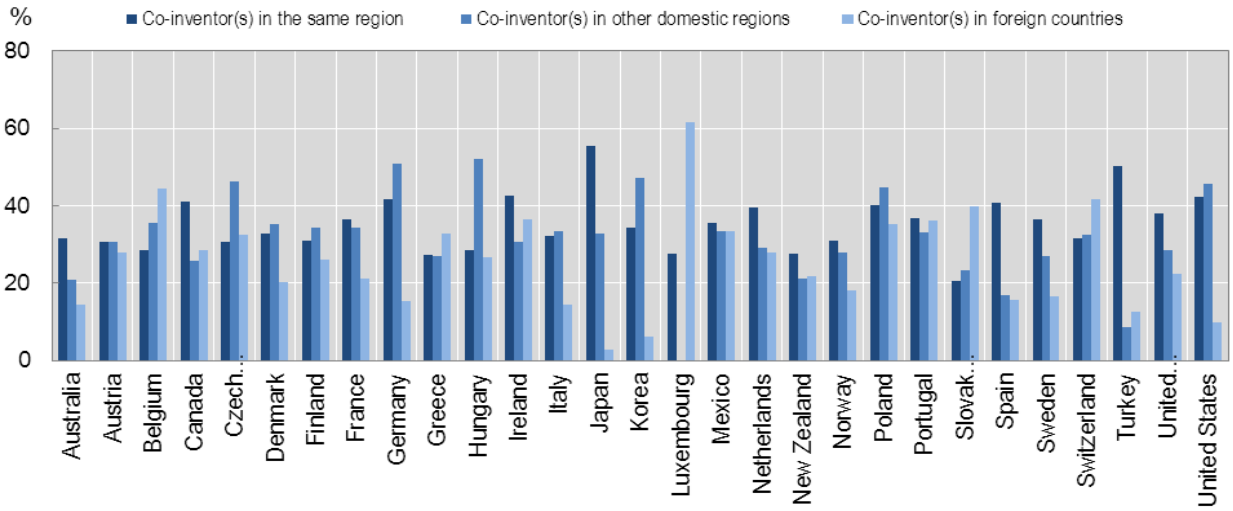

Figure 7. Regional average of PCT patents with co-inventor(s) by location, 2005-07, as a percentage of all patents (OECD, REGPAT Database, January 2010).
Data relate to patent applications filed under the Patent Co-operation Treaty (PCT), by priority date and inventor's region of residence. The regional breakdown refer to Territorial Level 2.

Using the patent data, the geographical pattern of collaboration shows some interesting results (Figure 7). Out of the total of 29 countries having the data, there are eight countries in which co-inventors were most often in the same region or in other domestic regions ("regional–national collaboration pattern"). Countries that represent the national collaboration pattern are Denmark, France, Germany, Italy, Norway, Sweden, United Kingdom and United States. Other domestic-oriented countries (6) are Australia, Canada, Japan, Netherlands, Spain and Turkey in which co-investors were most usually located in the same region.

There were also eight countries in a category in which co-inventors were equally distributed (difference between the geographical levels are 10 per cent or less) both in the same region or in other domestic regions or in foreign countries ("balanced collaboration pattern"). These countries are Austria, Finland, Greece, Mexico, New Zealand, Poland, Portugal and Switzerland. There is a group of three countries in which co-inventors are most often located in other regions of a country ("national collaboration pattern"). These three are Czech Republic, Hungary and Korea. In addition to the before-mentioned categories, co-inventors were most often located in other domestic regions and foreign countries in Belgium, in the same region and foreign countries in Ireland, and in foreign countries in Luxemburg and Slovak Republic.

What can be observed from these results? First, large countries tend to be somewhat inward-oriented in their collaboration patterns, as was noted also earlier here regarding some other indicators. Smaller countries form a more heterogeneous group as some small countries indicate the same inward-oriented tendency but for many small countries a more balanced or outward-oriented geographical collaboration pattern is also typical.

3.5 A regional perspective

While data above focused on the national level, it is important to remind that trans-nationalization of innovation activities and rate of innovation activities in general may be very different in different regions of the country. Figures 8 – 10 illustrate this viewpoint with a patent data from Finland and her two major economic regions, Uusimaa (including Helsinki region which is the biggest city-region with 1,4 million inhabitants) and Pirkanmaa (including Tampere which is the second biggest city-region with 0,5 million inhabitants) and Silicon Valley from the US.

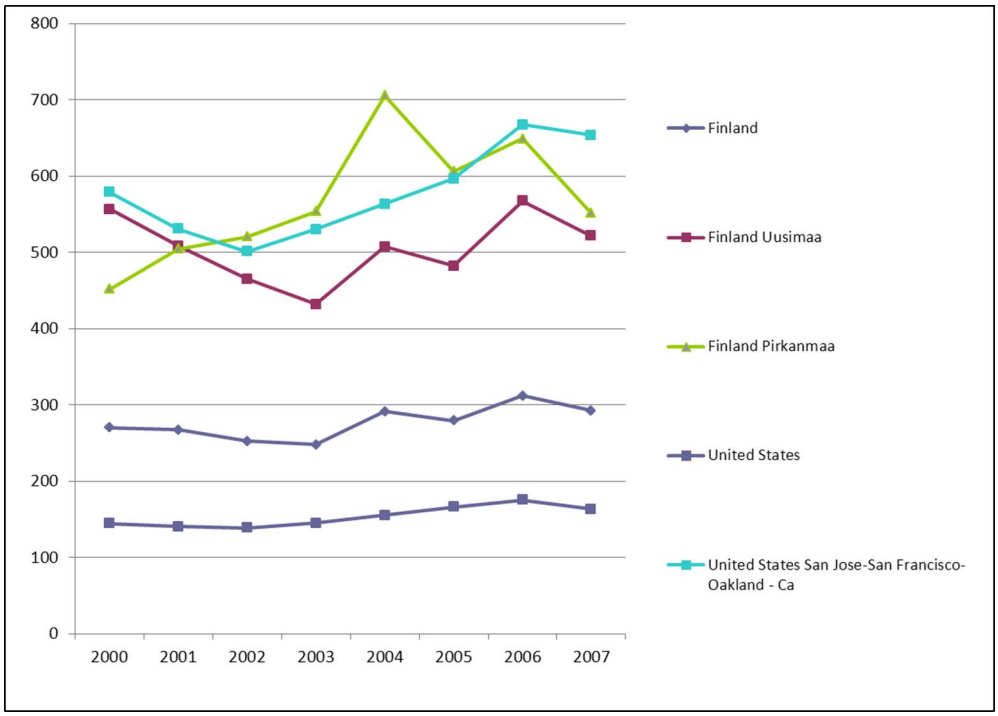

Figure 8. Patent applications per million inhabitants in US and Finland and key technology hubs (fractional count; by inventor and priority year) – level (OECD – Stat 13.6.2011)

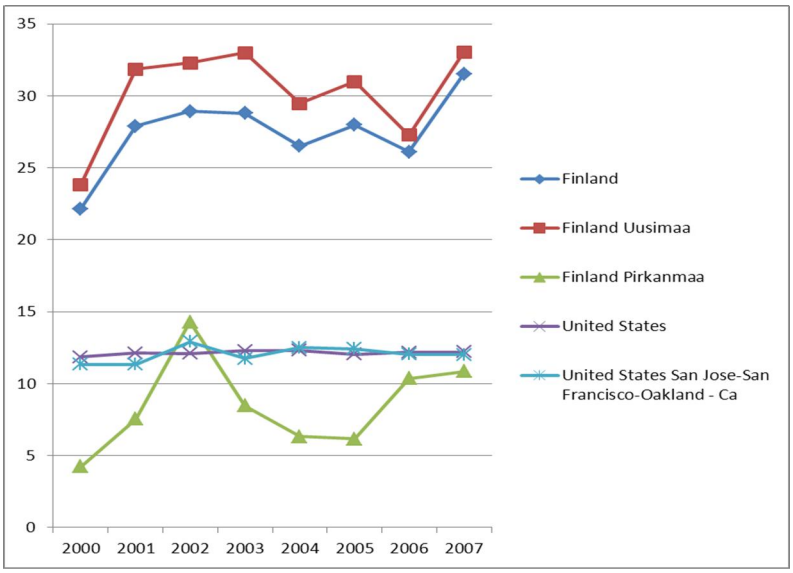

Figure 9. Domestic ownership of foreign patents (percent of PCT patents that have one or more foreign inventors and one or more domestic applicants in the total number of patents owned domestically, i.e. with one or more domestic applicants) (OECD – Stat 13.6.2011)

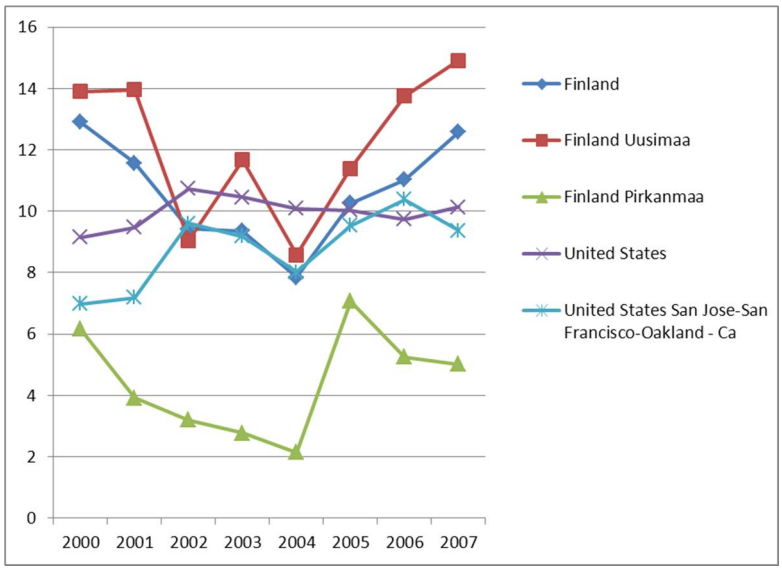

Figure 10. Foreign ownership of domestic patents (percent of PCT patents that have one or more domestic inventors and one or more foreign applicants in the total number of patents invented domestically, i.e. with one or more domestic inventors) (OECD – Stat 13.6.2011)

It seems, that at national level, Finland is above the US in her firms' and organizations' patenting activity (applications), but when looking at the key regions of the both countries, Silicon Valley has the same level of patent applications per inhabitant as Uusimaa (Helsinki region) and Pirkanmaa (Tampere region). In case of domestic ownership of foreign patent, when invention has been conducted at least partly by foreigners but it is owned by the applicant in the region, Finland has much higher score than Silicon Valley or the US but Pirkanmaa does not follow suit. When situation is otherway around, i.e. that invention has been conducted by (at least one) inventor from the region but it is owned by foreigners, the picture changes. Pirkanmaa is still on a lower level, but the difference between Silicon Valley and Uusimaa or Finland and the US is much smaller.

The result is parallel with those presented earlier, but important point is that Pirkanmaa is much less international (according to this measure) than is the case with Uusimaa or Silicon Valley (in case of domestic ownership of foreign patents), but in general patenting activity is roughly as high as in all three regions, and on clearly higher level than their national averages. Simply, due to significant

differences between the higly innovative regions, the regional aspect cannot be omitted in this context as the transnational connectivity is studied and its relation to innovation activities explained.

3.6 Summing up the lessons

We illustrated categories of "International exploitation of nationally produced innovations" and "Global techno-scientific collaborations" as well as regional aspect of trans-nationalizing innovation systems in order to outline the contours of the phenomenon. What we have found out?

- International technology flows have grown, during the last decade or so, in a majority of OECD countries although in some large economies such as the US, the growth has been only on a same level than the growth of GDP. This indicates that firms increasingly exploit internationally their domestically produced innovations by exporting innovative goods or by selling their intellectual property rights or by producing their innovative goods abroad.
- Out of 25 countries, in 14 it was reported that firms collaborate at least as much with foreign partners than with domestic partners. Again, it was mostly the large countries in which firms tend to have more often collaboration with domestic partners than with foreign ones.
- Concerning co-operation on scientific articles, over the period from 1985 to 2007, an evident tendency was from single authorship to co-authorships but here international co-operation have not, although grown considerably, caught up domestic co-operation but the gap has remained the same.
- Continuing with the co-operation on scientific articles, it seems that the small countries are more open to international co-operation and the large countries in general tend to be more inward-oriented. Nevertheless, in a case of the highly cited top scientific articles, the likelihood to foreign co-authorship increases. Among these articles, the position of the US is overwhelming as its share of these is as much as about 50 per cent.
- Within the OECD countries, the average share of international students is seven per cent of all students on the tertiary level. English-speaking countries have a stronghold here as six countries belong to the top-seven countries in this sense.
- Concerning the geographical pattern of patent collaboration (co-invention), out of the total of 29 countries with the data, in ten countries foreign co-inventors are as usual for inventors than co-inventors in their own region or in other domestic region. In other countries, same region or same country was more common.
- Spatial level of analysis is highly significant, if any conclusions are drawn. To recognize trans-nationalizing innovation systems, regional, city-region or labor-market area level data would be required. This is a challenge, since indicators of innovation are in general at their infancy rather than well-developed and easily available, not to mention international comparisons at the regional level, and further analyses of interdependence between the regional economies (consisting trans-national innovation systems).

As main outcomes of these findings, three things come before others. ***First, the phenomenon of trans-nationalizing of innovation activities seems to proceed although with very versatile pace and with heterogeneous forms varying from country to country. Second, the phenomenon seems to be more typical or acute for many small countries including some of the most dynamic innovation economies*** (e.g. the Nordic countries and Switzerland). ***Third, spatial level of analysis has to go beyond and within the nation-state.***

4. Trans-nationalization of innovation systems: CHAPS framework

In this section, we will present the evolving framework intended to facilitate the studies on trans-nationalizing innovation systems. The idea behind the twin concept of (trans-national) channel and (local) platform (CHAPS) is that, first, innovation activities are to a great extent concentrated to a limited number of localities around the globe and within countries – typically to the largest cities with universities, large R&D-intensive firms, other research and innovation facilities and specialized business services. Second, these knowledge-intensive agglomerations are increasingly becoming interconnected: actors in one agglomeration are searching for complementary competences and market opportunities, among other things, from another agglomeration often also in a great distance. Also labor mobility and trans-national entrepreneurship between such agglomerations (especially in cases with similarly specialized agglomerations) is becoming more intense as many examples indicate.

4.1 Towards the interconnected "hotspots" of innovation?

Trans-nationalization of innovation activities is actually very place-specific phenomenon in a sense that the innovation activities to a great extent concentrate on a limited number of locations around the globe. This notion is not in any way novel but instead has its roots that can be traced back to the Marshallian concept of an industrial district. Later, scholars such as Porter (Porter & Sölvell 1998, 441) stated that "(f)irst, a large proportion of total world output of particular goods is produced in a limited number of highly concentrated regions. Second, firms in particular industries, or firms which are technologically or otherwise related, tend to collocate and form spatial clusters. Third, these both these phenomena tend to be persistent over time."

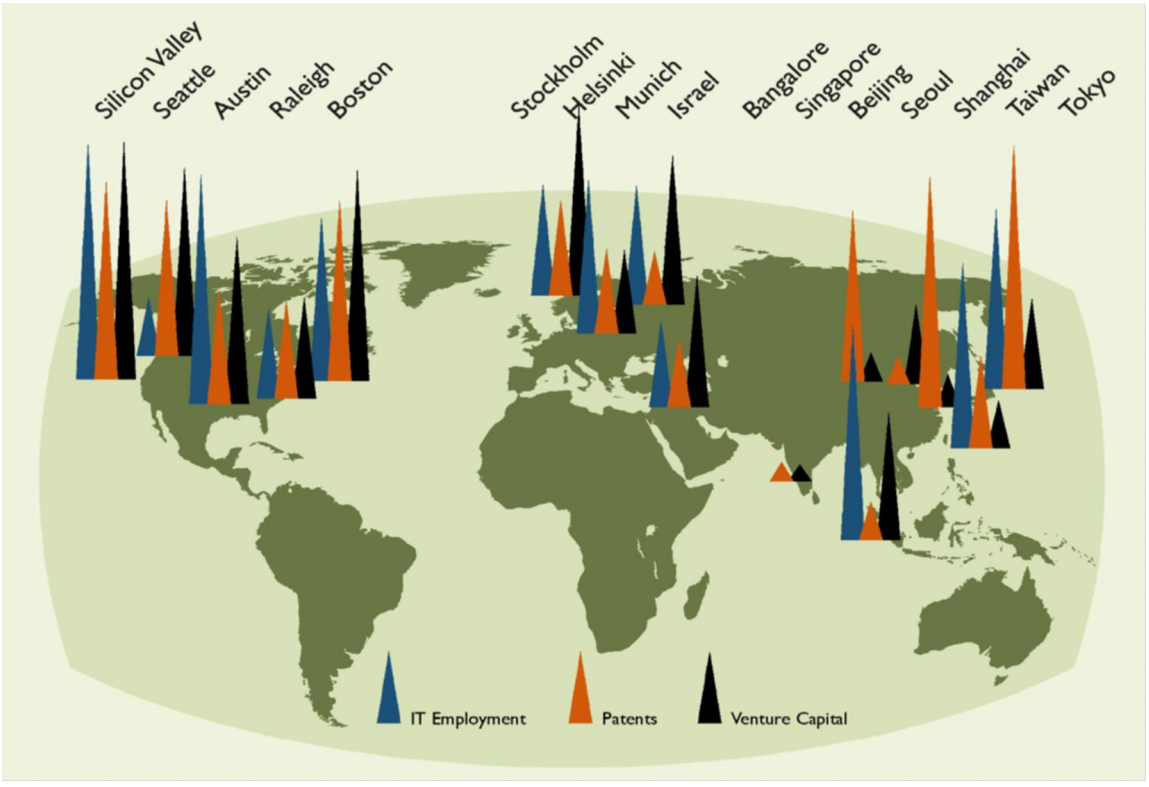

Figure 11. The world of innovation is spiky (source: Grose 2008; 2007 Index of Silicon Valley)

Recently, Florida (2005) has come up with an argument that "the world is spiky". He states that "…our world is amazingly 'spiky'. In terms of both sheer economic horsepower and cutting-edge innovation, surprisingly few regions truly matter in today's global economy. What's more, the tallest peaks – the cities and regions that drive the world economy – are growing ever higher, while the valleys mostly languish." (Ibid., 48).

The most fascinating issue nowadays, however, is not the spikes themselves but the drivers, increase and impacts of interconnections and interdependence of different types of knowledge-intensive and innovation-driven cities and other agglomerations. This is the starting-point for our efforts to build an analytical framework.

In our work, we deploy the concepts of the innovation system (IS) approach because we are interested in the wider system of informal and formal institutions and organizational settings that nurture or hinder innovation activities to develop beyond the national borders. At the same time, we consider that the IS approach is in the need of development: the national perspective still tends to focus on the nationally limited scale (see e.g. Lundvall 2010), and the regional variant (see e.g. Cooke 2010) has often recognized the multilevel characteristics and interdependencies of innovation but has not yet provided much tools to grasp the phenomenon. Sectoral perspective (see e.g. Malerba 2008) is more interested in the industrial dynamics as such than the institutional and spatial conditions that enable or hinder these dynamics. So far there has been a lack of innovation system level analyses and theorization of globalization (Oinas 2000, Carlsson 2004), with an exception concerning the role of large multi-national or trans-national companies (MNCs or TNCs) and their R&D structures as vehicles of knowledge transfer between different national innovation systems.

Only few attempts have been made so far to cover this challenging field in broader terms, including also other kinds of flows and linkages and trying to contribute to analytical and methodological development as well. Here we can refer especially to the contribution by Coe and Bunnell (2003, see also Bunnell and Coe 2001) on transnational innovation networks, and to the contribution by Wixted (2010) on the external, often global networks of geographical clusters, or as he puts it, "…at least one sub-field of the study of innovation systems should focus on a multi-spatial framework which facilitates analysis of how places are connected to one another" (ibid., ix). We prepared our first paper on the conceptualization of the trans-nationalizing innovation systems in 2010 (Kautonen & Raunio 2010) and intend to develop that further by adding also more and more empirical elements. On the firm level, concepts such as global pipeline by Owen-Smith & Powell (2004) and Bathelt et al. (2004) have recently been presented.

Interestingly, from the management literature perspective, Hagel and Brown (2011) ask how "talent spikes" can be weaved together, meaning that "(m)ost companies have a siloed view of talent spikes. They see open innovation and participation in highly specialized offshore locations as separate initiatives. They are still focused on developing the management practices required for participating effectively in individual spikes. As interesting as these opportunities are, they pale in comparison to those that will come from effectively orchestrating activities across a growing number of diverse spikes. How can a company take the deep expertise that is emerging in Shanghai and connect it with a spike that is emerging around mobile technology in Helsinki or Bangalore?

Now a company is networking pools of talent together across national and firm boundaries in ways that create more rapid learning through their interactions." The issue seems to be very topical.

Cooke and Laurentis (2010) integrate issue of governance of regional innovation systems to internationalization in their conclusions drawn from the extensive international research project (Eurodite). They have developed a regional governance models (including "platform governance") and emphasis the need of "being open to the world for understanding, while applying the transferred knowledge to indigenous economic assets." There is need to combine industrial and governance knowledge flows in as specific territory with international innovation system proximities. (Cooke & Laurentis 2010, 358.) In fact, several studies have conducted regional or national level analyses to pinpoint the benefits of spatial proximity and social capital based on the common history and mutual understanding and trust (Doloreux 2002; Maskell & Malmberg 2001; Storper 1997, etc). We are focusing on those increasingly more typical occasions, where there is no spatial proximity is lacking, but i.e. cognitive and relational proximity may be high.

4.2 Emerging CHAPS framework

We hope to shed some more light, with CHAPS approach, to this field through both, more accurate statistical analyses, better tailor-made concepts and strong case studies, since the complexity of the phenomenon cannot be captured with statistics only. Main conceptual tools are *channels and platforms*. Our view to a channel is not so much about communication, interaction or knowledge transfer as such, but we are *more concerned about the organization and governance of the channels, that provide significant resources for the innovative activities at the system level*. In these cases, channels may provide resources and potential opportunities, that may be difficult to recognize for the local agents and vice versa and well-functioning platforms are needed to intermediate or to "translate" the ideas and resources to fit with the novel environment[6].

Thus, our concept of channel always includes the platforms, that able the utilization of the resources provided. The main focus is how process is or is not organized and governed at the system level and by whom? To study this, the main content of flows (human capital, finance or ideas and technologies) and process how to utilize these (learning) have to be recognized as well as modes of flows (mobile, fixed or circulation) and at least to some extent also roles in innovation processes (establishing, complementing, renewing) should be recognized. To simplify, channels and platforms refer the governance of the two broad key processes of the innovation system – interaction and learning – over distance, where spatial proximity do not support the formation of cognitive or cultural proximity overtime and eventually emergence of social capital and communities (of practice) (see Kautonen & Raunio 2010)

Channels and platforms do not refer to, for example, connections and management systems between individual firms or within MNC's multiple locations, but between two economic regions (often city-regions). In sum, the first key concept, ***channel,* refers to *governance of the flows that***

[6] *Including:* ***Human capital flows*** (e e.g. foreign experts, "argonauts" who move back and forth between two locations, expats, international and foreign students, co-operation and collaboration with international partners), ***Corporate flows*** **(***financial flows*, e.g. foreign direct investments (inward and outward; greenfield and brownfield) and ***Policy flows*** (policy models, best practices, and supporting political and economic views and indicators that aim to impact on the form and functions of innovation systems in certain countries)

directly or indirectly support the innovative activity of the national or regional economy, cluster or a group of firms.

Channels (and platforms) may be defined according to a key agency (or agencies) in building of channel:

- ***Innovation generating channels*** (organized as multinational firms, VC, R&D consortia and/or strategic alliances etc.) where firms are key agents in channel building
- ***Innovation-enabling channels***
  - *policy-based channels* (organized as trans-national policy programs, trans-national innovation or export centers, scientific diasporas and/or various types of international university links, etc.) where policy makers and public sector are key agents of channel building
  - *individual-based channels* (organized as transnational social spaces, scientific diasporas and/or, trans-national entrepreneurship etc.) where individuals are key agents of channel building
  - *other channels* in which cases, for example, channels are established by NGOs or other agents not included to the previous categories. However, for example business associations build on personal relationships and community based goals, and may be included to the individual-based channels.

Importantly, channels are often ***implemented with mixed combinations of actors,*** with initiative and agency of multiple type of actors such as firms, transnational entrepreneurs, intermediary organizations, universities or NGOs, governmental institutes or alike. Especially policy-based channels rather facilitate the activities of firms, universities, NGOs or individuals in close co-operation with them. Then, allocation above refers more to leading role and goal setting than actual set of participating actors, which is often wide. Channels may also partly consist of flows that are not that intentional or the actors' intentions may be some other than directly to foster the innovativeness of an innovation system they are embedded into[7].

Platform refers **to utilizing of flows that channels provide**. They may exist on a variety of levels and may take different forms. Examples of platforms are innovation networks and clusters, communities of innovation, and single firms and organizations. Concepts of platform and channel are often overlapping and interdependent but serve for different ends of utilization and governance of flows. Platforms may be active in both ends of the channel (i.e. innovation system) or they may be very active in one end and less active in other end. The main division may be done between the *utilizing platforms* where flows are received and used to support innovation, and *generating platforms* where flows are created and sent to the new location – although these two may exist as combinations. As in the case of channels, also in case of platforms, the key agents and modes of governance should be recognized at the system level, but the focus is on generation or utilization of the resources. Obviously, utilization refers to importance of absorptive capacity (Cohen & Levinthal 1990) that platform supports. While the channel refers to relational proximity which always

[7] It should be noticed, that whereas a for example concept of global *pipeline* (Bathelt et. al 2004) refers to intentional collaboration between two firms, we want to underline that in *channel* there is often a large number of connections between a group of heterogeneous actors and numerous flows of resources between interconnected innovation systems. In addition, there are typically also attempts to somehow govern these connections and flows because these are usually considered important and at least potential sources of competitiveness.

includes interaction, the platform emphasizes also cognitive proximity, which refers similarities in mind-sets and behavioral patterns (see Bossard & Vicente 2011, 111).

The empirical content of a platform may include, for example, some university units and firms, which are closely connected with the same channel or it may contain customers and socio-cultural environment, where a service firm aims to introduce its novel (in the region) service concept. Thus, platform is rather generic notion referring to an intermediating process where "flow" is adjusted to its novel environment where innovative actions are carried out and tested.

5. Conclusions

We have here, within a very limited realm of a conference paper, discussed issues related to the measurement and data on globalizing innovation activities. This was followed by a statistical analysis that indicates, among other things, the phenomenon of trans-nationalizing of innovation activities seems to proceed although with very versatile pace and with heterogeneous forms varying from country to country. It was also noted that the process of trans-nationalization of innovation is more relevant in the context of such countries that can be characterized as small economies whereas the larger economies are yet less inclined to rely on external linkages (at least as an average on a national level). It also seemed evident that the regional level (or labour market area) would be a more appropriate spatial level of analysis than national. The paper then moved to discuss its key point which is that the trans-nationalizing to a great extent is a process involving especially those knowledge-intensive and innovation-driven geographical agglomerations, or "hotspots", and connects and builds interdependence between them. Innovation systems, then, co-evolve with these processes by their diverse formal and informal institutions and organizational settings. We then proceeded to outline the emerging CHAPS framework aimed to capture the essence of the drivers, formation and impacts of trans-nationalizing innovation systems.

Methodologically, the spatial level of analysis is highly significant in this context. To identify any processes and impacts of trans-nationalizing innovation systems, regional, city-region or labor-market area level data would be required. This is a challenge, because of the fact that the indicators of innovation are in general at their infancy rather than well-developed and easily available, not to mention international comparisons at the regional level, and further analyses of interdependence between the innovation-driven geographical agglomerations around the globe.

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