KNOWLEDGE FLOWS AND TECHNOLOGICAL TRAJECTORIES IN THE MEDITERANEAN AREA: EVIDENCE FROM PATENT CITATIONS

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Abstract

The innovation process is a fundamental source of economic growth and recent research in urban economics and economic geography suggests that geographical proximity between innovators may be important to technological innovation. Many authors also claim that the rise of a knowledge-based economy and changes in the organization of the innovation process have actually increased the value of such proximity to innovation. But yet there is little empirical research on how knowledge flows between developed countries to developing ones and vice versa.

A high level of consensus exists regarding the importance of scientific progress and technological innovation for the growth and competitiveness of firms and for the improvement of national economic performance.

Most of the literature focus on international technology diffusion between developed countries, The literature emphasize principally on three channel for the international knowledge diffusion: the international trade that assures free access to knowledge embodied in imported goods (Coe and Helpman 1995) and knowledge in global export markets through "learning by exporting" (Bernard and Jensen 1999) and the contact with advanced foreign firms; the labour mobility that is source of knowledge exchange because workers are endowed with specific know-how (Rhee 1990, Pesola, 2007); and finally foreign direct investment (FDI) (Blomstrom and Kokko 1998, Aitken and Harrison 1999, Crespo and Fontoura 2007) that represents an important source of technological spillovers although the empirical evidence remains mixed with regards to the distributions of benefits between the multinational and domestic companies.

In order to test the existence of a further channel in international knowledge diffusion, some recent empirical work analysed in a knowledge production framework (KPF) (Murseth and Verspagen 2002, Bottazzi and Peri 2003, Peri 2005). At sectoral level, Malerba et al. (2007) found that extremely relevant sectoral knowledge flows cross national borders.

Only few make a relationship between developing countries and developed ones. Coe et al. (1997) examined north–south R&D spillover. They found that total factor productivity in developing countries is significantly boosted by the R&D stock of industrial countries, which they computed as the import-share-weighted sum of the R&D expenditures of a developing country's trading partners in the north. They interpreted this as evidence of north–south R&D spillover. Hu and Jaffe (2003) examined patterns of knowledge diffusion from U.S. and Japan to Korea and Taiwan using patent citations. They found that Korean patents are more likely to cite Japanese patents than U.S. ones, maybe due to their proximity. They also found that both Korea and Taiwan are surprisingly reliant on relatively recent technology.

A comparison of patterns in knowledge diffusion from the US and South East Asia (Korea and Taiwan) and Latina America (Brazil and Mexico) from 1976 till 2002 has been presented in the IV Globelics Conference at Mexico City. Aboites and Beltran (2008) conclusion were that the patterns of knowledge diffusion from US to Latin American and South East Asian countries are quite different. They found that the South East had a higher number of patents granted in USPTO than their Latin American counterparts and the technologies registered in Korea and Taiwan were of high technology (Information and Communications, Electric and Electronics, etc.) meanwhile in Latin America (Brazil and Mexico) the technologies registered were of traditional tech fields (mechanical, chemical, etc.). In their studies, they found also that the citations received (forward) by Korea and Taiwan outnumber the citations received by Mexico and Brazil. That means that the value of knowledge in Asian countries.

Montobbio and Sterzi (2008) analysed nature, sources and determinants of international patenting activity in Latin American countries and the extent to which these countries benefit from R&D performed in some developed countries, using a patent citation analysis. They found that that the stock of ideas produced in the US has a strong impact on the international patenting activity of these countries.

The purpose of this paper is to investigate the pattern of knowledge flows and technological trajectories, as indicated by patent citations, between North Saharan (NS) countries and South European (SE) countries and explore the nature of these flows during the 1984-2003 period.

The results describes the patterns of knowledge diffusion for the NS area counties and SE area countries during the 1983-2004 period are quite different. We found that, obviously, the SE area countries had a higher number of patents granted in EPO than the NS area countries. Furthermore, the technologies registered in SE area countries were evenly distributed across sector meanwhile in NS countries the technologies registered were of traditional tech fields and tend to exclude the Mechanical Elements/Machine Tools/Transport and the Consumer goods sectors. That means that the value of knowledge in SE area countries is more important that the value of NS area countries. The other strong finding, to be further investigate, is the extremely high speed of knowledge diffusion seen both in forward and backward citations from/to the NS area countries for the sector of industrial process.

1. Introduction

International technology diffusion involves several different channels and affect significantly the way and the ability of developing countries to learn and innovate.

In this paper, we describe technologies trajectories and knowledge flows, using patent citations as an indicator from more technologically advanced South-European countries (SE) to North-Saharan (NS) developing economies and vice versa. We extract from the EPO Worldwide Patent Statistical Database, all patents taken out in the NS and SE countries, that have been granted from EPO, with priority dates from 1984 to 2003. We explore first the simple statistics of these data regarding the rate and technological composition of inventions in these countries over time.

All of these countries have seen a dramatic acceleration in their patenting over time, in particular among the lower end of "first world" countries in terms of patents per capita.
We then present simple statistics regarding the frequency with which inventors in each of these countries cite patents originating in the South-European countries.
The rest of the paper is laid out as follows. A review on background and previous literature is presented in section 2. Section 3 details the methodology and the data. Section 4 concludes.

2. Background and literature review.

A high level of consensus exists regarding the importance of scientific progress and technological innovation for the growth and competitiveness of firms and for the improvement of national economic performance.
Most of the literature focus on international technology diffusion between developed countries, The literature emphasize principally on three channel for the international knowledge diffusion: the international trade that assures free access to knowledge embodied in imported goods (Coe and Helpman 1995) and knowledge in global export markets through "learning by exporting" (Bernard and Jensen 1999) and the contact with advanced foreign firms; the labour mobility that is source of knowledge exchange because workers are endowed with specific know-how (Rhee 1990, Pesola, 2007); and finally foreign direct investment (FDI) (Blomstrom and Kokko 1998, Aitken and Harrison 1999, Crespo and Fontoura 2007) that represents an important source of technological spillovers although the empirical evidence remains mixed with regards to the distributions of benefits between the multinational and domestic companies.

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Knowledge flows and measuring.

As mentioned above, spillovers are often considered as synonymous of the side effects of a strategy (De Bondt 1996). Innovators may reduce or enhance the competitiveness of a rival producer, and the down steam firm may purchase the products as an intermediary or inputs, so that may also allow quality improvements or cost reductions that cannot fully be appropriated by the innovator (Griliches 1991). It is more practical that spillovers means, firstly, firms can gain valuable information about technology from other firms' innovation without pay; secondly, the information emitting firms have no sufficient way to protect their innovation results under current law and regulation systems. Just for this reason, firms in related fields tend to cluster together, and make it easy to share common information and innovation investments.

As De Bondt (1996) shows, that there are two limitations for spillovers in firm level. Firstly, it is the pattern of the firm to adopt new techniques since each has its own information gathering and transferring style. The second limitation is that spillovers only refer to the useful part of the information that has been exchanged. For example, although two firms may supply each other all their technological information, the spillover is relatively small, because their existing technologies or products are so different, or because of organizational resistance. And the possible reason may be the information that the two firms exchanged is just only a little part of their technology or information storage.

Perhaps, just because the importance of spillovers for the business, industry and national economic growth, the measuring that how much are the effects is becoming a more and more hot area. In order to be convenient, and also based on the literatures, we divide the measuring study into three categories according to the levels: international spillovers measuring, inter-industry spillovers measuring, and inter-organization/firm spillovers measuring. Obviously, the first level of the three refers to the measuring spillovers that occur between countries; and the second level refers to spillovers occur between related industries; lastly, the third level just refers to the spillovers happen between organizations, especially between firm, and also involving the spillovers occur between firms and research organization. We will discuss the measuring methods respectively.

a) Inter-national spillovers.

The study of measuring spillovers between countries began with Grossman and Helpman's (1990) endogenous growth theory. They make conclusions that R&D activities are the sources for economic growth, and at the same time, technology transferring is also a way to sustain economic growth. It is the first time that Coe and Helpman (1995) throw lights on studies of R&D spillover between countries, and they focus on the relationship between total factors productivity (TFP) and R&D capital. Based on the hypothesis that intermediaries in international trade are the main channel for knowledge spillovers, they measured international R&D spillovers by cross-sector data from 1971 to 1990.

In addition, Houser (1996) sets a knowledge cumulative model to evaluate the technology spillovers from innovators to imitators internationally.

b) Inter-sectoral spillovers.

In the related literature, there are, so far, two ways to measuring inter-sector spillovers: technology flow matrix, and technology proximity.

Scherer (1982) originally proposed a measuring method so called technology flow matrix (TFM), with innovation or patent data classified by the user and producer industries, to measuring spillovers flowing from the innovation producing sector to the innovation-using sector. The rows of the matrix are interpreted as spillover generating sectors, columns as spillovers receiving sectors. The cells typically measure the proportion of technology output of the row sector spilling over to the column-sector. In the literature, various principles may be used to do so, for example user-producer relationships in technology, input-output tables, links between technology classes describing the patent, or patent citation links between sectors.

Although the index of patent data holds advantages in measuring the spillovers, such as homogeneity in measuring, convenience for data collecting, and time sequence, etc, the patent data has shortcomings for itself. Griliches (1990) provides an overview of the main problems in this field. Three of these problems are worth to mention here. Firstly, not all new knowledge used to innovate are permitted to patent, not all innovators have the passion to patent, and, the most important, not all patents, used to measure spillovers, are equivalent. Secondly, according to patent law, different technologies would be patented in different fields and, also, different companies would have different patent rights, so there would be little comparability except for more insights in distinguishing the importance of different patent in different companies. Thirdly, generally speaking, patent statistics do not measure very well innovative activities in small firms (Verspagen 1999). Just about these problems, Stoneman (1983) reminds that, in using patent data to measuring spillovers, scholars should pay attention to (a) the differences in patent qualities (some patents would be valueless, although under-protection); (b) the suspicion of time-sequencing patents, for the all along changing patent law; and also should notice that (c) not all inventions would be permitted to patent.

Technology proximity, used to measuring inter-sector spillovers, was started by Jaffe (1986). He used the data of technological areas (classified into 21 classes) that firm's R&D is invested in, and the sales revenue in different kinds of product markets (classified into 20 classes), thus he finds out technological position vector (constitutes the quantity of R&D investments in different technology classes for each firm) and market position vector (constitutes the sales revenue in each market classes for each firm) of a certain firm. And by calculating the technological distance between technological position vector and market distance between market position vector, Jaffe estimated the existence of spillovers relationships between firms.

Based on these efforts, he calculated the technological proximities between sectors, and, furthermore, he measured the quantity of spillovers between sectors.

c) Inter-organization/firm spillovers.

Although measuring of spillovers in inter-nation and inter-sector had studied a lot, the measuring of spillovers between firms, or firm level, had dipped few, except for studies focused on the relationships between R&D spillovers and productivity in western countries.

For example, using panel data for a sample of private manufacturing firms in India over the period 1975-1986, Lakshmi (1995) estimated the productivity growth in private firms by an extended production function that includes the firms own R&D capital stock and the spillovers effect of the industry-wide R&D capital stock as input, as well as physical capital and labour hours.

How to enhance knowledge flows?

a) Acquiring Foreign Technology

There are three ways for developing countries to acquire technology: imitation of foreign capital goods; foreign direct investment; and foreign licensing. The government can influence these avenues of acquisition in a variety of ways including: FDI policies, foreign licensing regulations, intellectual property rights regimes, and the purchase of technologies for public enterprises.

More fundamentally, the government has a responsibility to contribute to the formation of the human and social capital needed to evaluate, choose, implement, and modify foreign technologies.

As a great deal of technological information is embodied in capital goods, developing countries might acquire technologies by importing them from developed countries and imitating them domestically, thus enabling them to keep apace with international market trends.

Naturally, trade and tariff laws, as well as intellectual property laws, go a long way in mediating

this avenue of acquisition. Since this type of technology acquisition does not include the transfer of theoretical or practical knowledge, it is of limited use without an already existing base of human capital capable of filling in those gaps. Furthermore, imitation costs can be close to innovation costs (Mansfield et. al., 1981) and the loose intellectual property rights that would be needed to maintain such a system might be prohibitively damaging to foreign trade relations.

Foreign direct investment (FDI) refers to the establishment of singly or jointly owned subsidiaries in a foreign country, and it includes "hiring foreign labor, setting up a new plant, meeting foreign regulations, [and] developing new marketing plans" (Saggi, 2000). Foreign licensing, on the other hand, involves leasing to previously established firms the rights, and sometimes the equipment, to produce a particular capital good. In the case of FDI and sometimes licensing, the foreign firm provides assistance implementing the new technology, and this presents an important source of theoretical and practical knowledge. Host countries can limit the bargaining power and options available to multinational firms by creating policies that either hamper or facilitate licensing vis-à-vis FDI (Pack and Saggi, 1997). Developing countries also might regulate the amount of domestic ownership in multinational firms, which would be consistent with protectionist economic policies, and more local ownership might also increase the networks available for spillovers to other domestic firms.

b) Using and Diffusing Technologies

Governments need to enact policies that aid domestic firms in using and diffusing these technologies throughout the country in order to take full advantage of acquired technologies,. A way to readily achieve this goal is to establish institutions and networks that dissipate the tacit and codified knowledge underlying novel technological systems. These networks do not develop automatically or immediately, but they are an essential part of a nation's "social absorptive capacity". With the help of government incentives, developing nations typically can create various formal and informal networks to improve: information, training, and extension; subcontracting; and standards, testing, and quality control.

In developing countries there is often a wide disparity between firms' performances within the same industry. In the early stages of development, "islands of modernization" can appear within an economy dominated by small firms engaged in cottage industries. In many cases, however, there are performance disparities even between firms using the same technology, which exhibits the difference in ability to make effective use of the technology, and thus the importance of diffusing technological know-how. The increasing reliance on scientifically advanced technologies has made the theoretical aspects of technological knowledge increasingly important. Until recently, trade schools and on-the-job training were suitable for producing individuals with the requisite knowledge for designing and developing technologies. In the modern development context, however, running modern technological systems requires higher levels of scientific training and the management skills to coordinate what is inevitably a multi-person or multi-firm affair (Nelson, 1990). Nations with low literacy rates and weak higher educational systems have a great deal of difficulty assimilating foreign technologies because they lack the essential human capital. Those with university-level education are needed to monitor and assess international technological developments, as well as implement any needed changes. Strong education is also necessary at the primary and secondary level to generally increase the literacy and numeracy of the population, and more specifically, so that entry-level employees can possess the understanding and skills necessary to make improvements on the shop floor.

Subcontracting is an effective way of conducting business while simultaneously creating the close contact that is required for effective tacit knowledge transfer. Exclusively contracting with more developed nations, however, precludes further diffusion of the technology locally, and thus a balance must be achieved. Korea, Singapore, and Taiwan, in particular, have realized that restrictive agreements will stymie local firms, and thus they have designed their economic policies to make local subcontractors more attractive in hopes that this will aid the spread of technology. To assure that local contractors produce products of similar quality, it is important to establish an organization that implements standards, testing, and quality control.

Standardization systems require a substantial collaboration between the private and public sectors, but are usually administered by the public sector, as they are archetypical "public goods".

c) Improving and Developing Technology

Technology is changing at an increasingly rapid pace but not all of that change is dramatic.

Incremental improvements in processes, inputs, or equipment are required to adapt products and processes to the local environment as well as enhance productivity and lower costs. Many of these changes do not come from formal R&D in labs, but rather occur on the shop floor, or "blue-collar innovations". The "cumulative productivity impact of small incremental changes that are usually undertaken on the shop floor can be much greater than the initial introduction of a major new technology" (Dahlman and Nelson, 95), which makes utility models or petty patents extremely important in the development context (Ranis, 1990).

Although too strong an emphasis on formal R&D might prevent firms from utilizing adequate pre-existing technologies, some commitment to R&D is essential once developing firms reach a certain stage of technological proficiency. If international competitiveness is the goal, then R&D labs are needed to conduct reverse engineering, tailor technologies to fit the needs of specific customers, and more generally keep apace with international industry trends. The applied knowledge generated in R&D facilities can spillover into other local industries or firms, but this is not necessarily the case. Restrictive FDI policies and weak intellectual property rights in India have produced a disincentive for multinational firms to conduct "cutting-edge" research there. In the Indian pharmaceutical industry, some R&D was necessary to comply with Indian safety regulations, but knowledge spillovers occurred exclusively between multinational firms (via cohesive trade associations), rather than between multinational and domestic firms (Feinberg and Majumda 2001).

The sheer quantity of R&D expenditure is less important than the purpose for which it is used. Military R&D, for example, contributes far fewer spillovers into the productive sector than R&D directed explicitly towards capital goods. One rough gauge of the commercial applicability

of a country's R&D program is the ratio between public and private R&D expenditures; Korea and Japan have a disproportionate percentage of R&D funded by the private sector, while the situation is reversed in the cases of India and Brazil (Dahlman and Nelson, 1995). It is important to note, however, that this figure should not be accepted at face value. A significant amount of shop floor innovation is necessary to make a product successful, Dahlman and Nelson hint that it may be more than initial R&D, is often not included in R&D figures.

Adapting technologies to new clients or new production facilities may be as difficult, and possibly as productive, as the initial innovation. In industries where technological innovation is particularly rapid, industrial R&D is absolutely necessary, if only to monitor advancements in the field. Developing nations should concentrate their efforts on the industrial R&D expenditures that focus on "intermediation and support for the acquisition, assimilation, adaptation, and improvement of technology obtained primarily from abroad" (Dahlman and Nelson,1995). Expenditures of this type provide the most immediate benefits to developing economies without discouraging investment in product innovation.

d) Investing in Human Capital

For any of the above strategies, research has demonstrated that an economy's absorptive capacity "depends heavily upon the level of education and training" (Mytelka, 2001, p. 2).

Nelson and Dahlman note "a key input is a technical human capital base able to assess and decide on technology matters, [which] requires a well-developed educational system that lays the necessary foundations at all levels." They argue that there are two levels, the university and primary/secondary, at which human capital investments must be aimed. The university level creates "qualified personnel who can monitor technological and other trends, assess their relevance to the prospects for the country and individual firms, and help to develop strategy for reacting to and taking advantage of trends" (Dahlman and Nelson 1995, p. 97). This means that there is a need "for strong scientific, engineering and socio-economic capabilities as a base for policy making, especially in sectors undergoing radical change" (Mytelka, 2001, p. 3). The primary/secondary level is a critical component necessary "to speed the diffusion and adoption of new technologies, to make local adaptations and improvements on the shop floor, and more generally to increase the awareness and ability to take advantage of technological opportunities" (Dahlman and Nelson 1995, p. 97).

3. Data and methodology.

Our source of patent data is a data set constructed and maintained by CESPRI at Bocconi University. This data set (from now on EP-KITES data set) includes all patent applications to the European Patent Office (EPO), from September 2nd 1977 to December 23th 2005. The data set comprises a total of 1,711,662 patents.

The European Patent Office (EPO) grants European patents for the contracting states to the European Patent Convention (EPC), which was signed in Munich on October 5th 1973 and entered into force on October 7th 1977.

The data set includes the full set of bibliographic variables concerning each patent application:

· Priority, application, and publication number;

· Priority dates, application and grant date;

· Title and abstract;

· Designated states for protection;

· Status of application;

· Main and secondary International Patent Classification (IPC) codes;

· Applicant's name and address;

· Inventors' names and addresses.

In addition, the data set also contains for each patent all citations made to other EPO patent documents. The data set includes a total of 642,218 citing patents and 834,328 cited patents, corresponding to a total of 1,621,359 citations.

All patent data were procured from the EPO and elaborated by CESPRI. In particular, bibliographic data on patent applications are derived from the Espace Bulletin CD-R produced by the EPO, while information on patent citations come from the REFI tape also provided by the EPO. Data processing consisted mainly in a thorough work of cleaning and standardisation of rough information provided by the EPO.

The data elements that we utilize are:

· Priority dates;

· Inventors' address;
· OST7 classification;
· Citations to other EPO patent.

Each European patent application is assigned by patent examiners to one main technology code and one (or more) secondary technology codes, based upon the International Patent Classification (IPC). The IPC is an internationally agreed, non-overlapping and comprehensive patent classification system.

Currently, the IPC (7th edition) refers to more than 64,000 individual codes and it may be used at different hierarchical levels (WIPO, 1994). For the purposes of this paper, we adopted a technology-oriented classification, jointly elaborated by Fraunhofer Gesellschaft-ISI (Karlsruhe), Institut National de la Propriété Industrielle (INPI, Paris) and Observatoire des Sciences and des Techniques (OST, Paris). This classification, aggregates all IPC codes into 7 technology fields. In this paper, we adopt this classification and assign patents to any of the 30 technology fields on the basis of their main (primary) IPC code.

Patent citations serve an important legal function, since they delimit the scope of the property rights awarded by the patent. Thus, if patent B cites patent A, it implies that patent A represents a piece of previously existing knowledge upon which patent B builds, and over which B cannot have a claim. The applicant has a legal duty to disclose any knowledge of the "prior art," but the decision regarding which patents to cite ultimately rests with the patent examiner, who is supposed to be an expert in the area and hence to be able to identify relevant prior art that the applicant misses or conceals. We assume that the frequency with which a given country's inventors cite the patents of another country is a proxy for the intensity of knowledge flow from the cited country to the citing country. For further discussion of the limitations of using citations data for this purpose, see Jaffe and Trajtenberg (1999) and Hall et al. (2001). Jaffe et al. (2000) present survey evidence regarding the extent to which citations reflect actual knowledge flows evidence regarding the extent to which citations reflect actual knowledge flows between inventors. They find that citations are a noisy indicator of knowledge flow, in the sense that knowledge flow is much more likely to have occurred where a citation is made; but many citations also occur in the absence of any knowledge flow.

In this paper we use the methodology of Jaffe and Trajtenberg (2002) and Hu and Jaffe (2003).

Table 1 presents how the two area, the North Saharan (NS) and South European (SE), are build and which country compose these areas.

Table 2 presents statistics of patent counts an citation counts of NS and SE areas. Table 2 shows the aggregate number of patens, the distribution of patents over the OST7 classification system and the average number of citations each patent received for the seven technological categories in each area. We report statistics aggregate by five year.

The first thing to note about Table 2 is that the absolute numbers of patents granted to residents of NS area are still fractions of those of the SE area. In the 1984-1988 period NS area citizen was granted 39 patents, 0,13 % of the SE area. Fifteen years later, NS area citizen claimed 124 patents, 0,18%, almost equal during the two decade period.

Due to the low number of patent granted to the NS area citizens, we cannot sufficiently describe the evolution of the technological concentration during the years.

Technological fields concentration

A more systematic measure of the concentration of patenting in these countries across technological fields, also used by Hu and Jaffe (2003), is the the Herfindahl–Hirschman Index (HHI) of patent concentration. As shown by Hall et al. (2001), the HHI measure is biased upward when the number of patents on which it is based is small. Essentially, if there is a modest "true" probability of a random patent being in one of many classes, the true concentration may be low; if very few patents are actually observed, they can only be in a few classes, and the measured concentration will be high. Assuming the unobserved distribution across classes is multinomial, and the observed draws from that distribution are independent, Hall, Jaffe, and Trajtenberg show that an unbiased measure of the true concentration is given by

$$\hat{H} = \frac{N \cdot HHI - 1}{N - 1}$$

where $\hat{H}$ is the bias-adjusted Herfindahl–Hirschman Index, N is the number of patents, and HHI is the traditional Herfindahl–Hirschman Index, calculated as the sum of squared shares across patente classes. As N grows large, $\hat{H}$ converges to the traditional measure, but for small N the adjustment can be quite large. For example, if there are ten patents spread evenly across five classes, the HHI is 0.20, but $\hat{H}$ is about 0.11. If there were only five patents spread across five classes, the HHI would still be 0.20, but $\hat{H}$ is actually zero.

Table 2 presents the bias-adjusted Herfindahl across patent classes over time for each area. It shows the technological concentration of the NS area during the first five year, that is also visible in Table 3, after which there is evidence of an upward trend. In the SE area the the bias-adjusted Herfindahl indicated an evenly distributed concentration across classes, as for US and Japan in Hu and Jaffe (2003).

In the Table 2 we compare, also, the technological significance of the two economies' patents using the average number of citations a patent receives as an indicator of the patent's quality. Given the strong evidence of the geographical localization of patent citation (Jaffe et al., 1993), the average cites we report in Table 2 are based on citations made by EPO patents only.

In the Table 2 can be appreciated the patenting per 100,000 inhabitants of NS and SE areas. As can be noted, SE area citizen patent 400 times more than their NS area counterparts.

At the beginning of the studied period 1984-1995, patents in the NS area where distributed not evenly in the 7 technological fields, but in the following period 1995-2003, NS area counties began to change considerably, covering almost 5 over 7 sector. The Mechanical Elements/Machine Tools/Transport and Consumer Goods where always lack of patenting activities.

Knowledge diffusion

Backward citations in patents are the source of the new knowledge. Forward citations on the other hand, reflect the importance of technology. Patents receiving a great number of forward citations reflect that their embedded technology is very valuable. Therefore, an increase of forward citations for some patents is associated with a growing value of knowledge.

Several dates are included in each European patent document and the choice of one date is important for correctly dating an invention. The so-called priority date, i.e. the date of the earliest filing of an application in any of the patent offices adhering to the Paris Convention, is the date that obviously gets closer to the actual timing of the patented invention and will be adopted in what follows for the purpose of dating patents.

It should be noted that subsequent filings seeking protection elsewhere, either by filing for patents in other individual countries in which protection is desired or by filing a regional application (e.g. a European application through EPO for

a number of European countries) or an international application with WIPO (PCT) to obtain protection in various countries by means of a single application, must be made within one year from the priority date. In addition to that, in the EPO system, unexamined patent applications are generally published 18 months after the application date, i.e. the date of filing for a European patent.

This implies that the time lag between the priority date and the publication date may range from 1.5 years, for patents directly filed to the EPO, to 2.5 years, for patents initially filed in a national patent office and later on extended to the EPO. Moreover, for the so-called PCT patent applications, which allow the applicants to delay the decision of filing for an EPO

patent until 30 months from the priority date, the time lag between priority and publication may well exceed 2.5 years.
So patents are typically granted one to three years after application; thus, a citation lag of zero or one implies that the citing patent may well have been applied for before the originating patent was actually granted, as pending applications are not public, so in this case the citation would almost have been identified by the patent examiner or that the inventors were in the same R&D team or had a *vis-à-vis* contact.
The average citations per patent over all years suggests, obviously, that patents of the SE area are technologically more significant than the NS area patents. However, this comparison is potentially misleading, because it does not control for the age distribution of the patent portfolios. SE area countries has many more older patents, which are more highly cited simply because they have been around longer, while NS area have patent portfolios weighted towards younger patents that are less highly cited. The fall in forward citations seen from 1999 to 2003 is a normal behaviour due to the great proximity to the granting date. Thus at the end of the data period, no patents have received very many citations because very little time has passed in which to observe them.
The citation lag between a patent and its patent reference is a measure of the time necessary for a firm or inventor to assimilate prior technological information and undertake its invention, thus an indicator of speed of knowledge diffusion.
Table 4, Figures 1 and 2 report the citation lag average respectively from the NS and SE area from the rest of the world. The speed of knowledge diffusion, as measured by the citation lag, is extremely low for the forward citation in the NS area, meaning that in this are the knowledge spread at very high speed, especially for Industrial processes forward citation from the SE area (1,9357 years). This data is also confirmed by the corresponding value for the backward citation (2,7132 years).
There is no doubt that this high speed in the knowledge diffusion can be referred to the greed of the inventors in this sector.

4. Conclusions.

Our investigation reinforces the importance of understanding the broad network influences on knowledge flows and learning in developing countries. A National Innovation System perspective supports the idea that successful economic development is linked to a nation's capacity to acquire, absorb, disseminate, and apply modern technologies. Thus, technological divides between rich and poor countries may conventionally be
The patterns of knowledge diffusion for the NS area counties and SE area countries during the 1983-2004 period are quite different. We found that, obviously, the SE area countries had

a higher number of patents granted in EPO than the NS area countries. Furthermore, the technologies registered in SE area countries were evenly distributed across sector meanwhile in NS countries the technologies registered were of traditional tech fields and tend to exclude the Mechanical Elements/Machine Tools/Transport and the Consumer goods sectors.
The citations received (forward) by SE area countries outnumber the citations received by NS area countries. That means that the value of knowledge in SE area countries is more important that the value of NS area countries.
The other strong finding, to be further investigate, is the extremely high speed of knowledge diffusion seen both in forward and backward citations from/to the NS area countries for the sector of industrial process. This is somewhat surprising given the NS area countries' low patenting activities in this sector, and could be maybe explained in their greediness to learn in this technological field.

5. Bibliography.

Aboites J. and Beltran T. (2008), Comparison of patterns in knowledge diffusion from the US to South East Asia (Korea and Taiwan) and Latin America (Brazil and Mexico) 1976-2002, *Paper presented in the IV Globelics Conference at Mexico City*, September 22-24 2008.

Aitken B.J. and Harrison A.E. (1999), "Do domestic firms benefit from foreign direct investment? Evidence from Venezuela", *American Economic Review*, June: 605-618.

Arora A. (1995). "Licensing Tacit Knowledge: Intellectual Property Rights and the Market for Know-How", *Economics of Innovation and New Technology*, 4, 41-59.

Bernard A.B. and Jensen J.B. (1999), "Exceptional exporter performance: cause, effect, or both?", *Journal of International Economics*, 47, 1-25.

Blomstrom M. and Kokko A. (1998), "Multinational corporations and spillovers", *Journal of Economic Survey*, 12, 247-277.

Bottazzi L. and Peri G. (2003), "Innovation and spillovers in regions: Evidence from European patent data", *European Economic Review*, 47, 687-710.

Chin J. C. and Grossman G. M. (1990), "Intellectual Property Rights and North-South Trade", *The political economy of international trade: Essays in honor of Robert E. Baldwin. R. W. Jones and A. O. Krueger*, Oxford and Cambridge, Blackwell, 90-107.

Coe D.T. and Helpman E. (1995), International R&D spillovers, *European Economic Review*, 39, 859–887.

Coe D.T., Helpman E. and Hoffmaister A.W. (1997), "North-South spillovers", *Economic Journal*, 107, 134-149.

Crespo N. and Fontoura M.P. (2007), "Determinant Factors of FDI Spillovers – What We Really Know?", *World Development*, 35, 410-425.

Dahlman C. J. and Nelson R. (1995), "Social Absorption Capability, National Innovation Systems and Economic Development", in Social capability and long-term economic growth, eds. Koo B. H. and Perkins D. H., Macmillan Press, 82-122.

De Bondt R. (1996), "Spillovers and Innovative Activities", *International Journal of Industrial Organization*, 15, 1-28.

Feinberg S. and Majumdar S. (2001), "Technology spillovers from foreign direct investment in the Indian pharmaceutical industry", *Journal of International Business Studies*, 32, 421-437.

Griliches Z. (1990), "Patent Statistics as Economic Indicators: A Survey", *Journal of Economic Literature*, 18, 1661-1707.

Griliches Z. (1991), "The search for R&D spillovers", *NBER Working Papers*, 3678.

Grossman G. and Helpman E. (1991), "Innovation and Growth in the Global Economy", MIT Press.

Hall B.H., Jaffe A.B. and Trajtenberg M. (2001), "The NBER patent citations data file: lessons, insights and methodological tools", *NBER Working Papers*, 8498.

Houser C. (1996), "Estimating international R&D knowledge spillovers", Eastern Economic Journal, 22, 411-419.

Hu A.G.Z. and Jaffe A.B. (2003), "Patent citations and international knowledge flow: the case of Korea and Taiwan", *International Journal of Industrial Organization*, 21, 849-880.

Jaffe A.B. (1986), "Technological opportunity and spillovers of R&D: evidence from firms' patents, profits and market value", *American Economic Review*, 76, 984–1001.

Jaffe A.B. and Trajtenberg M. (1999) International knowledge flows: evidence from patent citations", *Economics of Innovation & New Technology*, 8, 105–136.

Jaffe A.B., Trajtenberg M. and Fogarty M.S. (2000), "Knowledge spillovers and patent citations: evidence from a survey of inventors", *American Economic Review*, Papers and Proceedings, 215–218.

Lakshmi K.R. (1995), "R&D spillover and productivity growth: Evidence from Indian private firms", *Journal of Development Economics*, 48, 1-23.

Malerba F., Mancusi M., and Montobbio F. (2007), "Innovation, international R&D spillovers and the sectoral heterogeneity of knowledge flows", *Cespri WP*, 204.

Mansfield E. (1994). "Intellectual Property Protection, Foreign Direct Investment, and Technology Transfer.", *Discussion Paper*, International Finance Corporation.

Maskus K. E. (2000), "Intellectual property rights in the global economy". Institute for International Economics.

Maskus K. E. and Penubarti M. (1995). "How Trade-Related Are Intellectual Property Rights?" Journal of International Economics, 39, 227-48.

Maskus K. E. and Penubarti M. (1997). Patents and International Trade: An Empirical Study. Quiet pioneering: Robert M. Stern and his international economic legacy. K. E. Maskus and et al. Studies in International Economics. Ann Arbor, University of Michigan Press, 95-118.

Montobbio F. and Sterzi V. (2008), "Inventing Together: Exploring the Nature of International Knowledge Spillovers in Latin America", *Cespri WP*, 225.

Maurseth B. and Verspagen B. (2002), "Knowledge Spillovers in Europe: A Patent Citations Analysis", *Scandinavian Journal of Economics*, 104, 4, 531.

Mytelka L. (2001), "Promoting scientific and technological knowledge for sustainable development, paper for the Third UN Conference on Least Developed Countries", *Round Table: "Education for All and Sustainable Development in LDCs,"*, May 2001.

Nelson R. (1990), "US technological leadership: where did it come from and where did it go?", *Research Policy*, Vol. 19.2.

Pack H. and Saggi K. (1997). "Inflows of Foreign Technology and Indigenous Technological Development," *Review of Development Economics*, 1.

Peri G. (2005), "Determinants of Knowledge Flows and Their Effect on Innovation", *The Review of Economics and Statistics*, 87, 308-322.

Ranis G. (1990), "Asian and Latin American experience: lessons for Africa", *Journal of International Development*, 2.

Rhee Y. (1990), "The catalyst model of development: lessons from Bangladesh's success with garment exports", *World Development*, 18, 333-346.

Saggi K. (2000), "Trade, foreign direct investment and international technology transfer: a survey", *World Bank*, Washington DC.

Scherer F. M. (1982), "Inter-industry technology flows and productivity measurement", *Review of Economics and Statistics*, 64, 627-634.

Smith P. J. (1999). "Are Weak Patent Rights a Barrier to U S Exports?", *Journal of International Economics*, 48, 151-77.

Stoneman P. (1983), "The economics of technology change", Oxford University Press.

Verspagen B., and De Loo I., "Technology Spillovers between Sectors and over Time", *Technological Forecasting and Social Change*, 60, 215–235.

Table 1 – Area composition

Area 1	
North Saharan countries	
Country Code	Name
MA	Morocco
DZ	Algeria
TN	Tunisia
LY	Libyan Arab Jamahiriya
EG	Egypt

Area 2	
South European countries	
Country Code	Name
PT	Portugal
ES	Spain
FR	France
IT	Italy
SI	Slovenia
HR	Croatia
RS	Serbia
GR	Greece
TR	Turkey

Table 2
Distribution of patents granted by tech field and average foreard citations to residents in the specific Area

	1984-1988		1989-1993		1994-1998		1999-2003	
	Patents	Cites	Patents	Cites	Patents	Cites	Patents	Cites
Area 1: all classes	39	1,56	47	1,26	68	1,38	124	1,02
Electronics	15,38%	1,67	6,38%	1,00	25,00%	1,82	20,97%	1,00
Tools	17,95%	1,71	14,89%	1,14	10,29%	1,57	15,32%	1,00
Basic Materials Chemistry	43,59%	1,53	31,91%	1,33	17,65%	1,00	13,71%	1,00
Pharmaceutics/Biotech	2,56%	1,00	14,89%	1,57	26,47%	1,22	30,65%	1,05
Industrial processes	10,26%	2,00	14,89%	1,00	7,35%	1,00	13,71%	1,00
Mechanical Elements, Machine tools, Transport	5,13%	1,00	10,64%	1,40	5,88%	1,50	3,23%	1,00
Consumer Goods	5,13%	1,00	6,38%	1,00	7,35%	1,40	2,42%	1,00
Area 2: all classes	29858	1,83	38713	1,74	48410	1,40	66643	1,04
Electronics	16,62%	1,82	17,59%	1,65	19,65%	1,36	21,92%	1,03
Tools	13,32%	1,91	13,07%	1,73	12,48%	1,39	11,96%	1,03
Basic Materials Chemistry	15,74%	2,10	14,96%	2,09	13,48%	1,65	11,41%	1,07
Pharmaceutics/Biotech	5,43%	2,49	6,97%	2,39	8,90%	1,80	10,02%	1,10
Industrial processes	16,26%	1,78	16,57%	1,64	15,67%	1,31	15,15%	1,03
Mechanical Elements, Machine tools, Transport	20,59%	1,59	18,98%	1,54	18,00%	1,27	18,11%	1,02
Consumer Goods	12,05%	1,62	11,85%	1,54	11,82%	1,25	11,44%	1,03

Table 2
Basic patent statistics

		1984-1988	1984	1985	1986	1987	1988	1989-1993	1989	1990	1991	1992	1993
Area 1	Patents #	39	10	9	4	6	10	47	6	10	10	11	10
	Per 100,000 population	0,0073	0,0098	0,0086	0,0037	0,0054	0,0088	0,0077	0,0052	0,0084	0,0082	0,0088	0,0079
	Ĥ	0,24	0,36	0,19	0,17	0,13	0,27	0,17	0,40	0,11	0,16	0,13	0,24
Area 2	Patents #	29858	4725	5386	5780	6696	7271	38713	7863	7687	7899	7464	7800
	Per 100,000 population	2,5028	2,0110	2,2758	2,4255	2,7910	3,0104	3,1376	3,2299	3,1355	3,2001	3,0044	3,1179
	Ĥ	0,16	0,16	0,16	0,16	0,16	0,15	0,15	0,15	0,15	0,15	0,15	0,15

		1994-1998	1994	1995	1996	1997	1998	1999-2003	1999	2000	2001	2002	2003
Area 1	Patents #	68	8	6	14	21	19	124	16	24	35	28	21
	Per 100,000 population	0,0100	0,0062	0,0045	0,0104	0,0152	0,0135	0,0167	0,0112	0,0165	0,0236	0,0185	0,0137
	Ĥ	0,18	0,25	0,07	0,14	0,16	0,23	0,19	0,22	0,23	0,23	0,17	0,15
Area 2	Patents #	48412	8113	8471	9529	10751	11548	66643	12512	13158	13226	13603	14144
	Per 100,000 population	3,7939	3,2213	3,3431	3,7379	4,1915	4,4756	5,0704	4,8206	5,0390	5,0330	5,1436	5,3156
	Ĥ	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,16

Population source from U.S. Census Bureau, Population Division

Table 3
Patent distribution into OST classes, year per year

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Area 1: all classes (#)	10	9	4	6	10	6	10	10	11	10
Electronics	20%	11%	25%	0%	20%	0%	0%	10%	18%	0%
Tools	0%	44%	0%	33%	10%	50%	0%	10%	9%	20%
Basic Materials Chemistry	60%	22%	50%	33%	50%	50%	20%	20%	27%	50%
Pharmaceutics/Biotech	0%	11%	0%	0%	0%	0%	20%	40%	0%	10%
Industrial processes	10%	11%	25%	17%	0%	0%	20%	10%	27%	10%
Mechanical Elements, Machine tools, Transport	10%	0%	0%	17%	0%	0%	20%	10%	9%	10%
Consumer Goods	0%	0%	0%	0%	20%	0%	20%	0%	9%	0%
Area 2: all classes	4725	5386	5780	6696	7271	7863	7687	7899	7464	7800
Electronics	16%	17%	17%	16%	17%	16%	18%	17%	18%	19%
Tools	14%	13%	13%	13%	13%	13%	13%	13%	14%	12%
Basic Materials Chemistry	17%	16%	16%	16%	15%	16%	15%	16%	15%	14%
Pharmaceutics/Biotech	5%	5%	5%	5%	6%	6%	6%	8%	7%	7%
Industrial processes	16%	16%	17%	17%	16%	17%	18%	17%	15%	17%
Mechanical Elements, Machine tools, Transport	21%	22%	20%	21%	20%	19%	19%	19%	19%	19%
Consumer Goods	12%	11%	12%	12%	12%	13%	11%	11%	12%	12%

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Area 1: all classes	8	6	14	21	19	16	24	35	28	21
Electronics	50%	0%	29%	29%	16%	6%	29%	23%	21%	19%
Tools	13%	17%	14%	10%	5%	13%	4%	11%	21%	29%
Basic Materials Chemistry	0%	33%	7%	24%	21%	19%	8%	14%	11%	19%
Pharmaceutics/Biotech	25%	17%	21%	19%	42%	44%	29%	40%	25%	14%
Industrial processes	0%	17%	21%	5%	0%	13%	29%	3%	18%	10%
Mechanical Elements, Machine tools, Transport	0%	0%	0%	5%	16%	6%	0%	3%	4%	5%
Consumer Goods	13%	17%	7%	10%	0%	0%	0%	6%	0%	5%
Area 2: all classes	8113	8471	9529	10751	11548	12512	13158	13226	13603	14144
Electronics	19%	18%	19%	20%	21%	21%	22%	22%	22%	22%
Tools	13%	13%	13%	12%	12%	12%	12%	12%	12%	12%
Basic Materials Chemistry	14%	15%	14%	13%	12%	12%	12%	11%	11%	11%
Pharmaceutics/Biotech	9%	8%	9%	9%	10%	10%	10%	11%	10%	10%
Industrial processes	16%	16%	15%	15%	16%	16%	15%	15%	15%	15%
Mechanical Elements, Machine tools, Transport	18%	18%	18%	18%	18%	17%	17%	18%	18%	20%
Consumer Goods	11%	12%	12%	12%	12%	12%	11%	11%	12%	12%

Table 4
Forward citation lag average time, in years, form different areas, per technological field

	Citation Lag Average				
	Everywhere	Area 2	Area 1	RoW (except Area 2)	Row
Area 1: all classes	4,1590	4,4653	2,4449	4,1827	4,2420
Electronics	3,9819	-	3,0226	4,0110	4,0110
Tools	4,7113	5,6006	-	4,0645	4,7113
Basic Materials Chemistry	4,9246	4,4370	2,8528	5,5433	5,1219
Pharmaceutics/Biotech	3,3915	4,9654	1,9804	3,1894	3,5755
Industrial processes	3,9726	1,9357	-	4,4253	3,9726
Mechanical Elements, Machine tools, Transport	4,6720	2,2505	-	4,9747	4,6720
Consumer Goods	3,5736	2,4244	-	3,9567	3,5736
	Everywhere	Area 1	Area 2	RoW (except Area 1)	RoW
Area 2: all classes	4,7798	6,0752	4,4778	4,7793	4,7798
Electronics	4,3543	6,3600	4,3001	4,3541	4,3543
Tools	4,7866	7,4205	4,5691	4,7860	4,7866
Basic Materials Chemistry	4,6188	5,2131	4,0283	4,6184	4,6188
Pharmaceutics/Biotech	4,1356	7,0432	3,9967	4,1314	4,1356
Industrial processes	5,2027	2,7132	4,7716	5,2034	5,2027
Mechanical Elements, Machine tools, Transport	5,3012	-	4,8785	5,3012	5,3012
Consumer Goods	5,3823	5,9411	4,9395	5,3822	5,3823

Table 5
Number of citation received, per area and per citation lag

# Citation received	Citation Lag (Year)																			
Area 1 from:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Area 1	0	0	20	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area 2	5	0	55	20	15	5	0	0	10	0	10	0	0	0	10	0	0	0	0	0
Everywhere	5	70	180	120	70	20	45	35	40	20	20	5	5	5	10	0	0	0	0	0
RoW (except Area 2)	0	70	105	95	50	15	45	35	30	20	10	5	5	5	0	0	0	0	0	0
RoW	5	70	160	115	65	20	45	35	40	20	20	5	5	5	10	0	0	0	0	0

Area 2 from:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Area 2	3855	24785	60495	47090	34205	25760	19050	15055	11655	9150	7115	5200	4195	3030	1965	1160	800	420	170	35
Area 1	0	10	20	10	20	5	20	30	10	10	20	5	0	5	0	0	0	0	0	0
Everywhere	11105	56835	142485	113915	85685	65485	50520	39815	32190	26110	20240	14495	11915	8410	5475	3520	2135	1140	325	105
RoW (except Area 1)	7250	32040	81970	66815	51460	39720	31450	24730	20525	16950	13105	9290	7720	5375	3510	2360	1335	720	155	70
RoW	7250	32050	81990	66825	51480	39725	31470	24760	20535	16960	13125	9295	7720	5380	3510	2360	1335	720	155	70

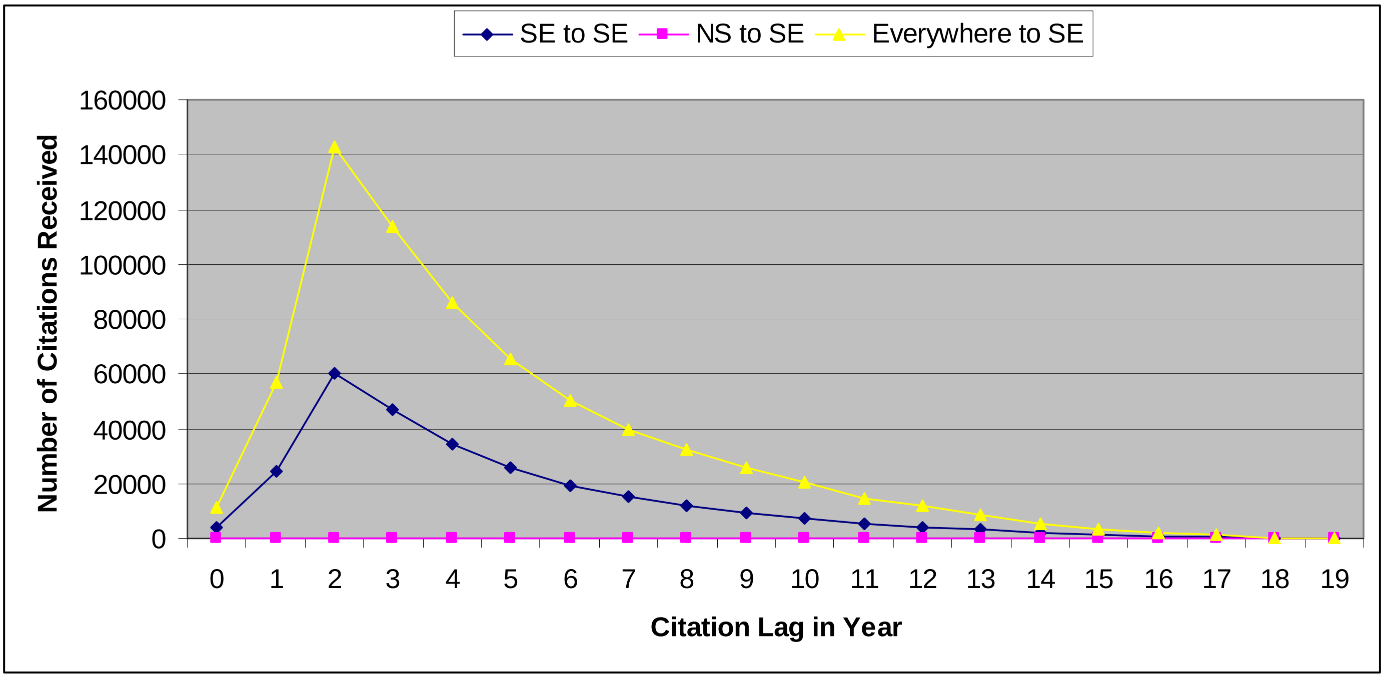

Figure 1 – Number of forward citation to SE area countries, per citation lag

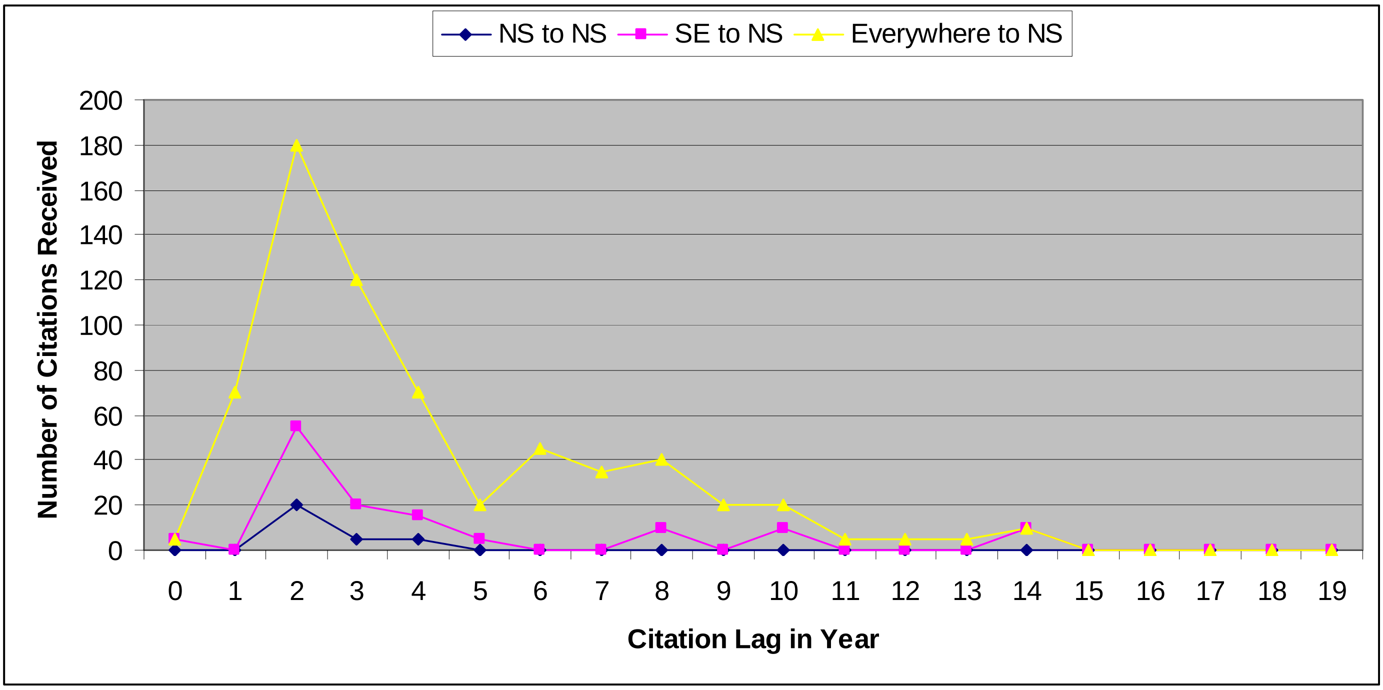

Figure 2 – Number of forward citation to NS area countries, per citation lag