DULBEA

épartement d'Economie Appliquée de l'Université Libre de Bruxelles

DOCUMENT DE TRAVAIL

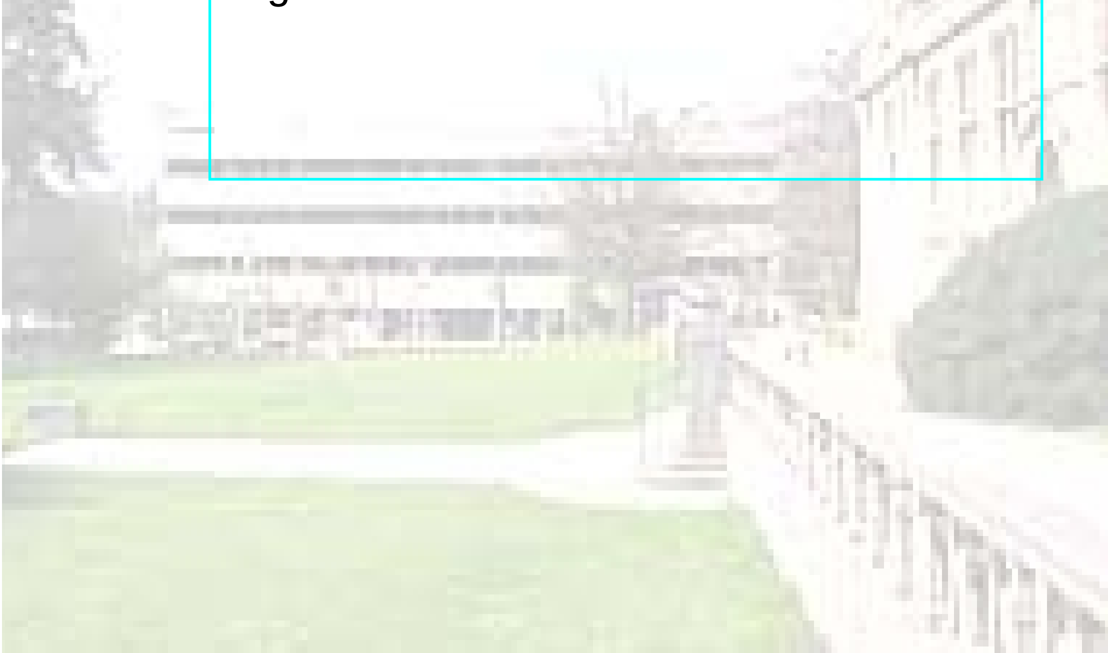
WORKING PAPER

N°08-18.RS

RESEARCH SERIES

TECHNOLOGICAL AND GEOGRAPHICAL PROXIMITY EFFECTS ON KNOWLEDGE SPILLOVERS: EVIDENCE FROM US PATENT CITATIONS.

Luigi ALDIERI



DULBEA l'Université Libre de Bruxelles

Avenue F.D. Roosevelt, 50 - CP-140 l B-1050 Brussels l Belgium

TECHNOLOGICAL AND GEOGRAPHICAL PROXIMITY EFFECTS ON KNOWLEDGE SPILLOVERS: EVIDENCE FROM US PATENT CITATIONS.

Luigi ALDIERI[♦]

Abstract.

The purpose of this paper is to investigate the pattern of knowledge flows as indicated by patent citations. In order to compute the technological proximity, we have followed the methodology developed by Jaffe (1986), where a technological vector is based on the distribution of patents of each firm across technology classes. As far as the geographic proximity is concerned, we have used the latitude and the longitude coordinates of the city in which each firm is located. The empirical results suggest that the effects of proximity variables on knowledge flows are rather differentiated.

Keywords: Innovation, Knowledge Spillovers, Technology Transfer, Patent Citations.

Jel Classification: F1, F2, O3.

[♦] University of Naples Parthenope & Université Libre de Bruxelles, DULBEA-CERT. Email : luigi.aldieri@uniparthenope.it

I am indebted to Michele Cincera for his insightful advice. I am grateful to the participants of the 2th INIR Doctoral Seminar on 'Topics in Innovation, Science and Technology Research' at K.U. Leuven, May 11-12, 2006 for their helpful suggestions. I also want to thank seminar participants of "Innovation and Knowledge diffusion" at the Université Libre de Bruxelles (ULB), December 12, 2007. In particular, I would like to thank Pierre-Guillaume Méon and Julien Ravet for their relevant comments and suggestions.
The usual disclaimers apply.

1. Introduction.

The innovation process is a fundamental source of economic growth. Then, it is important to identify the factors able to explain its dynamics. In this analysis, the diffusion of ideas plays a relevant role, since it is hard to appropriate knowledge which "spills over" to other agents in the economy. The knowledge flows between the source and the destination, such as firms, regions or countries, might be explored by two principal frameworks. We may assess the impact of spillovers on productivity, into an aggregate production function or we may study the relationship between newly produced knowledge (usually proxied by patents) and research inputs, into a knowledge production function. According to Griliches (1979), it is difficult to separate the impact of knowledge spillovers from that of rent spillovers, then the second approach should be preferred to the first. According to Bottazzi and Peri (2003), if the social rate of return of new inventions is higher than the private rate one, then knowledge spillovers are likely to occur. The private rate of return of a new invention may be measured by the value of the related patent, while for the assessment of the importance of spillovers generated by the invention, we could consider the patent citations flows, following Jaffe *et al.* (1993). Indeed, it is possible to use patent citations to identify knowledge flows across countries or firms, and between 'cited' patent to 'citing' patent.

In this paper, we have explored the question whether geographic and technological proximities affect the knowledge flows, proxied by patent citations for large international firms and how these effects change over time. We expect that the geographical proximity impact on knowledge flows is decreasing over time, since information travels at lower communication costs over time (Coyle, 1997 and Friedman, 2005). Yet, according to Evans and Harringan (2005), distance is still relevant in some technological sectors, where face-to-face interaction is fundamental and knowledge is tacit and hard to codify. Then, it is also interesting to analyse the impact of technological proximity on knowledge flows over time.

The paper is laid out as follows. A brief survey on previous studies are presented in Section 2. Section 3 details the data and the variables. Section 4 sketches our econometric model. After presenting the empirical results in Section 5, Section 6 concludes.

2. Related literature.

The empirical literature over the last decade has focused on the role of knowledge in innovation patterns. As a public good, knowledge has two properties: it is non-excludable and it is non rival, since it can be used by more firms at the same time and the innovator cannot impede other firms from using it. For this reason, knowledge produces externalities, referred in the literature as knowledge spillovers. De Bondt (1997) defines a 'knowledge spillover' as "*involutary leakage or voluntary exchange"* of technological knowledge. Empirically, there are different methodologies to deal with the knowledge flows. In order to measure the knowledge flows, it is useful to compute a 'weighting matrix', in such a manner that the diffusion of knowledge will be proportional to the degree of transaction between firms.

Concerning the papers based on a standard production function, the most influential contribution in the empirical literature on this topic has been the paper written by Coe and Helpman (1995). They use country level data on trade shares as a proxy for the intensity of knowledge flows between countries and find that international spillovers from foreign R&D positively affect productivity growth and that this effect is larger for small countries. Keller (1998) provides econometric evidence that casts doubt on the effectiveness of trade as a mechanism for knowledge transfer, finding higher coefficients on foreign R&D when using random weightings instead of those used by Coe and Helpman (1995), based on trade shares. As far as international trade is concerned as a channel of technology transfer, Sjoholm (1996) and Lichtenberg and van Pottelsberghe (1998, 2001) find a positive result, while Soete and Verspagen (1993) and Gittleman and Wolff (1995) do not find any effect. Lichtenberg and van Pottelsberghe (2001) find a positive effect of foreign direct investment (FDI) or technology payments on productivity. Soete and Verspagen (1993) conclude that FDI does not produce effects, while Mohnen and Lépine (1991) find different results. Orlando (2000), by means of a production function framework, examines the role of geographic and technological proximity for inter-firm spillovers from R&D. He finds that the firms which belong to the same industry, obtain the highest spillovers. The spillover effect within the narrowly defined technological groups are not attenuated by the distance, while geographic proximity seems to attenuate spillovers that cross narrowly defined technological boundaries. Greunz (2003) investigates inter-regional knowledge spillovers across European sub-national regions. She finds that there are interregional spillovers between geographically close regions and between regions characterized by similar technological properties. Aldieri and Cincera (2007) use an extended production function to take into account R&D spillover components, besides traditional inputs and own R&D capital stock. In this way they investigate the extent to which R&D spillovers effects are intensified by both geographic and technological proximities between spillover generating and receiving firms. The results, estimated by means of a panel data econometric method (system-GMM) indicate a positive and significant impact of both types of R&D spillovers on productivity performance for large international firms.

Concerning the papers based on a knowledge production function, many studies analyse the relationship between the patents and the determinants of the innovation process. Pakes and Griliches (1984), Hausmann *et al.* (1984), Blundell, Griffith and Windmeijer (2002) use current and past values of R&D expenditures as well as a time trend as determinants of the innovation process on American firms. Cincera (1997) takes into account technological and geographical opportunities as additional determinants of the innovation process. He finds three main outcomes: first, a high sensitivity of the results to the specification of the patent distribution; second, a GMM panel data method leads to a decreasing returns to scale in the technological activity; finally, from the analysis, he obtains a positive impact of technological spillovers on firms' own innovations. Crépon and Duguet (1997) introduce dummy variables and find a non linear effect of past patenting on the current innovation activities. Eaton and Kortum (1996, 1999) identify knowledge flows through cross country patenting and find that spillovers decline with geographical distance. Jaffe (1986) considers some technological dummies and a pool of international spillovers in the specification of the knowledge production function, finding that the distance is relevant for the spillovers. He uses the firms' patent distribution in a technological space as a weighting matrix. Branstetter (2001) follows a similar procedure to estimate the effects of domestic and foreign R&D spillovers for American and Japanese firms. He picks up a higher national impact than an international one.

According to Jaffe *et al.* (1993), patent citations can be taken as a paper trail of knowledge flows: a reference to a previous patent indicates that the knowledge of that patent was in some way useful for developing the new knowledge described in the citing patent. For this reason, citations provide the opportunity to avoid measuring proximity and look directly at the process of knowledge diffusion. Maurseth and Verspagen (2002) use citations by European patents to obtain estimates of knowledge flows across European regions. The results indicate that geographical distance has a negative impact on knowledge flows and that this impact is substantial. They find knowledge flows to be larger within countries than between regions located in separate countries, as well as within regions sharing the same language. Their results also indicate that knowledge flows are industry specific and that regions' technological specialisation is an important determinant for their technological attraction as spillovers producers or receivers. Peri (2003), using NBER patent and citations data (Hall *et al.*, 2001), does a similar exercise and then uses the obtained estimates to build a measure of accessible external R&D and determines the impact of spillovers within and across regions. He finds that only fifteen percent of average knowledge is learned outside the region of origin and only nine percent outside the country of origin. However, his results suggest that knowledge in highly technological sectors and knowledge generated by technological leaders flow substantially farther. Bottazzi and Peri (2003) use European patents and R&D data to estimate a knowledge production function on a cross-section of European regions. They use a measure of proximity based on the geographical distance to weight R&D external to a region and find that spillovers are localised and exist only within a distance of 300 km. Finally, Griffith, Lee and Van Reenen (2007) examine the "home bias" of international knowledge spillovers measured as the speed of patent citations. In particular, they implement an estimator controlling for correlated fixed effects and censoring in duration models, by using USPTO patent citations data. They find that home bias declines substantially when we control for fixed effects.

As emphasized in Jaffe *et al.* (1993), the relevance of localization for knowledge flows identified by patent citations may depend on a pre-existing pattern of geographic concentration of technologically related activities. For this reason, they construct a 'control' sample, where for each citing patent, all patents, in the same patent class and the same application year, are selected. They exclude only other patents that cite the same originating patent. Through this control

sample, they are able to test for the hypothesis whether the geographic matching frequency, between the citations and originating patents, is significantly greater than the geographic matching frequency, between the controls and originating patents. They find the localization effects of spillovers even after controlling for timing and technology.
Furthermore, in order to pick up widely the geographical and technological effects of spillovers from patent citations, it is necessary to take into account some relevant variables reflecting the patent quality or characteristics. In particular, Cincera (2008) considers several variables to identify the economic value of the patents, such as the number of given citations, the number of received citations, the number of European countries where the patents are protected, a dummy variable indicating whether the patent is official only in Europe or also in America and Japan or in all the world, and the number of claims. He takes into account the Herfindal index for the concentration of technological activities. This information is relevant in the innovation analysis, since we expect that the sectors characterized by higher Herfindal index could experiment higher number of citations.

The main contribution of this paper is to implement an empirical model where we estimate the effects of technological and geographical proximities on the citation probability in such a manner that we can distinguish whether these effects are conditionated on a citation link or are due to sectoral characteristics.

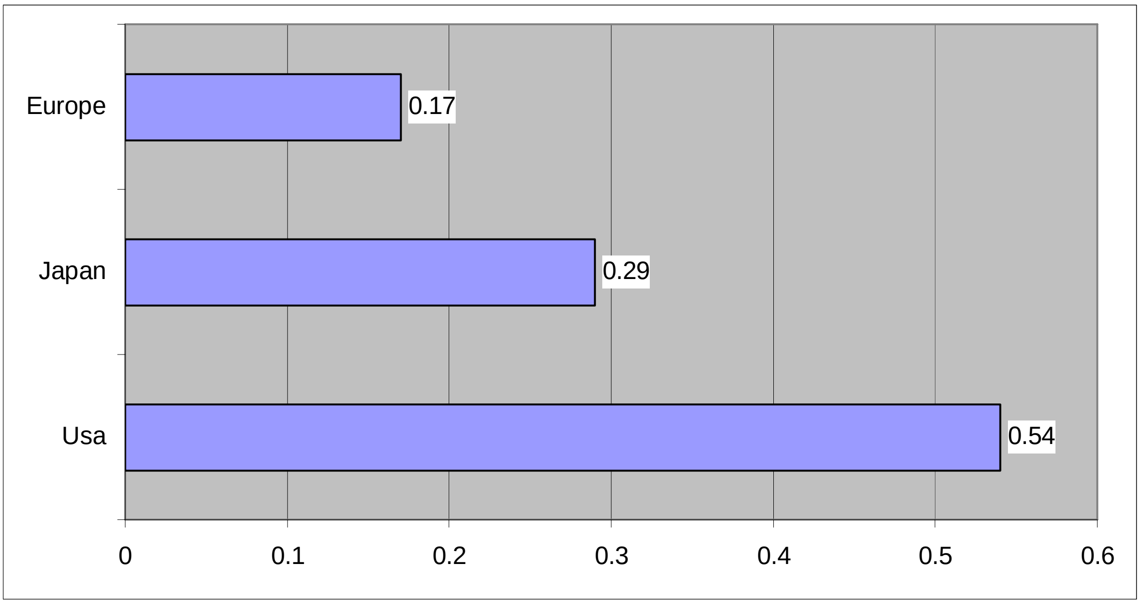
3. Description of Data and Variables.

We have used information from Hall *et al.* (2001) Patent Citations Data File, which is widely used in the empirical analysis of knowledge spillovers. It refers to all patents taken out at the United States Patent Office (USPTO), while the assignees and inventors may be located anywhere in the world. We have selected 808 International firms from the Worldscope/Disclosure database[1] and matched their names to the patents' assignees. In particular, our sample is composed by 116 European, 227 Japanese and 465 US firms. A major task in assembling the dataset has been the matching of patents from the Hall *et al.* (2001) data with firms considered. Two difficulties have been encountered. First, patents are assigned to firms on the basis of their names which can vary from one data source to the other, e.g. 'Co' instead of 'Corporation', 'Incorporated' or 'Inc' and other such changes or abbreviations. Second, many large firms have several subsidiaries in several countries and it is not obvious to link the patents applied by these subsidiaries to the parent company. Ideally, one has to get a 'mapping' of the main firms to their subsidiaries and affiliates. However, it is not easy to construct an accurate mapping, since it changes over time through the process of merger and acquisition.

Figure 1 gives an indication of the citations by patents for the countries in the sample.

[1] See Cincera (1998) for a detailed description of this database.

Figure 1. Sample distribution of the citations by patents



The USA is the country with the highest number of citations by patents.

As far as the technological proximity is concerned, we have followed the methodology developed by Jaffe (1986). This procedure rests in the construction of a technological vector for each firm based on the distribution of its patents across technology classes[2]. These vectors allow one to locate firms into a multi-dimensional technological space where technological proximities between firms are performed as the uncentered correlation coefficient between the corresponding technology vectors:

$$P_{ij} = \frac{\sum_{k=1}^{K} T_{ik} T_{jk}}{\sqrt{\sum_{k=1}^{K} T_{ik}^2 \sum_{k=1}^{K} T_{jk}^2}} \qquad (1)$$

[2] Thanks to the USPTO patent classification system, it is possible to identify the technological classes to which patents are assigned. In order to construct the technological proximity measures, we have used the higher level classification proposed by Hall *et al.* (2001) which consists of 36 two-digit technological categories.
The technological sub-categories are further aggregated into 6 main categories : Chemical, Computers and Communications, Drugs and Medical, Electrical and Electronics, Mechanical and Others.
"Others" field includes: Agriculture, Husbandry, Food, Amusement Devices, Apparel & Textiles, Earth Working & Wells, Furniture, House Fixtures, Heating, Pipe & Joints, Receptacles

where: *Ti.* is the technological vector of the firm *i* and

P_{ij} is the technological proximity between firm *i* and *j*.

For the geographical distance, we have used the latitude and the longitude coordinates of the cities where the firms are located. Assuming a spherical earth of actual earth volume, the arc distance in miles between any two firms *i* and *j* can be performed according to the Haversine formula:

$$d_{ij} = 2*3.959*\arcsin\sqrt{\sin^2\left(\frac{lat_j - lat_i}{2}\right) + \cos(lat_j) + \cos(lat_i)\sin^2\left(\frac{lon_j - lon_i}{2}\right)} \quad (2)$$

where: 3.959 is the radius of the earth in miles and latitude and longitude values are in radians (Orlando, 2000).

To test for the hypothesis whether the localization effects of spillovers are conditioned on a citation link, we have followed the strategy as in Jaffe *et al.* (1993). In particular, we need to compare the probability of a patent matching the originating patent by geographic area, conditional on its citing the originating patent, with the probability of a match not conditionated on the existence of a citation link. To this end, for each citing patent, we have identified all patents in the same technological class with the same application year and we have excluded any other patents that have cited the same originating patent. In this way, we have selected a 'control' sample with the same technological and temporal profile as the 'citation' sample but without the citation link. Then, we have used a dummy variable *(FC)* which takes the value one if the geographic localization of the control patent has matched that of the originating one.

In order to take into account the concentration degree in the sectors analysed, we have used as additional explanatory variable an Herfindal index, as in Cincera (2008):

$$H_j = \sum_{k=1}^{6} ms_{jk}^2 \quad (3)$$

where ms_{jk} are % of patents of firm j in technological class k (k=1...6) over total of patents of firm j.

Table 1 shows the summary statistics of our sample.

Table 1. Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
C_{ij}	7.71	1.103	0	15
FC	0.35	0.112	0	1
H_j	0.74	0.332	0	1
P_{ij}	0.47	0.234	0	1
D_{ij}	5.265	2.176	1.82	12.35
lpp	16.18	1.969	11.21	25.36

Notes: 652,056 observations.

Table 2 reports the knowledge flows in percentage measured by the citations, for all countries in the sample, and their relative weights. In particular, the percentages in the table refer to the share of citations from the citing country directed towards the cited countries (i.e. row sums are equal to 1). Most of the citations are to patents held by American firms. The self citations takes into account the citations to own patents (knowledge internal to the firm). The higher the average number of self citations in a sector, the more firms innovating within such sector build upon internal knowledge in generating new ideas.

Table 2. Matrix of knowledge flows in percentage across countries based on citation data as average among the firms.

	eu[3]	jap	usa	self	tot.
eu[4]	0.10	0.14	0.36	0.40	1.00
jap	0.05	0.32	0.35	0.27	1.00
usa	0.05	0.13	0.37	0.44	1.00

[3] Cited country.
[4] Citing country.

4. Econometric Modelling Strategy.

We have computed a 808x808 firm-by-firm citation matrix, with rows indicating spillovers received (citing patents) and columns indicating spillovers generated (cited patents). This matrix will be referred to as the 'data matrix'. Our main dependent variable consists of the number of patent citations. Since the intra-firm citations (the diagonal elements of the matrix) will be left out, we get 808x808-808 = 652,056 observations.

The model that will be estimated is the following:

$$C_{ij} = f\,(P_{ij}\,, FC,\, H_{j,}\, D_{ij}\,,\, P_i\,,\, P_j\,,\, L) \quad (4)$$

In this equation, C_{ij} is the number of citations by firm i to patents applied for by firm j , P_{ij} is the technological proximity, D_{ij} is the geographical distance, P_i and P_j are the numer of patents of firm i and firm j, L is a dummy variable that is equal to one for pairs of firms localized in countries that share the same language, and zero otherwise, FC is a dummy variable taking value one if the control patent matches the same geographic localization than the originating patent, H_j the Herfindal index measuring the concentration degree in the sample. All variables are taken in natural logarithm terms to attenuate the impact of the outliers and to reduce heteroskedasticity.

Citations to patents that belong to the same assignee represent transfers of knowledge that are mostly internalized (self-citations), while citations to patents belonging to different assignees are to be considered pure spillovers. Instead of entering both P_i and P_j in the equation separately, we choose to enter them jointly in the form of $ln(P_i\ P_j\ )$, denoted by *lpp*, as in Maurseth and Verspagen (2002).

Our expectations on the signs of the coefficients to be estimated are as follows. For technological proximity a positive sign is expected, while for the geographic distance a negative sign coefficient is expected. Indeed, according to the theory, higher proximity (technological) leads to more spillovers and higher geographic distance affect them negatively. Because patenting is a prerequisite for patent citations (and thus knowledge spillovers) to occur, a positive sign is expected on the variable *lpp*. Finally, also for L and H_j variables we expect positive sign coefficients.

Because the citations are count data[5] and are not normally distributed, OLS is not appropriate.

In order to handle count dependent variables, the Poisson model is usually implemented. The Poisson regression model has been extensively used to model patents as a function of R&D (Hall, Hausman, Griliches, 1984).

This model estimates the relationship between the arrival rate of patents (patent citations, in this case) and the independent variables. The dependent variable y_{it} is assumed to have a Poisson distribution with parameter μ_{it} which, in turn, depends on a set of exogenous variables *xit* according to a log-linear function:

$$\ln \mu_{it} = \alpha_i + \beta x_{it} \qquad (5)$$

where α_i captures the individual effect.

One way to estimate this model is to run the conditional Poisson regression by maximum likelihood, including the dummy variables for all individuals (less one) to directly estimate the fixed effects. If there is not a specific interest in the fixed effects or if their number is a large conditional maximum likelihood, it represents an alternative method. Conditioning on the count total for each individual, $\sum_i y_{it}$, it leads to a conditional likelihood proportional to:

$$\prod_i \prod_t \left(\frac{\exp(\beta x_{it})}{\sum_s \exp(\beta x_{is})} \right)^{y_{it}} \qquad (6)$$

which no longer includes the α_i parameters.

The fixed effects Poisson regression model allows for unrestricted heterogeneity across individuals, but requires the mean of counts for each individual to be equal to its variance, i.e. $E(y_{it}) = V(y_{it}) = \mu_{it}$. This is an undesired feature whenever there is an additional heterogeneity not accounted for by the model, when the data show evidence of overdispersion. Such problem might be dealt with by assuming that the variable *yit* has a negative binomial distribution (Hall, Hausman, Griliches, 1984), which can be regarded as a generalisation of the Poisson distribution with an additional parameter allowing the variance to exceed the mean.

---

[5] See Greene (1994) and Winkelmann and Zimmermann (1995) for a survey of count data models.

In the Hall, Hausman, Griliches (1984) negative binomial model, it is assumed that :

$y_{it} / \gamma_{it} \sim$ Poisson (γ_{it}) and $\gamma_{it} / \theta_i \sim$ Gamma $(\lambda_{it}, 1/\theta_i)$, where θ_i is the dispersion parameter and $\ln \lambda_{it} = \beta x_{it}$. This leads to the following density function:

$$f(y_{it} / \lambda_{it}, \theta_i) = \frac{\Gamma(\lambda_{it} + y_{it})}{\Gamma(\lambda_{it})\Gamma(y_{it} + 1)} \left(\frac{1}{1+\theta_i}\right)^{\lambda_{it}} \left(\frac{\theta_i}{1+\theta_i}\right)^{y_{it}} \quad (7)$$

where Γ is the gamma function. Looking at the within-group effects only, this specification yields a negative binomial model for *I-th* individual with:

$$\begin{aligned} E(y_{it}) &= \theta_i \lambda_{it} \\ V(y_{it}) &= (1+\theta_i)\theta_i \lambda_{it} \end{aligned} \quad (8)$$

Under this model the ratio of the variance to the mean (dispersion) is constant within group and equal to $(1+\theta_i)$.

Hall, Hausman, Griliches (1984) further assume that for each individual *I* the *yit* are independent over time. This implies that $\sum_i y_{it}$ also has a negative binomial distribution with parameter θ_i and $\sum_t \lambda_{it}$. Conditioning on the sum of counts, the resulting likelihood function for a single individual is

$$\frac{\Gamma(\sum_t y_{it} + 1)\Gamma(\sum_t \lambda_{it})}{\Gamma(\sum_t y_{it} + \sum_t \lambda_{it})} \prod_t \frac{\Gamma(\lambda_{it} + y_{it})}{\Gamma(\lambda_{it})\Gamma(y_{it} + 1)} \quad (9)$$

which is free of the θ_i parameters. The likelihood of the entire sample is then obtained multiplying all the individual terms like in (7) and can be maximized with respect to β the parameters using conventional numerical methods.

5. Empirical results.

5.1. Basic results

From the inspection of Table 3, we may observe the basic empirical results concerning the proximities effects on knowledge flows, proxied by the number of patent citations, and we may compare the Negative Binomial model coefficients to those of Maurseth and Verspagen (2002).

Table 3. Estimation results.

	Fixed effects Poisson (this paper)	Negative Binomial regression (this paper).	Negative Binomial regression (Maurseth and Verspagen (2002)).
FC	0.14 (0.008)*	0.11 (0.007)*	
H_j	0.03 (0.001)*	0.04 (0.002)*	
Pij	2.14 (0.096)*	2.31 (0.101)*	2.54 (0.106)*
D_{ij}	-0.05 (0.027)*	-0.08 (0.029)*	-0.30 (0.019)*
Lpp	0.96 (0.021)*	1.01 (0.022)*	0.97 (0.027)*
L	0.39 (0.073)*	0.47 (0.083)*	0.20 (0.036)*
$Pseudo - R^2$	0.67	0.72	0.94

Note: *=statistically significant at the 5 % level. Standard errors are reported in brackets.

Results from different empirical studies seem to suggest that knowledge spillovers are sensitive to technological and geographical proximity variables, even if we control for timing, technology and the concentration index, the coefficient of *lpp* is positive as expected. The role of technological and geographical proximities evidenced here through the coefficients estimation has relevant implications for our assessment of the efficiency of concentrated market structures in knowledge intensive industries. The finding that the technological proximity coefficient is higher than the geographic proximity one leads us to prefer more concentration, in particular, on industries, instead of mergers between firms in a particular geographic region.

This industrial process might also be used in an analysis of institutional arrangements that facilitate industrial convergence. Indeed, the aim of this policy is to avoid that firms without moderately advanced technology sectors may not take advantage of knowledge spillovers from more developed economies.

5.2. Analysis of proximities effects over time

Now we can focus our attention on the relevant issue whether the proximities effects are stable over time. For this aim, we have split our sample into an 'early' period (1975-1989) and a 'late' period (1990-1999), characterized by a similar absolute number of citations. We have estimated the Negative Binomial model on this two sub-periods separately. In particular, we have distinguished low tech and high tech sectors. The former includes: Chemical, Drugs and Medical, Mechanical. The latter includes: Computers and Communications, Electrical and Electronics.

We might expect that geography plays a less important role as time passes in explaining the diffusion of knowledge, since information travels around the world at rapid speed, but there are sectors, such as Computers or Electronics, where the contact between individuals is fundamental for the knowledge flows. This depends on the fact that all knowledge is not codified and where personal characteristics are intrinsic in innovations, knowledge may be transferred only by personal mobility. As a result, in these cases, we should expect a more persistent geographic effect.

Table 4. Estimation results

	Negative Binomial 1975-1989	Negative Binomial 1990-1997
FC	0.12 (0.006)*	0.13 (0.007)*
H_j	0.04 (0.001)*	0.03 (0.001)*
P_{ij}	2.43 (0.95)*	2.37 (0.098)*
D_{ij}	-0.41 (0.023)*	-0.28 (0.019)*
Lpp	0.97 (0.024)*	0.93 (0.019)*
L	0.27 (0.037)*	0.26 (0.039)*
$Pseudo-R^2$	0.93	0.93
	Negative Binomial Low tech 1975-1989	Negative Binomial Low tech 1990-1999
FC	0.11 (0.005)*	0.12 (0.006)*
H_j	0.02 (0.001)*	0.02 (0.001)*
P_{ij}	2.33 (0.098)*	2.32 (0.100)*
D_{ij}	-0.43 (0.025)*	-0.11 (0.018)*
Lpp	0.93 (0.019)*	0.94 (0.028)
L	0.21 (0.030)*	0.22 (0.037)*
$Pseudo-R^2$	0.94	0.94
	Negative Binomial High tech 1975-1989	Negative Binomial High tech 1990-1999
FC	0.13 (0.006)*	0.12 (0.004)*
H_j	0.06 (0.003)*	0.06 (0.003)*
P_{ij}	2.56 (0.102)*	2.52 (0.102)*
D_{ij}	-0.36 (0.022)*	-0.33 (0.022)*
Lpp	0.97 (0.022)*	0.93 (0.026)*
L	0.23 (0.032)*	0.21 (0.037)*
$Pseudo-R^2$	0.92	0.92

From the empirical results in Table 4, we can observe that the localization effect has fallen over time, due to the decreasing costs of communication and travel, while technological knowledge is stable over time. Finally, the fall of the geographical effect is more relevant in the traditional sectors with respect to the modern ones.

6. Conclusions.

In this work we have used information from US patent citations data to investigate to what extent the technological and the geographical proximity affect the knowledge flows, measured by the number of citations, between 808 large international firms. In order to compute the technological proximity, we have followed the methodology developed by Jaffe (1986). This procedure rests in the construction of a technological vector for each firm based on the distribution of its patents across technology classes. These vectors allow one to locate firms into a multi-dimensional technological space where technological proximities between firms are performed as the uncentered correlation coefficient between the corresponding technology vectors. As far as the geographic proximity is concerned, we have used the latitude and the longitude coordinates of the cities where the firms are located. Given the count variable nature of the number of patent citations, the dependent variable in the model, we have implemented alternative models to OLS estimator. In particular, we have performed two estimation procedures: Fixed Effect Poisson model and Negative Binomial model. Since it is hard to identify whether these effects are conditionated on a citation link or are due to sectoral characteristics in our sample, we have used as explanatory variables a dummy variable taking the value one if the geographic localization of the control patent matches that of the originating patent, and the Herfindal index to consider the concentration degree.

The empirical results indicate that geographic distance has a negative impact on knowledge flows, that are also industry-specific. We have also found that the number of patent citations are positively sensitive to the language shared by citing and cited firms. Therefore, the finding of this paper is that the technology flows are both industry-specific and confined by geography and language, even if we control for timing, technology and the concentration index. Our results are in line with Maurseth and Verspagen (2002).

Even if knowledge travels around the world at rapid speed, distance may still differ if face-to-face interaction is relevant in some sectors, such as high tech sectors, where the knowledge is tacit and hard to codify (Griffith, Lee and Van Reenen, 2007). To test for this idea, we have divided our sample into an "early" period (1975-1989) and a "late" period (1990-1999). In particular, we have identified a sample of traditional sectors (Chemical, Drugs and Medical, Mechanical) and a sample of high tech sectors (Computers, Electrical and Electronics).

From the empirical results, we have observed that the localization effect has fallen over time, due to the decreasing costs of communication and travel, while technological knowledge is almost stable over time. Finally, the fall of the geographical effect is more relevant in the traditional sectors with respect to the modern ones.

Breschi and Lissoni (2004) apply a social network analysis to derive maps of social relationship between inventors and measures of social proximity between citing and cited patents. In this work, we suppose that social connectedness exists and that the 'distance' between citing and cited patents are not very extensive. But in the future, it would be interesting to investigate the social network of patent citations data, to delete those citations characterized by the absence of social connectedness with respect to other patents in the database, and to analyse how this procedure affects the final econometric results. Furthermore, it would be interesting to replicate this analysis by using both the EPO and USPTO Patent data.

References.

- Aldieri L., M. Cincera (2007), "Geographic and technological R&D Spillovers within the Triad: Micro evidence from US patents", forthcoming in *Journal of Technology Transfer*

- Blundell R., R. Griffith, F. Windmeijer (2002), "Individual effects and dynamics in count data models", *Journal of Econometrics,* 108(1), 113-131

- Bondt R. D. (1997), "Spillovers and innovative activities", *International Journal of Industrial Organization*, 15, 1-28

- Bottazzi L., G. Peri (2003), "Innovation and Spillovers in Regions: Evidence from European Patent Data", *European Economic Review,* 47(4): 687-710

- Branstetter L. (2001), "Are knowledge spillovers are international or intranational in scope? Microeconometric evidence from the US and Japan", *Journal of International Economics,* 53(1), 53-79

- Breschi S., F. Lissoni (2004), "Knowledge Networks from Patent Data: Methodological issues and Research Targets", CESPRI, Università Bocconi di Milano, Working Paper N. 150

- Cincera M. (1997), "Patents, R&D and Technological Spillovers at the firm level: evidence from econometric count models for panel data", *Journal of Applied Econometrics,* 12: 265-280

- Cincera M. (1998), "Economic and Technological performances on International firms", PhD thesis, Université Libre de Bruxelles

- Cincera M. (2008), "Determinants des Oppositions de Brevets: Une Analyse Microeconomique au niveau Belge", Dulbea Working Paper N. 08-02.RS

- Coe D. T., E. Helpman (1995), "International R&D Spillovers", *European Economic Review,* 39(5), 859-887

- Coyle D. (1997), "Weightless World", Princeton: Princeton University Press

- Crépon B., E. Duguet (1997), "Estimating the innovation function from patent numbers: GMM on count panel data", *Journal of Applied Econometrics,* 12(3): 243-263

- Eaton J., S. Kortum (1996), "Trade in ideas. Patenting and productivity in the OECD", *Journal of International Economics,* 40(3-4): 251-278

- Eaton J., S. Kortum (1999), "International Technology Diffusion: Theory and Measurement", *International Economic Review,* 40(3): 537-570

- Evans C., J. Harringan (2005), "Distance, time and specialization: Lean Retailing in general equilibrium", *American Economic Review,* 95: 292-313

- Friedman T. (2005), "The World is Flat", New York: Farrar, Strauss and Giroux

- Gittleman M. B., E. N. Wolff (1995), "R&D activity and Cross-Country Growth Comparison", *Cambridge Journal of Economics,* 19(1), 189-207

- Greene W. R. (1994), "Accounting for excess zeros and sample selection in poisson and binomial regression models", Working Paper N. 94-10. New York University

- Greunz L. (2003), "Geographically and Technologically Mediated Knowledge Spillovers between European Regions", *The Annals of Regional Science*, 37, 657-680.

- Griffith R., Lee S., Van Reenen J. (2007), "Is Distance Dying at Last? Falling Home Bias in Fixed Effects Models of Patent Citations", CEP Discussion Paper N. 818, August

- Griliches Z. (1979), "Issues in Assessing the Contributions of Reseach and Development to Productivity Growth", *Bell Journal of Economics,* 10(1): 92-116

- Hall B. H., A. B. Jaffe, M. Trajtenberg (2001), "The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools", NBER Working Paper N. 8498

- Hausman J., B. Hall, Z. Griliches (1984), "Econometric Models for Count Data and an Application to the Patents-R&D Relationship", *Econometrica*, 52(4): 909-938

- Jaffe A. B. (1986), "Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits and Market Value", *American Economic Review,* 76(5): 984-1001

- Jaffe A. B., M. Trajtenberg, R. Henderson (1993), "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations", *Quaterly Journal of Economics,* 108(3): 577-598

- Keller W. (1998), "Are International R&D Spillovers Trade Related? Analyzing Spillovers among Randomly Generated Trade Partners", *European Economic Review,* 42(8): 1469-1481

- Lichtenberg F., B. Van Pottelsberghe de la Potterie (1998), "International R&D Spillovers: a comment", *European Economic Review,* 42(8), 1483-1491

- Lichtenberg F., B. Van Pottelsberghe de la Potterie (2001), "Does Foreign Direct Investment Transfer Technology Across Borders?", *The Review of Economics and Statistics,* 83(3), 490-497

- Maurseth P. B., B. Verspagen (2002), "Knowledge Spillovers in Europe: A Patent Citation Analysis", *Scandinavian Journal of Economics,* 104(4): 531-545

- Mohnen P., N. Lépine (1991), "R&D, r&d spillovers, and payment for technology: Canadian evidence", *Structural Change and Economic Dynamics,* 2(1), 213-228

- Orlando M. J. (2000), "On the importance of Geographic and Technological proximity for R&D Spillovers: An Empirical Investigation", Federal Reserve Bank of Kansas City, RWP 00-02

- Pakes A., Z. Griliches (1984), "Patents and R&D at the Firm Level: A First Look", The University of Chicago Press

- Peri G. (2003), "Knowledge Flows, R&D Spillovers and Innovation", ZEW Discussion Papers 03-40, Center for European Economic Research

- Sjoholm F. (1996), "International transfer of knowledge: The role of international trade and geographic proximity", *Weltwirtschafliches Archiv*, 132(1), 97-115

- Soete L., B. Verspagen (1993), "Technology and growth. The complex Dynamics of catching up, Falling Behind and Taking Over" in: Pilot D., Szirmai E. B. Van Ark (eds), Explaining Economic Growth, 101-127

- Wilkelmann R. and K. Zimmermann (1995), "Recent developmnents in count data modelling:Theory and application", *Journal of Economic Surveys*, 9, 1-24

DULBEA Working Paper Series

2008

N°.08-18.RS Luigi Aldieri « Technological and geographical proximity effects on knowledge spillovers: evidence from us patent citations », September 2008.

N°.08-17.RS François Rycx, Ilan Tojerow and Daphné Valsamis « Wage differentials across sectors in Europe: an east-west comparison », August 2008.

N°.08-16.RS Michael Rusinek and François Rycx « Quelle est l'influence des négociations d'entreprise sur la structure des salaires ? », July 2008.

N°.08-15.RS Jean-Luc De Meulemeester « Vers une convergence des modèles ? Une réflexion à la lumière des expériences européennes de réforme des systèmes d'enseignement supérieur », July 2008.

N°.08-14.RS Etienne Farvaque and Gaël Lagadec « Les promesses sont-elles des dettes ? Economie Politique des promesses électorales », June 2008.

N°.08-13.RS Benoît Mahy, François Rycx and Mélanie Volral « L'influence de la dispersion salariale sur la performance des grandes entreprises belges », May 2008.

N°.08-12.RS Olivier Debande and Jean-Luc Demeulemeester « Quality and variety competition in higher education », May 2008.

N°.08-11.RS Robert Plasman, Michael Rusinek and Ilan Tojerow « Les différences régionales de productivité se reflètent-elles dans la formation des salaires ? » April 2008.

N°.08-10.RS Hassan Ayoub, Jérôme Creel and Etienne Farvaque « Détermination du niveau des prix et finances publiques : le cas du Liban 1965-2005 », March 2008.

N°.08-09.RS Michael Rusinek and François Rycx « Rent-sharing under Different Bargaining Regimes: Evidence from Linked Employer-Employee Data », March 2008.

N°.08-08.RR Danièle Meulders and Sîle O'Dorchai « Childcare in Belgium », March 2008.

N°.08-07.RS Abdeslam Marfouk « The African Brain Drain: Scope and Determinants », March 2008.

N°.08-06.RS Sîle O'Dorchai « Pay inequality in 25 European countries », March 2008.

N°.08-05.RS Leila Maron and Danièle Meulders « Having a child: A penalty or bonus for mother's and father's employment in Europe? », February 2008.

N° 08-04.RR Robert Plasman, Michael Rusinek, François Rycx, Ilan Tojerow « Loonstructuur in België », January 2008.

N° 08-03.RS Caroline Gerschlager « Foolishness and Identity: Amartya Sen and Adam Smith », January 2008.

N° 08-02.RS Michele Cincera « Déterminants des oppositions de brevets: une analyse micro-économique au niveau belge », January 2008.

N° 08-01.RR Robert Plasman, Michael Rusinek, François Rycx, Ilan Tojerow « La structure des salaires en Belgique », January 2008.

2007

N° 07-22.RS Axel Dreher, Pierre-Guillaume Méon and Friedrich Schneider « The devil is in the shadow Do institutions affect income and productivity or only official income and official productivity », November 2007.

N° 07-21.RS Ariane Szafarz « Hiring People-like-Yourself: A Representation of Discrimination on the Job Market », November 2007.

N° 07-20.RS Amynah Gangji and Robert Plasman « Microeconomic analysis of unemployment in Belgium », October 2007.

N° 07-19.RS Amynah Gangji and Robert Plasman « The Matthew effect of unemployment: how does it affect wages in Belgium », October 2007.

N° 07-18.RS Pierre-Guillaume Méon, Friedrich Schneider and Laurent Weill « Does taking the shadow economy into account matter to measure aggregate efficiency», October 2007.

N° 07-17.RS Henri Capron and Michele Cincera « EU Pre-competitive and Near-the-market S&T Collaborations », October 2007.

N° 07-16.RS Henri Capron « Politique de cohésion et développement régional », October 2007.

N° 07-15.RS Jean-Luc De Meulemeester « L'Economie de l'Education fait-elle des Progrès ? Une Perspective d'Histoire de la Pensée Economique », October 2007.

N° 07-14.RS Jérôme de Henau, Leila Maron, Danièle Meulders and Sîle O'Dorchai « Travail et Maternité en Europe, Conditions de Travail et Politiques Publiques », October 2007.

N° 07-13.RS Pierre-Guillaume Méon and Khalid Sekkat «Revisiting the Relationship between Governance and Foreign Direct Investment», October 2007.

N° 07-12.RS Robert Plamsan, François Rycx and Ilan Tojerow « Wage Differentials in Belgium : The Role of Worker and Employer Characteristics », October 2007.

N° 07-11.RS Etienne Farvaque, Norimichi Matsueda and Pierre-Guillaume Méon« How committees reduce the volatility of policy rates », July 2007.

N° 07-10.RS Caroline Gerschlager «Adam Smith's Account of Self-Deceit and Informal Institutions », May 2007.

N° 07-09.RS Marie Pfiffelmann « Which optimal design for lottery linked deposit », May 2007.

N° 07-08.RS Marc Lévy « Control in Pyramidal Structures », May 2007.

N° 07-07.RS Olga Bourachnikova «Weighting Function in the Behavioral Portfolio Theory», May 2007.

N° 07-06.RS Régis Blazy and Laurent Weill « The Impact of Legal Sanctions on Moral Hazard when Debt Contracts are Renegotiable », May 2007.

N° 07-05.RS Janine Leschke «Are unemployment insurance systems in Europe adapting to new risks arising from non-standard employment? », March 2007.

N° 07-04.RS Robert Plasman, Michael Rusinek, Ilan Tojerow « La régionalisation de la négociation salariale en Belgique : vraie nécessité ou faux débat ? », March 2007.

N° 07-03.RS Oscar Bernal and Jean-Yves Gnabo « Talks, financial operations or both? Generalizing central banks' FX reaction functions », February 2007.

N° 07-02.RS Sîle O'Dorchai, Robert Plasman and François Rycx « The part-time wage penalty in European countries: How large is it for men? », January 2007.

N° 07-01.RS Guido Citoni « Are Bruxellois and Walloons more optimistic about their health? », January 2007.

2006

N° 06-15.RS Michel Beine, Oscar Bernal, Jean-Yves Gnabo, Christelle Lecourt « Intervention policy of the BoJ: a unified approach » November 2006.

N° 06-14.RS Robert Plasman, François Rycx, Ilan Tojerow « Industry wage differentials, unobserved ability, and rent-sharing: Evidence from matched worker-firm data, 1995-2002»

N° 06-13.RS Laurent Weill, Pierre-Guillaume Méon « Does financial intermediation matter for macroeconomic efficiency? », October 2006.

N° 06-12.RS Anne-France Delannay, Pierre-Guillaume Méon « The impact of European integration on the nineties' wave of mergers and acquisitions », July 2006.

N° 06-11.RS Michele Cincera, Lydia Greunz, Jean-Luc Guyot, Olivier Lohest « Capital humain et processus de création d'entreprise : le cas des primo-créateurs wallons », June 2006.

N° 06-10.RS Luigi Aldieri and Michele Cincera « Geographic and technological R&D spillovers within the triad: micro evidence from us patents », May 2006.

N° 06-09.RS Verena Bikar, Henri Capron, Michele Cincera « An integrated evaluation scheme of innovation systems from an institutional perspective », May 2006.

N° 06-08.RR Didier Baudewyns, Benoît Bayenet, Robert Plasman, Catherine Van Den Steen, « Impact de la fiscalité et des dépenses communales sur la localisation intramétropolitaine des entreprises et des ménages: Bruxelles et sa périphérie», May 2006.

N° 06-07.RS Michel Beine, Pierre-Yves Preumont, Ariane Szafarz « Sector diversification during crises: A European perspective », May 2006.

N° 06-06.RS Pierre-Guillaume Méon, Khalid Sekkat « Institutional quality and trade: which institutions? which trade? », April 2006.

N° 06-05.RS Pierre-Guillaume Méon « Majority voting with stochastic preferences: The whims of a committee are smaller than the whims of its members », April 2006.

N° 06-04.RR Didier Baudewyns, Amynah Gangji, Robert Plasman « Analyse exploratoire d'un programme d'allocations-loyers en Région de Bruxelles-Capitale: comparaison nternationale et évaluation budgétaire et économique selon trois scénarios », April 2006.

N° 06-03.RS Oscar Bernal « Do interactions between political authorities and central banks influence FX interventions? Evidence from Japan », April 2006.

N° 06-02.RS Jerôme De Henau, Danièle Meulders, and Sile O'Dorchai « The comparative effectiveness of public policies to fight motherhood-induced employment penalties and decreasing fertility in the former EU-15 », March 2006.

N° 06-01.RS Robert Plasman, Michael Rusinek, and François Rycx « Wages and the Bargaining Regime under Multi-level Bargaining : Belgium, Denmark and Spain », January 2006.

2005

N° 05-20.RS Emanuele Ciriolo « Inequity aversion and trustees' reciprocity in the trust game », May 2006.

N° 05-19.RS Thierry Lallemand, Robert Plasman, and François Rycx « Women and Competition in Elimination Tournaments: Evidence from Professional Tennis Data », November 2005.

N° 05-18.RS Thierry Lallemand and François Rycx « Establishment size and the dispersion of wages: evidence from European countries », September 2005.

N° 05-17.RS Maria Jepsen, Sile O'Dorchai, Robert Plasman, and François Rycx « The wage penalty induced by part-time work: the case of Belgium », September 2005.

N° 05-16.RS Giuseppe Diana and Pierre-Guillaume Méon « Monetary policy in the presence of asymmetric wage indexation », September 2005.

N° 05-15.RS Didier Baudewyns « Structure économique et croissance locale : étude économétrique des arrondissements belges, 1991-1997 », July 2005.

N° 05-14.RS Thierry Lallemand, Robert Plasman, and François Rycx « Wage structure and firm productivity in Belgium », May 2005.

N° 05-12.RS Robert Plasman and Salimata Sissoko « Comparing apples with oranges: revisiting the gender wage gap in an international perspective », April 2005.

N° 05-11.RR Michele Cincera « L'importance et l'étendue des barrières légales et administratives dans le cadre de la directive 'Bolkestein' : Une étude comparative entre la Belgique et ses principaux partenaires commerciaux », April 2005.

N° 05-10.RS Michele Cincera « The link between firms' R&D by type of activity and source of funding and the decision to patent », April 2005.

N° 05-09.RS Michel Beine and Oscar Bernal « Why do central banks intervene secretly? Preliminary evidence from the Bank of Japan », April 2005.

N° 05-08.RS Pierre-Guillaume Méon and Laurent Weill « Can Mergers in Europe Help Banks Hedge Against Macroeconomic Risk ? », February 2005.

N° 05-07.RS Thierry Lallemand, Robert Plasman, and François Rycx « The Establishment-Size Wage Premium: Evidence from European Countries », February 2005.

N° 05-06.RS Khalid Sekkat and Marie-Ange Veganzones-Varoudakis « Trade and Foreign Exchange Liberalization, Investment Climate and FDI in the MENA », February 2005.

N° 05-05.RS Ariane Chapelle and Ariane Szafarz « Controlling Firms Through the Majority Voting Rule », February 2005.

N° 05-04.RS Carlos Martinez-Mongay and Khalid Sekkat « The Tradeoff Between Efficiency and Macroeconomic Stabilization in Europe », February 2005.

N° 05-03.RS Thibault Biebuyck, Ariane Chapelle et Ariane Szafarz « Les leviers de contrôle des actionnaires majoritaires», February 2005.

N° 05-02.RS Pierre-Guillaume Méon « Voting and Turning Out for Monetary Integration: the Case of the French Referendum on the Maastricht Treaty », February 2005.

N° 05-01.RS Brenda Gannon, Robert Plasman, Ilan Tojerow, and François Rycx « Interindustry Wage Differentials and the Gender Wage Gap : Evidence from European Countries », February 2005.

Brussels Economic Review

University of Brussels
DULBEA, CP140
Avenue F.D. Roosevelt, 50
B-1050 Brussels

Belgium

ISSN 0008-0195

Apart from its working papers series, DULBEA also publishes the ***Brussels Economic Review-Cahiers Economiques de Bruxelles***.

Aims and scope

First published in 1958, *Brussels Economic Review-Cahiers Economiques de Bruxelles* is one of the oldest economic reviews in Belgium. Since the beginning, it publishes quarterly the Brussels statistical series. The aim of the Brussels Economic Review is to publish unsolicited manuscripts in all areas of applied economics. Contributions that place emphasis on the policy relevance of their substantive results, propose new data sources and research methods, or evaluate existing economic theory are particularly encouraged. Theoretical contributions are also welcomed but attention should be drawn on their implications for policy recommendations and/or empirical investigation. Regularly the review publishes special issues edited by guest editors.

Authors wishing to submit a paper to be considered for publication in the *Brussels Economic Review* should send an e-mail to Michele Cincera: mcincera@ulb.ac.be, with their manuscript as an attachment. An anonymous refereeing process is guaranteed.

Additional instructions for authors and subscription information may be found on the *Brussels Economic Review*'s website at the following address:

http://homepages.vub.ac.be/~mcincera/BER/BER.html