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THE GEOGRAPHY OF INNOVATION: THE EFFECTS OF UNIVERSITY RESEARCH[1]

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Abstract:

Applied studies on the relationship between geography and technological innovation for United States, Germany, France and Italy have shown the positive effects that academic research exerts on the innovative output of firms at a spatial level. The purpose of this paper is to look for new evidence on the possible effects of the university research for the case of Spain. To do so, within the framework of a Griliches-Jaffe knowledge production function, and using panel data and count models, the relationship between innovative inputs and patents, in the case of the Spanish regions is explored.

Key words: geography of innovation, R&D, patents
JEL Classification: O30, O18, R30, R58

Resumen:

En el marco de los análisis sobre las relaciones entre la geografía y la innovación tecnológica numerosos estudios aplicados para Estados Unidos, Alemania, Francia e Italia han puesto de manifiesto los efectos positivos que la investigación académica ejerce sobre los resultados innovadores de las empresas de su entorno mientras que en el caso de España existe escasa evidencia a favor de una influencia positiva de la investigación universitaria. El objetivo de este trabajo es examinar los determinantes de la innovación regional y, en particular, buscar nueva evidencia sobre los posibles efectos de la investigación universitaria para el caso de España. Para ello, a partir de una función de producción de conocimientos tecnológicos Griliches-Jaffe y con el uso de datos de panel, se examina la relación entre diversos recursos generadores de innovaciones y los resultados innovadores, medidos por las patentes, en el caso de las regiones españolas.

1. Introduction

In the framework of analyses on the relationship between geography and technological innovation the study of the effects of university research on regional and local innovative output has occupied a predominant place. The applied analyses, mainly carried out in the United States, but also in the main European countries have shown that university research positively influences the capacity for innovation of the surrounding firms (Jaffe, 1989; Acs et al., 1992; Feldman, 1994; Anselin et al., 1997; Piergiovanni et al., 1997; Blind and Grupp, 1999; Piergiovanni and Santarelli, 2001; Autant-Bernard, 2001; Acs et al, 2002).

In the case of Spain, however, the reports of experts (COTEC, 1998), the opinions of the firms (INE, 1998) and some applied analyses (García-Quevedo, 2002) offer scant evidence in favour of a positive influence of university research on private innovation. Nevertheless, a very significant process of territorial expansion of the university system, has taken place in recent years, and the technological links between firms and universities have improved. Initiatives like the creation of scientific parks or the increase in the volume of contracts of the Offices for the Transfer of Research Results (OTRI) show an expansion of the relationship between the universities and firms in the transmission of knowledge. Therefore, the case of Spain is of considerable interest because of this process of territorial expansion that has led to there currently being universities in all the regions, and also because of Spain's position as an intermediate economy in terms of technological level.

The main purpose of this paper is to analyse the relationship between university research and innovative output at a regional level. The paper is organised as follows. Firstly, the main channels between academic research and private technological activities are presented. Secondly, some data is presented on the research activity of Spanish universities and on their relationships with firms. Thirdly, through an applied analysis, the relationship between the geographical distribution of innovative ouput and university research in Spanish regions (NUTS-2) is explored. Private applications for European patents have been used to measure innovative output. European patents are more technologically significant than those registered with national patent offices and university research is more likely to affect the most advanced aspects of regional innovative output, due to the fact that universities prefer to carry out research rather than development. In this analysis count data models and panel data have been used for the period 1996-2000 which allows the advantages of panel data to be exploited in the estimations. Finally the conclusions obtained are presented.

2. Universities and the location of innovation

The contribution of basic research to technological innovation and the interrelation between the universities and industry occur through various channels (Rosenberg and Nelson, 1994; Mowery, 1995). The main ones are obtaining, through academic research, useful inputs of knowledge, the training of scientists and engineers, the knowledge of academic researchers derived from their experience and training, participation in national and international networks, and the creation of new firms -spin-offs– based on discoveries made in universities (Pavitt, 1998).

Therefore the various possibilities for interaction between academic research and the technological activities of firms allow the importance of geographical distance in the transmission of knowledge to be shown. While in the accessibility of the results, once published, of university research, geographical distance does not have any influence, there are other knowledge transmission channels that lead to a geographical agglomeration of the benefits of university research. This happens especially when the transmission of knowledge, often of tacit nature, requires interaction between agents, personal mobility, and frequent contact (Pavitt, 1998).

The analysis of the regional impact of the universities has deservedly been the centre of growing interest. The effects of universities are very diverse: demographic, economic, cultural or infrastructural, among others (Florax, 1992). However, the creation of knowledge and the transfer of technology are among the main functions of universities. The majority of studies that have analysed knowledge impact use a production function with some measure of innovation as the dependent variable and a possible group of explanatory variables, all of them measured for a common geographical unit (Feldman, 1999). Specifically, these studies use the production knowledge function proposed by Griliches (1979, 1990) introducing the spatial dimension to examine the importance of geographical proximity in the transmission of knowledge. The subjacent hypothesis in this approach is that innovative activity will concentrate in those regions where knowledge inputs are greater due to the fact that knowledge transmission is favoured by geographical proximity (Feldman, 1999).

The basic specification of these models (Audretsch, 1998; Feldman, 1999) is:

$$\log INN_i = \beta_0 + \beta_1 \log GID_i + \beta_2 \log UNIV_i + \varepsilon_i \qquad (1)$$

where INNi measures innovative output for geographical areas, GIDi is private expenditures on R&D and UNIVi is an indicator of university research, R&D expenditures or R&D personnel. Therefore, in contrast to the usual approach where the observation unit is the firm, in this approach the unit of observation is at the spatial level. This function, the so-called Griliches-Jaffe knowledge production function, should be considered as an empirical model because from a theoretical viewpoint there is no specific framework to study the existence of local spillovers or to analyse the regional distribution of innovative output.

Jaffe (1989), in the first study with this approach, shows the importance of geographical proximity for the transmission to firms of the knowledge generated in the universities in the United States. As Jaffe points out (1989), although the means by which knowledge is transmitted between universities and firms are not well known, presumably distance may play an important role. Other studies in the United States (Acs et al., 1992; Feldman, 1994; Anselin et al., 1997; Acs et al, 2002), Germany (Blind and Grupp, 1999), France (Piergiovanni and Santarelli, 2001; Autant-Bernard, 2001) and Italy (Piergiovanni et al., 1997) have confirmed this conclusion and have shown that university research exerts a positive influence on the innovative output of the firms in the region where the universities are located.

3. The academic research in Spain

Universities are one of the main agents of the Spanish system of innovation. In 2000, the R&D expenditure of the universities represented 29.6% of the total spent on R&D. Nevertheless, university expenditure on R&D in Spain is only 0.28% of GDP, a percentage far from the 0.39% corresponding to the European Union. In the final years of the eighties and in the nineties a very considerable expansion of the university network took place with the creation of new universities. In the directory of the National Statistical Institute (INE) of the "Survey on technology research and development" in 1990 there were 37 universities that carried out R&D activities, 50 in 1995, and 64 in 2000. This expansion has led, from a territorial point of view, to a regional redistribution of R&D activities.

Universities should constitute a source for the generation of new knowledge and favour the development of technological innovations contributing to economic growth. Although the analyses on the processes of technological change (Dosi et al., 1988) have allowed the lineal pattern of innovation approach to be surpassed, the transfer of knowledge from the universities to firms continues to be a key factor in the generation of innovations. Also, in recent years, scientific research has gained importance as a source of innovative ideas (European Commission, 2000).

In Spain, various studies and analysis have shown that there are weaknesses in the relationship between universities and firms. The main reasons for this conclusion are:

Firstly, the opinions of the experts, in reports on the Spanish system of innovation (COTEC, 1988) and on the university system (Bricall et al., 2000) have shown the lack of mutual knowledge between universities and firms and the weaknesses in the processes of technology transfer and knowledge from universities to firms. Also, according to the opinion of Spanish innovative firms, universities have little importance as a source of innovative ideas, and these firms place them last among the different possible sources (INE, 1998). Nevertheless, this evaluation varies significantly depending on the sector in question. In science based sectors, such as the pharmaceutical industry or electronics, the opinions of the firms are much more favourable.

Secondly, the weaknesses of the Spanish system of innovation, with a small number of firms that carry out R&D activities systematically, a limited effort in R&D - lower than in the European Union-, and the importance of the use of foreign technology are also factors that limit the transmission of knowledge between universities and firms.

Finally, the use of the Griliches-Jaffe knowledge production function in the case of Spain (García-Quevedo, 2002), with the use of Spanish patents and data for one single year -1995- showed that, with the exception of the electronics industry, the results did not provide evidence to support a positive relationship between university research and regional innovation.

In contrast to these conclusions, diverse sources and indicators show that in recent years the research productivity of Spanish universities and their relationship with firms has improved. The main reasons for making this statement are:

Firstly, the quantity of science and scientific productivity in Spain have improved substantially in the last decade (Jiménez-Contreras et al., 2003). From representing 1.6% of the world scientific production in 1990 Spain has gone on to reach 2.5% in the year 1998 (INE, 2002). The effort carried out in recent years (1995-1999) has been substantial, with an annual increment of the Spanish scientific publications of 7%, well above the 2.9% corresponding to the European Union (Rubiralta, 2002).

Secondly, as has been pointed out, the process of territorial expansion of the Spanish university system has been very considerable, especially in the first years of the nineties. These university campuses, closer to the firms, have been a booster as well as an agglutinative element for research and development activities (Bricall et al., 2000). Therefore, after a certain period of time to link up with the firms in the same region and for the transmission of knowledge, it seems that the creation of new universities has favoured the innovative capacity of the territory in which they are located. There has been also an increase in collaboration between universities and firms in most of developed countries. This is due fundamentally to the development of science in fields with more commercial application such as molecular biology, to the growing scientific and technological content of industrial production and the verification of the growing effectiveness of the transfer of scientific and technological knowledge from universities to firms. Although significant differences still exist regarding the most advanced countries, the Spanish universities have participated in this process. In 2000, 5.5% of the innovative firms had developed R&D cooperation relations with universities, while in 1996 this percentage was only 3.6% (INE, 2002).

Finally, universities have developed some initiatives such as the creation of scientific parks to favour the connection with the productive system and the creation of innovative companies, spin-offs, based on discoveries from scientific research. Especially, the activity of the OTRIs, bodies that have the mission to promote relationships between the university and firms in the area of R&D, underwent very significant growth in the period 1996-2000, reaching the figure of 200 million Euros in 2000, more than double the amount in 1996. This sum corresponds to R&D contracts between the universities and firms managed by the OTRIs. Most of these contracts, 80% of them, are with the firms located in the same region as the university. In this same period, according to data from the INE, the business financing of university R&D activities has experienced a real annual growth of 3.4%. This growth has allowed business financing to stay at around 7% of total funds, a percentage greater by more than one point to that corresponding to the European Union (OECD, 2002).

In synthesis, although the connection between the university system and the productive system continues to present weaknesses, some indicators show an advance in this relationship. The objective of the following section is to examine whether universities have a positive impact on the innovative output at a spatial level with an applied analysis based on the approaches of the recent economic literature.

4. Applied analysis: model, data and results

The usual theoretical framework for the econometric analysis of the processes of innovation is based on the knowledge production function proposed by Griliches (1979, 1990). This function is supported by abundant empirical evidence and has been the basis for many applied studies at a regional level (Audretsch, 1998).

The analysis of the case of Spain is based on this model and on the empirical analyses that use models where the geographical innovative output depends on the presence of innovative inputs in the same territory. The main objective is, as has been pointed out, to examine the influence of university research in the spatial distribution of private innovative output.

The model is:

$$INNOV_i = f\ (GID_i,\ GUNIV_i) \qquad (2)$$

where INNOVi is the number of innovations - corporate patents (PATi) - at a regional level, GIDi is an indicator of the private resources for innovation and GUNIVi is the university research, for the same region.

Regional innovative output has been measured using private patent applications, excluding applications by universities or public institutions. This indicator, despite its limitations, has been the most common in applied analyses, and as Acs et al. (2002) have shown, patents provide a fairly reliable measure of regional innovative activity. Specifically, the number of applications by residents in Spain for European patents has been used, which information is provided by the Spanish Office of Patents and Marks (OEPM) with details of the region of the applicant's residence. In Spain, the regional distribution of the European patents classified by the applicant's place of residence or that of the inventor is very similar. With information corresponding to the applications for European patents for the period 1978-1997 the correlation is 0,999 (Sanz and Arias, 1998). The number of applications for European patents has experienced growth in recent years. Compared to the 434 in 1996, applications for European patents reached almost 700 in the year 2000, a level nevertheless very far from other countries such as Germany, France or Italy. The regional concentration is very high and superior to that of economic activity. Two regions, Catalonia and Madrid, concentrate more than 50% of the applications for European patents in Spain in the period 1996-2000 (Table 1).

To measure private regional effort in innovation the usual indicator - R&D (GID) expenditures- has been used from the survey of the INE. The INE requests that firms assign R&D expenditures to the region where the expenditure is made. This approach guarantees an appropriate territorial distribution avoiding the problem of assignment of all the R&D expenditures of a company with centres in different regions to its main headquarters. Business expenditures on R&D present a high degree of territorial concentration, even superior to that of the applications for patents. Madrid and Catalonia concentrate more than 60% of R&D expenditures, while there are regions such as the Basque country and Andalusia with lower percentages.

To measure regional academic research, university R&D expenditures (UNIVG), provided by the INE, have been used. The universities carry out research in different scientific disciplines with a very different degree of industrial and commercial applicability. Therefore not all academic research results in useful knowledge for firms which pursue a commercial application. However, research in certain scientific fields should constitute a relevant source of ideas for private R&D activities (Nelson, 1986;

Von Hippel, 1988). For this reason, of the group of scientific fields into which the INE classifies university research, only R&D expenditures in the most relevant disciplines for generating information of utility for private innovative activity have been used. Specifically, the INE uses the classification proposed by the UNESCO that considers the following six areas: Maths and Natural Sciences, Engineering and Technology, Medicine, Agricultural Sciences, Social Sciences and Humanities.

Of these six areas only the first four have been used, excluding Social Sciences and Humanities, since in these first four disciplines the connection with private innovative activity is greater. Of the total R&D expenditure of the universities 78.7% was carried out in these four disciplines in the year 2000. The expansion of the universities has meant that there are R&D activities in the four disciplines in all the regions.

Table 1

For this data there is information available for the 17 regions for the period 1996-2000, which has permitted the construction of a panel of data to carry out the estimations. To do so, a Cobb-Douglas production function has been used, the usual specification in the applied studies on this subject. Population (POP) has been used as a control variable due to the different sizes of the regions (Jaffe, 1989).

Therefore, the model is:

$$PAT_{it} = \beta_0 + \beta_1 \log GID_{it} + \beta_2 \log GUNIV_{it} + \beta_3 \log POP_{it} + \varepsilon_{it} \qquad (3)$$

$t = 1,\ldots, 5$ and $i = 1,\ldots,17$

To carry out the estimations the characteristics of the dependent variable should be taken into consideration. Patents constitute a typical example of count data. In this case a specification like the Poisson model is preferable to a linear regression model estimated by ordinary least squares because the later method of estimation does not take account of the nonlinear relationship between the variables of the model. On the other hand the count data model respects the discreteness of the dependent variable of the model as well as this nonlinear relationship (Hausman, Hall and Griliches, 1984; Cameron and Trivedi, 1998)[1]. The use of the Poisson model is very frequent in applied analysis based on patent data or numbers of innovations (Hausman, Hall and Griliches, 1984; Baptista and Swann, 1998; Feldman and Audretsch, 1999). In the Poisson model, the mean and the variance of the endogenous variable are assumed to be equal, which is a very restrictive assumption. A common alternative is the negative binomial specification. The estimations have been carried out using the Poisson model and the negative binomial model for panel data. Private and university R&D expenditures have been deflated with the deflator of the GDP.

Tables 2 and 3

Although the results corresponding to both models are presented, in this case, the most appropriate is the negative binomial model due to the presence of overdispersion, the variance being more than twice the mean. Time dummies have been introduced into the estimations to control the aspects common to all the regions such as the economic cycle. As in linear panel data models, a fixed effects or a random effects model may be used.

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[1] Nevertheless, estimations of the model using standard panel data methods have been carried out and the obtained results are not consistent with the economic background of the model.

The Hausman test makes it possible to discriminate between both possibilities and the result shows, that in the negative binomial specification, the random effects model is preferable.

The results for the period 1996-2000 show that both variables, private R&D expenditures and university research, have positive and statistically significant coefficients. The regional distribution of the effort that the firms dedicate to R&D activities is an explanatory variable of the regional innovative output. The values[2], around 0.4, are very similar to those obtained by other studies (Jaffe, 1989; Feldman, 1994; Anselin et al, 1997; Autant-Bernard, 2001).

University research during this period has also exerts a positive influence on the regional distribution of innovative output, measured by applications for European patents that should be considered to concern innovations of a higher technological level than those related to applications for Spanish patents. Consequently, for this type of innovation, academic research is a relevant source of knowledge for the firms located in the same region as the university where the research is done. This result is consistent with those obtained, as has been pointed out, for the United States, Germany, France and Italy. The coefficients estimated for university research are also very similar to those obtained for France (Piergiovanni and Santarelli, 2001). These results show that the consolidation, from a territorial point of view, of the Spanish university system, the increase in the level of academic research and the efforts made to favour the transfer of the results of university research to the firms has allowed, in recent years, the link-up between universities and firms to be improved.

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[2] Note that in these models (see Cameron and Trivedi (1998)) when the exogenous variables are measured in logarithms the estimated parameters of the models can be interpreted as the elasticity.

5. Concluding remarks

In this paper, the relationship between university research and regional territorial innovative output has been examined using a Griliches Jaffe knowledge production function. For this purpose a panel of data for the period 1996-2000 was constructed, using appropriate econometric techniques for the estimations, such as the Poisson model and the negative binomial specification, for the treatment of count data. The results obtained in the estimations show that for innovations of high technological content, measured by applications for European patents, academic research exerts a positive influence. These results, for an intermediate economy in technological level like Spain, coincide with the evidence obtained in the United States and in other European countries that have shown that the transmission of knowledge from the universities to the firms is favoured by geographical proximity.

The indicators, such as R&D contracts or cooperation agreements, point toward an improvement in the relationship between universities and firms in Spain. Furthermore the applied analysis carried out shows the positive effect of university research on private patents at a spatial level, at least for patents with a higher technological content. Therefore, and in spite of this progress, a significant increase in the financial resources and efforts in this field is necessary to reduce the differences that separate the level of technology in Spain from that of the developed countries.

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Table 1. Innovation. Regional distribution. 1996-2000

CCAA	PATENTS	GID	GUNIV
Andalusia	4.45%	5.52%	14.49%
Aragon	4.25%	2.52%	2.36%
Asturias	1.00%	1.26%	2.61%
Balearic Isles	0.94%	0.16%	1.49%
Canary Isles	1.44%	0.62%	4.68%
Cantabria	0.40%	0.57%	1.24%
Castilla y Leon	3.11%	2.59%	6.25%
Castilla - La Mancha	1.54%	2.28%	1.59%
Catalonia	34.72%	27.98%	18.25%
Comunidad Valenciana	10.70%	4.65%	12.25%
Extremadura	0.50%	0.28%	1.61%
Galicia	1.94%	1.92%	5.48%
Madrid	18.83%	32.95%	18.46%
Murcia	1.17%	1.22%	2.31%
Navarra	4.05%	1.97%	1.95%
The Basque Country	10.67%	13.07%	4.57%
Rioja, La	0.30%	0.44%	0.40%
	100.00%	100.00%	100.00%

Source: own elaboration with information provided by the OEPM and the INE.

Table 2. Regression results. Poisson model.
Dependent variable: number of patents

	Fixed effects				Random effects			
	1		2		1		2	
	$\hat{\beta}_j$	sd	$\hat{\beta}_j$	sd	$\hat{\beta}_j$	sd	$\hat{\beta}_j$	sd
LGID	0.305	0.115***	0.125	0.139	0.473	0.080***	0.416	0.098***
LGUNIV	0.660	0.218***	0.491	0.265*	0.740	0.178***	0.712	0.214***
LPOP	2.120	1.575	1.633	2.033	-0.286	0.221	-0.181	0.291
dyear2			0.168	0.067**			0.163	0.065**
dyear3			0.288	0.088***			0.204	0.071**
dyear4			0.298	0.098***			0.216	0.071***
dyear5			0.220	0.140			0.099	0.085
Cons					-5.936	2.038***	-6.663	2.293***
$a = 1/\theta$ [a]					0.184	0.071	0.204	0.084
LR a=0 [b]					370.770	***	371.330	***
Log-L	-184.969		-175.144		-271.003		-263.029	
T_H [c]					12.113	***	16.531	**

Fixed effect model: $y_{it} \sim P(\mu_{it} = \alpha_i \lambda_{it}) \quad \lambda_{it} = \exp(x_{it}'\beta), E[y_{it} \mid x_{it}] = VAR[y_{it} \mid x_{it}] = \mu_{it}$.

Method of estimation conditional maximum likelihood, where the log-likelihood used is obtained from the joint density function of an observation i conditional to the distribution of a sufficient statistic of the regional effect α_i with $P\left(y_{i1}, y_{i2}, \cdots, y_{iT} \mid \sum_{t=1}^{T} y_{it}\right)$.

Random effect model: $y_{it} \sim P(\mu_{it} = \alpha_i \lambda_{it}) \quad \lambda_{it} = \exp(x_{it}'\beta)$, where now α_i is a random variable. The distribution assumed for the regional effects is

[a] Gamma(θ,θ), $E[y_{it} \mid x_{it}] = \lambda_{it}, VAR[y_{it} \mid x_{it}] = \lambda_{it} + \lambda_{it}^2/\theta$.

[b] Likelihood ratio test. H_0: a=0, due to $VAR[\alpha_i] = 1/\theta = a$, to reject H_0 leads to reject of the possibility of working with a pool of data versus a panel data model.

Significant at 10% *, 5% ** and 1% ***.

[c] Hausman's test, under H_0 the random effects are not correlated with the independent variables. To reject the H_0 leads to a rejection of the random effects model.

Table 3. Regression results. Binomial negative model NB
Dependent variable: number of patents

	Fixed effects				Random effects			
	1		2		1		2	
	$\hat{\beta}_j$	sd	$\hat{\beta}_j$	sd	$\hat{\beta}_j$	sd	$\hat{\beta}_j$	sd
LGID	0.329	0.117***	0.084	0.151	0.466	0.091***	0.422	0.104***
LGUNIV	0.774	0.246***	0.409	0.294	0.748	0.200***	0.714	0.225***
LPOP	-0.272	0.604	0.714	0.907	-0.297	0.243	-0.190	0.309
Dyear2			0.173	0.073**			0.160	0.071**
Dyear3			0.327	0.093***			0.201	0.077***
Dyear4			0.340	0.096***			0.210	0.077***
Dyear5			0.296	0.125**			0.092	0.092
Cons	-4.066	8.090	-10.838	12.327	-4.863	2.122**	-4.733	2.597*
a [a]					20.489	11.626	39.020	42.442
b [a]					7.732	3.503	5.766	2.687
LR pool [b]					85.100	***	94.740	***
Log-L	-183.326		-174.648		-268.551		-262.589	
T_H [c]					6.440		10.954	

Fixed effects model: $y_{it} \sim \text{NB1}$ with parameters α_i, λ_{it} y ϕ_i, where α_i are the individual effects, $\lambda_{it} = \exp(x_{it}'\beta)$ and ϕ_i is the parameter that allows overdispersion. $E[y_{it} \mid x_{it}] = \alpha_i \lambda_{it} / \phi_i$ and $\text{VAR}[y_{it} \mid x_{it}] = (\alpha_i \lambda_{it} / \phi_i)(1 + \alpha_i / \phi_i)$. The method of estimation is conditional maximum likelihood.

Random effects model: $y_{it} \sim \text{NB2}$ with parameters α_i, λ_{it} y ϕ_i, where $\lambda_{it} = \exp(x_{it}'\beta)\ \alpha_i$ and it is assumed that $(1 + \alpha_i / \phi_i)^{-1}$ follows a Beta distribution (a,b)[a]. $E[y_{it} \mid x_{it}] = \alpha_i \lambda_{it} / \phi_i$ and $\text{VAR}[y_{it} \mid x_{it}] = (\alpha_i \lambda_{it} / \phi_i)(1 + \alpha_i / \phi_i)$.

[b] Likelihood ratio test that compares the fitted panel data model with the pool of data model. H_0: pool of data.

Significant at 10% *, 5% ** and 1% ***.

[c] Hausman's test, under H_0 the random effects are not correlated with the independent variables. To reject the H_0 leads to a rejection of the random effects model.