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LOCAL HUMAN CAPITAL AND EXTERNAL ECONOMIES: EVIDENCE FOR SPAIN [a b]

Esteve Sanromà[c], Raúl Ramos[d]

ABSTRACT: It is assumed that human capital external economies can increase factor productivity. However, as human capital is accumulated in an unequal way in the territory, productivity improvements will be different among territories. So, in the presence of labour mobility, wage differences will induce migratory movements that would concentrate population in a given geographical area and increasing housing rents until the net advantage of residing and working in different places is equal. In this paper we estimate wage and housing rents equations following Rauch (1993) model using microdata from the EPF 1990/91. The results offer evidence of local human capital external economies for the Spanish economy.

RESUMEN: La existencia de economías externas asociadas al capital humano puede incrementar la productividad de los factores. Sin embargo, como el capital humano se acumula de manera desigual en el territorio, las mejoras de la productividad también son diferentes. De este modo, si existe suficiente movilidad laboral, las diferencias salariales causarán movimientos migratorios que concentrarán la población en una área geográfica concreta aumentando los alquileres hasta que la ventaja neta de vivir y trabajar en sitios diferentes se iguale. En este trabajo se estiman ecuaciones de salarios y del coste de la vivienda para contrastar la existencia de economías externas asociadas al capital humano en la economía española. Los resultados ofrecen evidencia favorable a su existencia.

Keywords: Human capital, external economies
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1. Introduction

Since long time ago, economic literature has always highlighted the positive effects of education on productivity (Smith, 1776, book I, chapter 10-1). But it was Marshall (1890) who remarked that these effects are not only limited to the individual productivity but to the rest of workers in the same territory[1]. In the middle of this century, the contributions in the framework of the Human Capital Theory (Shultz, 1960; Becker, 1964) reinforce these ideas and, in particular, the concept of investment in human capital as an individual and collective investment is widely diffused.

In spite of the continuous attempts to quantify social returns to education (Psacharopoulos, 1993), most empirical works have focused in testing –in a most refined way- the central core of the theory: the higher the level of education is, the higher the productivity is[2].

Nevertheless, the apparition of the endogenous growth theory in the second half of the eighties and the role of externalities in the same, especially those associated to human capital (Lucas, 1988) has renovated the interest in the analysis of human capital external effects.

At the same time, the development of the new economic geography and, in particular, the economy of cities -highlighting the special character of cities as centres of exchange of ideas- has promoted the convenience of establishing the territorial limits where the external effects of human capital act.

This state of the art conduced, in the decade of the nineties, to the beginning of different empirical works that try to contrast the presence and the magnitude of local human capital externalities for the case of the United States. In all these empirical works, individual data are used and the considered territorial unit is the urban area (defined as the Standard Metropolitan Area).

In a seminal contribution, Rauch (1993) proposes a spatial equilibrium model where the local human capital is considered as a territorial characteristic having positive effects on productivity and no effects as amenity. In this model, when the average territorial level of human capital increases, it generates through productivity improvements an increase of local wages that to keep the spatial equilibrium of workers and firms has to be compensated by an increase in housing costs. The estimation of the reduced form of the model using hedonic equations for wages and rents for 1980 Census data offers clear evidence in favour of the existence of local human capital external economies. The estimation of the model using 1990 Census data confirms the previous results and even reinforces the role of human capital external economies (Almond, 1997). Adserà (2000), estimating local costs functions (wages plus land rents) with 1990 data, also confirms the relevance of local human capital externalities on wages and rents.

For the Spanish case, the empirical evidence on human capital external economies is very scarce. Only Sanromá and Ramos (1999) have made a first approximation to the identification and quantification of human capital external effects in the context of the Spanish industrial sector using micro data. The obtained results provide evidence about the empirical relevance of external economies generated by human capital accumulation and the productive specialisation of the territory (intraindustrial marshallian external economies).

The objective of this paper is to analyse the possible existence of external economies generated by local human capital, complementing the previously exposed results. In particular, we try to contrast the presence and the magnitude of local human capital externalities for the case of Spain, taking the province as the territorial unit of analysis. The methodological approach used in the paper consists of estimating wage and housing costs equations which include, apart from individual and house characteristics to control for specific effects on both variables, two variables related to local human capital: the average level of studies in the province and the average level of experience. The obtained results are similar to those obtained by previous authors for the United States, providing evidence in favour of the existence of local human capital external economies at a territorial level in Spain.

The structure of the paper is as follows: first, statistical sources used in the analysis are described; next, the applied econometric methodology is explained and the results of estimating wage and housing cost equations are presented; last, we conclude summarising the main results and pointing some weak points of the considered approach that could be improved in future research if more detailed data is available.

2. Empirical evidence for Spain

In this section, empirical evidence on the effects of local human capital external economies for the Spanish provinces using micro data is presented. First, data sources are described and, second, the results of estimating enlarged Mincer equations and house cost equations including variables to control for individual effects and proxy variables of local human external economies are presented.

2.1. Statistical sources and variable definition

Wages, housing costs and personal and job characteristics

The estimates presented here are based on data on individual wages and house costs from the *Encuesta de Presupuestos Familiares* (Family Budget Survey) carried out by the *INE* (the Spanish Institute of Statistics) for the second quarter of 1990 to the first quarter of 1991. Although the main objective of this survey is the analysis of Spanish family consumption expenses, it also facilitates information about personal and job characteristics and wages and also of house costs and its characteristics. The availability of this broad individualised information suggested its use in this paper.

In reference to wages, we have worked with data on 16.949 individuals who declared annual positive incomes from paid employment in non-agricultural industries and all the necessary information about personal and job characteristics was provided. In respect to the housing sample, we have included the 9104 units for which the up-to-date value of the house cost is given and all the required information about house characteristics is available. Although the survey also gives information about rents, we have preferred to use housing cost as the endogenous variable for the second equation of the model because survey data on rents are not real data. In fact, these data refer to what the house's owners believe he/she could get from renting his property. So, as the Spanish rent market is very few developed and information flows about rents are not transparent, these data could be enormously biased.

Data from the Spanish FBS is also appropriate for the analysis as it permits to control for the territorial dimension. In particular, data on individuals and house is always related to the "*provincia*", the Spanish territorial administrative unit for the NUTS-III level classification. Although this territorial unit has not the most appropriate extension for this kind of studies, it is small enough to assume that provinces are quite close to the concept of local labour market. Data on wages and rents are then related to one of the fifty Spanish provinces (see table 1).

Local human capital external economies

To approximate local human capital external economies, we have calculated the same two measures of local human capital as Rauch (1993) and that have also been used in other different empirical studies such as Almond (1997). In particular, we have calculated the average level of studies in the province and the average level of experience in the province using data from the available sample.

In respect to the average level of studies in the province, this variable has been constructed as the average level of schooling years of workers in the sample. The equivalence between the different levels of studies indicated in the survey and the number of schooling years of each of them is shown in table 2.

In reference to the average level of experience in the province, this variable has been constructed as the average level of potential experience of workers in the sample. Potential experience has been defined, as usual, as age minus schooling years minus six.

2.2. Methodology

The methodological approach used in this paper consists of estimating hedonic wage and housing costs equations which include, apart from individual and house characteristics to control for specific effects on both variables, the previously defined two variables related to local human capital: the average level of studies in the province and the average level of experience. The chosen functional form for both equations has been a semi-logarithmic function, which according to Mincer (1974) is the more appropriate functional form.

The proposed model for the wage equation is the following:

$$lnW_{ij} = f(s_{ij}, x_{ij}, z_{ij}, e_j) + u_{ij} \quad (1)$$

where ln W_{ij} is the natural logarithm of annual wage of individual i who resides in province j, s_{ij} is a measure of the level of studies of the individual, x_{ij} a measure of his/her experience and z_{ij} includes other individuals factors that can affect wages, such as gender, part or job characteristics (such as the activity sector -table 3- and the individual's occupation –table 4). e_j is a group of variables that try to approximate the effect of local human capital external economies on wages. Finally, u_{ij} is supposed to be a random error term following a normal distribution with zero mean and constant variance.

The proposed model for the housing costs equation is the following:

$$\ln H_{ij} = f(h_{ij}, e_j) + v_{ij} \quad (2)$$

where ln H_{ij} is the natural logarithm of the up-to-date cost of the housing unit i located in province j, h_{ij} includes variables related to house characteristics that can affect its cost, such as the number of rooms, squared meters, garden, garage, swimming-pool, etc. As in wages, e_j is a group of variables that try to approximate the effect of local human capital external economies on housing costs. Last, v_{ij} is supposed to be a random error term following a normal distribution with zero mean and constant variance.

As the standard procedure in local public goods literature is to estimate equations (1) and (2) by OLS, this technique implicitly assumes that every relevant characteristic of the territory has been observed and are included in the considered specification. For this reason, and due to the obvious non-fulfilment of this assumption, it seems more appropriate to specify a random effects model such as the following (only the equations for wages are given as expressions for the housing cost equation would be equivalent):

$$lnW_{ij} = f(s_{ij}, x_{ij}, z_{ij}, e_j) + \mu_j + u_{ij} \quad (3)$$

where μ_j is a term that captures the effects of not-observed provincial characteristics. As the error term of equation (3), μ_j+u_{ij}, is not spherical, the OLS estimation would give inefficient estimates of coefficients and biased and inconsistent estimates of its standard errors[3]. For this reason, the estimation of the proposed models has been done by generalised least squares (Greene, 1997, pp. 558-559). In particular, the applied estimation procedure involves the next three steps:

1. first, a consistent estimation of the variance of u_{ij} is obtained from the OLS estimation of (3) (without e_j) also considering provincial dummy variables;

2. next, the provincial average values (cell means) of the residuals from the previous step are calculated and a new regression is estimated using the e_j varibles as explanatory variables. The variance of the residuals of this second regression, σ_*^2, is related with the variances of μ_j and ε_{ij}, the estimates of the random term u_{ij} in (3), as it can be seen in (4) (Rauch, 1993, p. 388):

$$\sigma_*^2 = \sigma_\mu^2 + \left[1/n \cdot \sum_{j=1} \sigma_\varepsilon^2 / n_j \right], \qquad (4)$$

   where n is the total number of observations and n_j is the number of observations of province j. In this sense, using the estimate of σ_ε^2 obtained in the previous step, it is possible to calculate the value of σ_μ^2; and,

3. Last, using the estimates of the provincial variances, it is possible to transform properly the original data and obtained efficient estimates for the desired coefficients using OLS.

2.3. Estimation results

The results of estimating equations (1) and (2) are shown, respectively, in tables 5 and 6. The results of estimating by OLS wage and housing cost equations where no variables related to human capital external economies are considered, are presented in the first column of both tables (Model 1).

In reference to the wage equation, the considered explanatory variables are similar to the ones considered in a usual enlarged Mincer equation. All the individual variables included to control for individual effects on wages are significant and have the correct expected sign and magnitude. In particular, variables related to individual level of studies and potential experience (which has been introduced assuming a quadratic form) show the existence of a positive relationship between individual human capital and wages similar to the one obtained by other studies. The model also includes dummy variables related to the occupations and activity sectors to control for the effect of job characteristics -for example, fatigue or risk- and the various productive and employment structures in the various provinces on wages. In general, the results are found to be satisfactory as around the 40% of the variance of wages is explained, a similar percentage to that of other studies on the topic using individual data.

In respect to the housing cost equation, explanatory variables include dummy variables related to house characteristics that can explain the costs without taking into account the house territorial location. In particular, a dummy variable for houses located in urban areas is included, the number of squared meters of the house surface, the number of rooms, the number of bathrooms depending on its characteristics, the number of floors of the building where the housing unit is located and the availability of different services or equipment such as garden, garage, swimming-pool, lift, central heating or conditioned air, are included in the regression. All these variables are significant and have the correct expected sign and magnitude. As happened with wages, in general, the results are found to be satisfactory as around the 35% of the variance of house costs is explained, a similar percentage to that of other studies on the topic.

As it has been exposed, and taking into account the objective of the paper, we have taken as a starting point the previous models and we have added two more explanatory variables related to local human capital, the average level of studies in the province and the average level of experience in each regression. The results of estimating wage and house cost equations by GLS are shown in column 2 of tables 5 and 6 (model 2), respectively. The coefficients associated to both variables are similar to those obtained by Rauch (1993) and Almond (1997) for the United States: there is evidence that the average level of territorial human capital generates a positive external effect on productivity. The coefficient associated to the average level of studies is positive and significant in both equations while the coefficient associated to the average level of experience is only significant in the house costs equation. The magnitude of the coefficients associated to the average level of studies (0.044 on wages and 0.209 on housing costs) is higher than the one associated to the average level of experience (-0.006 on wages and 0.041 on housing costs). This fact implies that the average level of studies has a much greater productive external effect than the average level of experience. As Rauch (1993, p. 291) suggests, this fact would be consistent with the idea that "... the probability that a meeting between agents in a territory will be productive is increased more by a year of average education than by a year of average experience, since a major part of formal education is concerned with communication skills, i.e., reading, writing, and (to a lesser extent) oral presentation". It is also interesting to remark that the magnitude of the obtained coefficients in both equations for the Spanish provinces are very close to that obtained by Rauch (1993) and Almond (1998) following the same methodology for the American SMA using 1980 and 1990 data, respectively. If we compare the values of the coefficients obtained by both authors (tables 7 and 8 – Initial estimates column) with the ones obtained here (tables 5 and 6 – model 2), there are strong similarities.

However, the large values of the coefficients associated to variables approximating local human capital external economies can be the result of the association of average education with other exogenous variables that increase/decrease wages and/or rents at the provincial level. So, following this line of reasoning, one would expect that if these exogenous variables are included in the regressions, the magnitude of human capital external economies will be reduced or even not statistically significant.

In this sense, in those territories with a high concentration of technological innovation activities, wages can be higher not as a result of human capital external economies but due to the higher productivity generated by these activities. In other words, the concentration research and development activities on a province could have generated the same local effects on productivity that we have identified with external economies effects. In Model 3 we have included a technological innovation indicator (see annex 2 for details) to contrast these hypothesis. As expected, the effect on wages and housing costs is positive and significant and the value of the coefficients associated to the average level of studies and the average level of experience are lower than before, although significant in the same cases. The value of the coefficient associated to the average level of studies reduces from 0.044 in model 1 to 0.037 in model 2 for wages, while it goes from 0.209 to 0.202 in the housing costs equation.

The average level of studies and/or the average level of experience can also be correlated with other omitted variables related to territorial amenities. The idea is that workers do not maximise wages but utility. In this context, in those territories with higher attractions, workers could achieve the same utility than in others with lower wages. However, in those territories with higher attractions, housing costs would be higher. In this sense, if the presence of amenities lowers wages and raises housing costs, such a correlation would bias downwards (upwards) the estimated coefficient on the average level of studies in the wage (rent) equation. One example of this kind of variables would be the territorial level of cultural facilities. When Rauch (1993) introduces a "culture per capita" index in both regressions, the results are not the expected. While the cultural index has a negative effect and it is significant in the wage regression rising the value of the coefficient of the level of studies, in the rent equation it is not significant. Almond (1997) also introduces an "Arts index" in his regressions using 1990 data, but the considered variable plays exactly the opposite role: it has a positive and significant effect on both regressions. So, the amenity nature of culture facilities is not very clear. In this paper, we have not been able to include a similar index as available territorial data on cultural facilities are not homogeneous because this information is compiled and provided by local institutions that do not follow unique criteria. As a result, an important and inequal bias could be introduced in both regressions if we consider this indicator.

However, there are two other territorial characteristics that can be related with wages and housing costs that have been omitted in the previous models and that regularly appear in the literature: climatic conditions and coastal location. The interpretation of both variables as amenities probably needs no explanation, but it is important to remark that they can also be related to territorial productivity levels. So, the effect on wages and housing costs is not clear. In this case, the evidence obtained by both, Rauch (1993) and Almond (1997), suggest that the productivity effect predominates on wages and rents. Models 4 and 5 of tables 5 and 6 show the results of adding to previous explanatory variables a climatic mildness indicator (see annex 2) and a dummy variable which takes value one for provinces with coast and zero for the rest in the regressions for the Spanish provinces. The results obtained seem to reinforce the conclusions by previous authors. In wage equations, the climatic mildness indicator is not significant at a 5% level but its coefficient has the negative sign expected for amenities. However, the value of the coefficient associated to the average level of studies decreases instead of raising. On the opposite, in housing costs equations, the results of the climatic mildness indicator are more related with the idea of amenity: it has a positive and significant effect but it raises the values of the coefficients associated to the provincial human capital variables instead of reducing it. When including the dummy variable "coast", the evidence on the productivity effect is much more clear: It has a significant and positive effects on wages, reducing the value of the average level of studies coefficient and it has no significant effects on housing costs.

Summarising the obtained results, there is clear evidence in favour of local human capital external economies at a territorial level in the Spanish economy. The initial estimates of the human capital external economies effects on wages and housing costs were substantially high than the final estimates obtained after including different omitted variables related to innovation activities, climatic conditions or coastal location. The final estimates of the effect of the provincial average level of studies on wages and rents are still relevant, although lower than the ones obtained in other studies for the American SMA. Two facts should be remarked in relation with the results: first, we are working with annual data for wages instead of the average hourly wage and this fact could be possibly relevant as differences in terms of rents/housing costs are lower; second, the considered territorial unit, due to data availability, is the province that has a bigger extension than the SMA.

3. Conclusions

In this paper, the possible existence of external economies generated by local human capital in Spain has been considered. In particular, taking the province as the territorial unit of analysis, wage and housing costs equations have been estimated using micro data from the *Encuesta de Presupuestos Familiares* 1990/91 to contrast the existence and to quantify the external effects of local human capital on both variables. The obtained results permit to affirm that there is similar evidence in favour of local human capital external economies at a territorial level in Spain to those found by Rauch (1993) and Almond (1997) for the SMA of the United States.

However, the methodology proposed by Rauch (1993), the one followed in this paper, has received several criticisms.

A first problem consists in the possible presence of unobserved spatial heterogeneity. To address this question, Rauch (1993) specifies a random effect model and estimates it using Generalised Least Squares, being this the approach followed in this paper. Moretti (1998) uses data from the 1980 and 1990 Census to obtain estimates of the social return to education that are robust to unobserved spatial heterogeneity after differentiating the data to eliminate city-specific effects. This methodology has also been applied by Ciccone *et al.* (1999) with data for 1970, 1980 and 1990.

The second criticism is related to one basic assumption in Rauch (1993). This assumption is that local human capital can be considered as exogenous[4]. As Moretti (1998, p.2) remarks "Rauch's assumption that city average education is historically predetermined is problematic, if better-educated workers tend to move to cities with higher wages". In this sense, high-paid territories would be more attractive for qualified workers than areas with lower wages, the average level of education in a territory would not be totally independent of wages paid there. So, if the geographical mobility of workers is very high, Rauch's assumption would not be appropriated. In Spain, however, we think that the assumption that the provincial human capital is exogenous is not a very strong assumption. Although internal migrations have been quantitatively relevant during the last decades (about four million people changed their province residence from 1970 to 1990 from a total population of 40 million), workers movements do not seem to have been motivated by wage differentials. During the seventies (at least during the first half), most migrants were low-qualified agricultural workers who were moving to industrial areas. During the first half of the eighties, and as a result of the rising unemployment in industrial areas caused by the first and second oil shocks and the following industrial reconversion, some of the migrants in the previous periods tended to come back to their origin province, moving, then, to low-wage areas (Ródenas, 1994). For these reasons, it seems that Rauch's assumption of human capital exogeneity will be less restrictive for Spain than for the United States.

In this sense, to address this problem for the United States, Moretti (1998) and Ciccone *et al*. (1999) propose to use three different sets of instrumental variables: variables related to quality of life, to the ethnic composition of the population and to the demographic composition of the population. This approach will also be considered for the Spanish case in future research.

Last, other important criticism to Rauch's (1993) approach is the one remarked by Peri (1998) and Ciccone *et al.* (1999). According to Ciccone *et al.* (1999, p.7), "the main problem with Rauch's approach is that he assumes implicitly that average levels of schooling affect wages only through externality-driven shifts of labor demand curves. But average levels of schooling may affect wages also through supply-driven movements along (fixed) labor demand curves (which we call supply effects)". To address this issue, they develop an empirically implementable approach where the average level of human capital in cities may affect wages through externality-driven shifts of labor demand curves as well as supply-driven movements along labor demand curves (supply effects). After estimating the model, they find a strong complementarity between human capital and labour but no clear evidence of local human capital externalities.

The consideration of these two last questions as a way to improve the obtained results for the Spanish case is not possible nowadays due to the defficiencies of the available data. As survey data for the *Encuesta de Presupuestos Familiares*[5] is only available for 1990-91, we cannot use panel data to eliminate fixed-city effects or to empirically implement the model of Ciccone *et al.* (1999) for the Spanish case as it necessarily implies differencing the data. Further research on this and other previously mentioned questions could be carried out for the Spanish case as soon as more detailed data becomes available.

Final notes

[1] In his exposition on the "industrial district", Marshall shows as one of its possible advantages, the existence of technological spillovers as a result of the interaction between workers of the district, promoting learning which increases productivity.

[2] See Card (1998) for a current survey.

[3] Moulton (1986) analyses the consequences of applying inappropriately OLS estimation for individual data with high intra-group correlations, concluding that standard error of the coefficient are under-estimated.

[4] "Like the site characteristics used in the empirical local public goods literature, the average level of human capital in a SMA is exogenous from the point of view of an individual consumer or firm making its location decision" (Rauch, 1993, p. 385).

[5] The main problem with the *Encuesta Continua de Presupuestos Familiares*, that would provide data for different time periods, is that it is only representative at a national level and not for every province.

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Annex 1. Tables and figures

Table 1. Code and name of the Spanish 50 provinces (NUTS-III Classification)

Code	Province	Code	Province	Code	Province	Code	Province
PR1	Alava	PR14	Córdoba	PR27	Lugo	PR40	Segovia
PR2	Albacete	PR15	Coruña (La)	PR28	Madrid	PR41	Sevilla
PR3	Alicante	PR16	Cuenca	PR29	Málaga	PR42	Soria
PR4	Almería	PR17	Girona	PR30	Murcia	PR43	Tarragona
PR5	Avila	PR18	Granada	PR31	Navarra	PR44	Teruel
PR6	Badajoz	PR19	Guadalajara	PR32	Orense	PR45	Toledo
PR7	Baleares	PR20	Guipúzcoa	PR33	Asturias	PR46	Valencia
PR8	Barcelona	PR21	Huelva	PR34	Palencia	PR47	Valladolid
PR9	Burgos	PR22	Huesca	PR35	Palmas (Las)	PR48	Vizcaya
PR10	Cáceres	PR23	Jaén	PR36	Pontevedra	PR49	Zamora
PR11	Cádiz	PR24	León	PR37	Salamanca	PR50	Zaragoza
PR12	Castellón de la Plana	PR25	Lleida	PR38	Sta. Cruz Tenerife		
PR13	Ciudad Real	PR26	Rioja (La)	PR39	Cantabria		

Table 2. Equivalence betwen the different levels of study and the number of schooling years

Levels of study	Schooling years	Description
	0 years (sch01)	Illiterate-without studies
elementary	6 years (sch2)	Primary education
	9 years (sch3)	EGB or equivalent
medium	11 years (sch4)	Technical studies, first degree (FP-1)
	12 years (sch5)	BUP or equivalent
previous to high	13 years (sch6)	COU
	14 years (sch7)	Technical studies, second degree (FP-2)
high	16 years (sch8)	Medium university studies or equivalent
	18 years (sch9)	High university studies or equivalent

Table 3. Industries description

se10	Energy and water
se20	Extraction and non-energetic minerals transformation, chemistry industry
se30	Metallic elaboration industriess, precision mechanics
se40	Other manufacturing industries
se50	Building
se60	Commerce, restaurants and hotels, repairs
se70	Transport and communications
se80	Financial institutions, insurance, services to firms and rents
se90	Other services

Table 4. Occupations description

OCCUPATIONS DESCRIPTION	
OC1	Law and science professionals and technicians,teachers
OC2	Artistic and sports professionals and technicians
OC3	Public sector managers and officers
OC4	Office, transport and communications services managers
OC5	Administrative services workers
OC6	Managers of companies, commercial establishments and in hotels and catering
OC7	Sales executives
OC8	Traders,
OC9	Non-sale services workers
OC10	Shop managers, foremen and persons in charge
OC11	Extraction of minerals industry workers
OC12	Elaboration of minerals industry workers
OC13	Chemical industry workers
OC14	Food, wood, clothes, shoes, furnitures, etc. Industry workers
OC15	Electricists and electronic technicians
OC16	Graphic arts, paper and plastic industry workers
OC17	Construction workers
OC18	Drivers
OC19	Labourers

Table 5.Estimates for the different models of the natural logarithm of annual nominal wages 1990/91

	Model 1 [a]	Model 2 [b]	Model 3 [b]	Model 4 [b]	Model 5 [b]
Intercept	12.817 (0.023)	12.583 (0.128)	12.596 (0.128)	12.801 (0.210)	13.060 (0.223)
Gender	-0.371 (0.011)	-0.374 (0.011)	-0.375 (0.011)	-0.375 (0.011)	-0.377 (0.011)
Sch01	-0.411 (0.023)	-0.389 (0.023)	-0.388 (0.023)	-0.388 (0.023)	-0.386 (0.023)
Sch2	-0.150 (0.014)	-0.145 (0.014)	-0.144 (0.014)	-0.144 (0.014)	-0.144 (0.014)
Sch4	0.300 (0.020)	0.296 (0.020)	0.297 (0.020)	0.297 (0.020)	0.296 (0.020)
Sch5	0.354 (0.024)	0.349 (0.024)	0.350 (0.023)	0.350 (0.023)	0.348 (0.023)
Sch6	0.213 (0.022)	0.199 (0.022)	0.197 (0.022)	0.197 (0.022)	0.195 (0.022)
Sch7	0.375 (0.022)	0.363 (0.022)	0.361 (0.022)	0.361 (0.022)	0.359 (0.022)
Sch8	0.643 (0.022)	0.637 (0.022)	0.638 (0.022)	0.639 (0.022)	0.639 (0.022)
Sch9	0.782 (0.025)	0.771 (0.025)	0.770 (0.025)	0.771 (0.025)	0.770 (0.025)
Exp	0.056 (0.001)	0.056 (0.001)	0.056 (0.001)	0.056 (0.001)	0.056 (0.001)
Exp2	$-0.7 \cdot 10^{-3}$ $(0.02 \cdot 10^{-3})$	$-0.7 \cdot 10^{-3}$ $(0.02 \cdot 10^{-3})$	$-0.7 \cdot 10^{-3}$ $(0.02 \cdot 10^{-3})$	$-0.7 \cdot 10^{-3}$ $(0.02 \cdot 10^{-3})$	$-0.7 \cdot 10^{-3}$ $(0.02 \cdot 10^{-3})$
Pt	-0.463 (0.032)	-0.478 (0.032)	-0.479 (0.032)	-0.480 (0.032)	-0.481 (0.032)
Sect+Oc	Yes	Yes	Yes	Yes	Yes
Sch-pr		0.044 (0.007)	0.037 (0.007)	0.032 (0.008)	0.010 (0.005)
Exp-pr		-0.006* (0.005)	-0.005* (0.004)	-0.007* (0.005)	-0.010* (0.010)
R+D			0.003 (0.0006)	0.003 (0.0006)	0.002 (0.0006)
Climate				$-0.1 \cdot 10^{-3}$* $(0.1 \cdot 10^{-3})$	$-0.1 \cdot 10^{-3}$* $(0.1 \cdot 10^{-3})$
Coast					0.046 (0.014)

[a] OLS estimates. [b] GLS estimates.

* Not significant at a 5% level. The values in parenthesis are estimated standard errors.

Gender: Dummy variable which takes value one for women and zero for men; *Sch01-Sch9*: Dummy variables for the different categories of individual schooling years (see table 2 for the equivalences); *Exp:* Indicator of individual potential experience years; *Exp2*: Square of *Exp*; *Tp*: Dummy variable with value one for the individuals working part-time; *Sect.+Oc. dummies*: Sectoral and occupational dummy variables (see tables 3 and 4); *Sch-pr:* Provincial average level of schooling years; *Exp-pr:* Provincial average level of potential experience years; *R+D:* Provincial technological innovation indicator; *Clim:* Climate mildness indicator; *Coast:* Dummy variable which takes value 1 for provinces with coast.

Table 6. Estimates for the different models of the natural logarithm of house costs 1990/91

	Model 1[a]	Model 2[b]	Model 3[b]	Model 4[b]	Model 5[b]
Intercept	10.914 (0.690)	6.343 (0.705)	6.297 (0.704)	5.951 (0.723)	5.886 (0.723)
Urban	0.098 (0.013)	0.118 (0.013)	0.119 (0.013)	0.118 (0.013)	0.118 (0.013)
Sq. M	0.004 ($0.2 \cdot 10^{-3}$)	0.004 ($0.2 \cdot 10^{-3}$)	0.004 ($0.2 \cdot 10^{-3}$)	0.004 ($0.2 \cdot 10^{-3}$)	0.004 ($0.2 \cdot 10^{-3}$)
Year	0.0006 (0.0002)	0.0016 (0.0002)	0.0017 (0.0002)	0.0017 (0.0002)	0.0017 (0.0002)
Rooms	0.011 (0.005)	0.014 (0.005)	0.013 (0.005)	0.014 (0.005)	0.014 (0.005)
Bath1	0.295 (0.015)	0.311 (0.014)	0.313 (0.014)	0.311 (0.014)	0.311 (0.014)
Bath2	0.192 (0.017)	0.203 (0.017)	0.206 (0.017)	0.206 (0.017)	0.206 (0.017)
Bath3	0.171 (0.026)	0.210 (0.025)	0.213 (0.025)	0.212 (0.025)	0.212 (0.025)
Floor1	2.279 (0.381)	2.135 (0.366)	2.132 (0.366)	2.131 (0.366)	2.132 (0.366)
Floor2	2.409 (0.382)	2.258 (0.367)	2.254 (0.367)	2.251 (0.367)	2.254 (0.367)
Floor3	2.444 (0.381)	2.445 (0.366)	2.339 (0.366)	2.238 (0.366)	2.240 (0.366)
Floor4	2.467 (0.411)	2.391 (0.396)	2.391 (0.396)	2.397 (0.395)	2.399 (0.395)
Lift	0.225 (0.015)	0.217 (0.014)	0.215 (0.014)	0.215 (0.014)	0.215 (0.014)
Garage	0.129 (0.013)	0.121 (0.012)	0.122 (0.012)	0.123 (0.012)	0.123 (0.012)
Garden	0.155 (0.016)	0.133 (0.015)	0.134 (0.016)	0.132 (0.016)	0.132 (0.015)
Swim-pool	0.200 (0.057)	0.185 (0.055)	0.182 (0.055)	0.178 (0.055)	0.176 (0.055)
Heating	0.264 (0.013)	0.137 (0.013)	0.134 (0.013)	0.139 (0.013)	0.138 (0.013)
Air	0.070 (0.032)	0.139 (0.032)	0.136 (0.032)	0.138 (0.032)	0.136 (0.032)
Sch-pr		0.209 (0.008)	0.202 (0.009)	0.211 (0.010)	0.212 (0.013)
Exp-pr		0.041 (0.008)	0.042 (0.006)	0.045 (0.006)	0.046 (0.006)
R+D			0.003 (0.0007)	0.003 (0.0007)	0.003 (0.0007)
Climate				0.0003 (0.0001)	0.0003 (0.0001)
Coast					-0.014* (0.016)

[a] OLS estimates. [b] GLS estimates.

* Not significant at a 5% level. The values in parenthesis are estimated standard errors.

Urban: Dummy variable which takes value one for houses located in urban areas and zeros for the rest; *Sq. M.*: Number of squared meters of the house; *Year:* Building year; *Rooms:* Number of rooms; *Bath1:* Number of basic bathrooms; *Bath2:* Number of bathrooms with medium-equipment; *Bath3*: Number of totally-equipped bathrooms; *Floor1-4:* Dummy variable which takes value one for houses located in buildings with 1-4 (or more) floors and zero for the rest; *Lift, garage, garden, swimming-pool, central heating and conditioned air:* Dummy variable which takes value one for houses with each of these equipments and zero for the rest; *Sch-pr:* Provincial average level of schooling years; *Exp-pr:* Provincial average level of potential experience years; *R+D:* Provincial technological innovation indicator; *Clim:* Climate mildness indicator; *Coast:* Dummy variable which takes value 1 for provinces with coast.

Table 7. Rauch's (1993) local human capital external economies estimates

	Wage equations		Rent equations	
	Initial estimates	Final estimates	Initial estimates	Final estimates
Sch-pr	0.051 (0.013)	0.033 (0.012)	0.199 (0.023)	0.112 (0.017)
Exp-pr	0.005 (0.004)	0.003* (0.003)	0.027 (0.006)	0.013 (0.005)

* Not significant at a 5% level. The values in parenthesis are estimated standard errors.

Table 8. Almond's (1997) local human capital external economies estimates

	Wage equations		Rent equations	
	Initial estimates	Final estimates	Initial estimates	Final estimates
Sch-pr	0.083 (0.014)	0.077 (0.005)	0.276 (0.037)	0.194 (0.030)
Exp-pr	0.013 (0.005)	0.010* (0.009)	0.032 (0.012)	0.016* (0.010)

* Not significant at a 5% level. The values in parenthesis are estimated standard errors.

Annex 2. Data description and sources for technological innovation and climate mildness indicators

Technological innovation indicator

Technological research and development data come from the *Encuesta sobre innovación tecnológica de las empresas* (survey about R&D in firms) carried out by the *INE*. This survey does not provide data at a provincial level, but we have had access to data at this level of territorial detail from a specific exploitation of original registries made by the *INE* following the request of a research unit of the University of Barcelona. Although these data refer to 1994, it has not been possible to obtain data for 1990 at an equivalent level of territorial detail and, for this reason, we have used information for 1994 as a proxy of the territorial structure of the 1990 R&D. Also to correct the possible distortion of the unequal level of economic activity in the different territories, we have weighted R&D by added value.

Climate mildness indicator

Because most people tend to prefer mild climate conditions to extreme ones, we have taken as a starting point to approximate the possible effects of provincial climate conditions on wages and housing costs, the methodology proposed in the *Places Rated Almanac*. According to this methodology, each territory (in our case the province and for the United States, the metropolitan area) is given a base number of 1000 points, from which points are substracted to the following indicators, based on yearly averages from 1931 to 1980 (primary source for this data is the *Anuario Estadístico de España*, INE):

- *Very hot and very cold moths:* Ten points are substracted for each month in which the mean temperature is above 21 Celsius degrees or below 0 Celsius degrees. An additional 10 points are subtracted, for a total of 20 points, if the mean temperature is above 27 Celsius degrees or below –7.
- *Seasonal temperature variation*: The difference in Celsius degrees between the mean maximum temperature and the mean minimum temperature is subtracted from the base score.
- *Rainy and freezing days*: One point is subtracted for the number of rainy days and one more for each day on which the average temperature is 0 Celsius degrees or below.
- *Extremely hot temperature*: Since relative humidity has a profound effect on felt heat, points are substracted in accordance with each location's mean humidity and maximum temperatures. If maximum temperature is above 40 degrees, 3 points are substracted multiplied by 5 if relative humidity is below 60%, by 10 if it is between 60% and 65%, by 15 between 65% and 70%, by 20 between 70% and 75% and by 25% if relative humidity is above 75%. If maximum temperature is between 36 and 50, 2 points are subtracted with the same correction in function of relative humidity as before. And, last, if maximum temperature is between 32 and 36, 1 point is substracted with the same relative humidity correction.