DOES HUMAN CAPITAL STIMULATE INVESTMENTS IN PHYSICAL CAPITAL?

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This paper analyses if the important accumulation of human capital in the Spanish economy in the last decades has stimulated private physical capital investment. Previous international evidence has not reached a consensus on the topic, in some cases due to the fact that the capital-skill complementary hypothesis can be dependent on the level of development of the economy (Goldin y Katz, 1998; Duffy et al, 2004). In our case, we use the dual framework to value the relationship between the two factors for the Spanish regional case. We also obtain conclusions on whether the link between skill and capital depends on the regional development level.

JEL: C30, J24, O11, O47, R11, R53

1. INTRODUCTION

The role that human capital has as a stimulus of the technical progress and of the investment in physical capital has been stressed in the economic literature. De la Fuente and da Rocha (1996) suggest that the human capital stock in an economy not only favours the generation and absorption of technology but also the incentive to invest in education will increase with technical progress. This way, if the latter is linked to the investment in physical capital there will be a complementary relationship between both types of capital. Additionally, through the stimulus to change the production structure, from sectors with lower to higher capitalisation ratios, a positive relationship between educational and physical capital can be deduced (Tamura, 2002). In fact, this relationship has been used in some empirical studies to justify the scarce impact of human capital in the estimation of growth regressions that control for the accumulation of physical capital. Barro (1991), for instance, argues that a significant part of the effect of human capital is channelled through an increase in the investment rate of physical capital. The same is obtained by Sianesi and Van Reenen (2000) and Krueger and Lindahl (2001). Even with a more disaggregated evidence in the same line, Vand de Walle (2000) obtains that the net marginal benefit of the investments in watering system in Vietnam depend on the level of education of the farmers.

On the other hand, one could argue that the accumulation of human capital could have compensated the neoclassical mechanism of decreasing returns to the accumulation of physical capital. In this sense, Barro (1998) argues that an economy with an initial low ratio of physical capital-human capital (as after a war or a catastrophe, or after a period of quick accumulation of human capital because of non economic reasons), will tend to increase quickly due to the increasing in the stock of physical capital, until the ratio between both types of capital is equilibrated. This circumstance can be deduced from the growth models in which the ratio physical capital-human capital is constant in the long run. So, if there is a disequilibrium in the economy at any moment, for instance due to an abundant stock of human capital in relation with that of physical capital, there will be a turn back to the equilibrium through a higher investment in the stock of the capital which was initially less abundant (Barro and Sala-i-Martin, 1995).

As a consequence of the reasons signalled above we believe that it is interesting to analyse whether the accumulation of education in an economy stimulates private investment. The most recent contributions in this line have not reached a common conclusion, in some cases due to the fact that this effect could depend on the development level of one economy. Duffy et al (2004) estimate a CES production function for a sample of countries in which the assumption of constant elasticities of substitution between factors is relaxed, not being able to find a positive relationship between the educational level and physical capital. However, these authors recognise that this could be due to the high heterogeneity of the sample of countries they use to check this assumption, with economies with very different development levels, in the line of the argument given by Goldin and Katz (1998) according to what the complementarity between both capital depend on the development level.

Therefore, although the direct effect of human capital on economic growth has widely been recognised in the economic literature, its indirect effect through the stimulation of private investment in physical capital has not received much attention and if so, has not reached clear conclusions. This paper aims at providing empirical evidence on whether the important accumulation of human capital in Spain has stimulated the investment in physical capital. This being the case, this paper will provide evidence on the reasons behind this process. In this sense, we assume that if a higher level of education of the workforce leads to higher investments in physical capital, this can be due to the fact that the higher skill level of the workers will allow extracting a higher return from the investment in capital. Finally, and given that the empirical evidence is given for the 17 Spanish Autonomous Regions (NUTS II regions), we aim at analysing to what extent the results may be different according to the development level of the region under analysis.

In order to provide evidence to the two main points in this paper, the relationship between human and physical capital is estimated within the framework established by duality theory, by estimating a cost system (similarly to Morrison and Siegel, 1997). The dual framework has the advantage of overcoming, or at least mitigating, problems due to endogeneity and takes into account the possibility that effects of human capital obtained from estimates of production functions might not be linear.

The situation in the Spanish regions could be paradigmatic since that there has been a spectacular increase in educational attainment in all Spanish regions[1] and this has coincided

[1] Nonetheless significant inter-regional differences remain today and are expected to do so in the near future (De la Fuente et al, 2003; De la Fuente, 2005).

with a virtually uninterrupted process in which these regions have been opened up to and exposed to competition. Consequently, the modernisation of production and institutional structures has affected all the regions of Spain to a greater or lesser extent. It seems therefore that the situation in Spain is ideal for assessing the impact of human capital and the relationship it maintains with physical capital.

The paper is outlined as follows. In the second section we present the model based on the duality theory that includes the human capital stock as a factor that influences the technology of production in an economy, and describe the empirical specification from which the effect of human capital on physical investments can be obtained. The third section describes the dataset and the major variables in the empirical analysis, paying special attention to the accumulation of human and physical capital in the Spanish regions over the last decades. The results are reported in the fourth section and finally we conclude.

2. THEORETICAL AND EMPIRICAL FRAMEWORK

2.1 Cost function expanded with human capital

Consider a production function, where Y is the output and X_i ($i=1,...,r$) the i-th input:

$$Y = F(X_1,..., X_r) \tag{1}$$

It is assumed that a typical firm in the economy must accept a vector of input prices, $P_1,..,P_r$, so that the optimization problem consists in determining the amount of inputs that minimizes the cost of producing a given output, Y. Then, the level of optimal cost (C) —the solution to the optimization problem— yields a cost function that is dual to the production function, which is dependent on input prices, output and the technology implicit in the production function:

$$C = C(P_1,..., P_r, Y) \tag{2}$$

We assume that all factors of production can be adjusted within one time period so that the firm instantaneously determines long-run factor demands. As proposed in Brown and Christensen (1981), this can be defined as the full static equilibrium hypothesis (FSE) for production factors. Nevertheless, rather than assume that all inputs adjust instantaneously to their long-run equilibrium values, there are reasons to believe that certain factors do not follow an adjustment mechanism of this kind. These reasons might include price controls and regulations and institutional constraints that are above and beyond the influence of an individual firm in the short-run. The inputs that are in equilibrium are referred to as variable inputs, while those that are not are designated quasi-fixed inputs - a situation known as partial static equilibrium (PSE).

We consider here a framework that distinguishes between variable and quasi-fixed inputs, where the latter adjust only partially to their full equilibrium levels within one time period. This allows us to define a variable cost function which refers to a PSE situation in which the presence of certain inputs fixed at values other than their full equilibrium level implies that there are adjustment costs associated with changing the quasi-fixed factors. These inputs appear in the variable cost function through their amounts and not their prices. Let's define Z the vector of X inputs which are not in equilibrium, with a variable cost function with the following expression:

$$VC = VC\,(P_1,...P_s, Y, Z_1,...Z_m) \tag{3}$$

where $VC = \sum_{i=1}^{s} P_i X_i$ and s+m=r, where r is the total number of inputs. Whereas in the FSE, since all inputs are considered to be variable and the purpose of firms in the economy is to minimize total costs in (2), in a PSE situation the objective is to minimize the cost of variable inputs conditioned to a stock of quasi-fixed inputs and the level of output (Y).

Using both the full and the partial static equilibrium frameworks, cost functions have been widely used to analyze the substitution relationships between production factors. However, the particular purpose of this paper is to allow the identification of the impact of the aggregate stock of human capital in the economy, the latter understood as an external factor, that is, one which is not explicitly under the control of the firm. Endogenous growth models emphasize the role of returns to capital that embodies new knowledge, this capital being understood as a general notion that also encompasses aspects of human capital, among others. As stated in Morrison and Siegel (1997) these knowledge factors are hypothesized to be external to the industry, so that the resulting effects on productivity are interpreted as evidence of spillovers which can be considered as efficiency factors. These underlying efficiency factors can cause downward shifts of cost curves, so that their effect on productivity can be examined through a cost-function approach. Although firms pay for the human capital embedded in their employees through their wages, they do not pay for the rest of human capital available in the economy, which is considered as an external environmental variable in our framework.[2]

Therefore, we focus our attention on an aggregate production function expanded with this type of capital. This aspect must be taken into account when obtaining the corresponding PSE model, which presents an associated aggregate variable cost function as follows:

$$VC = VC(P_L, P_M, Y, K, H) \tag{4}$$

where we consider two variable inputs, labor (L) and intermediates (M) which appear in the cost function through their prices, P_L and P_M respectively; a quasi-fixed input, physical capital, K; Y is output and H is human capital. In other words, economies of scale in a cost function are now outlined to include this new argument, so that variations in the human capital stock available in the economy can lead to shifts in cost curves.

Thus, the short-run cost function is the sum of the variable cost and the cost of the services provided by the existing capital:

$$SC = VC(\cdot) + P_K \cdot K \tag{5}$$

By applying Shephard's lemma, the vector of the different variable inputs that minimize costs (cost-minimizing demands) is obtained:

$$X_i = X_i(P_L, P_M, Y, K, H) = \frac{\partial VC}{\partial P_i} \qquad i = L, M \tag{6}$$

Furthermore, we can calculate each factor share (S_i), that is, the percentage of the cost supposed by the *i*-th input:

$$S_i = \frac{P_i \cdot X_i}{VC} = \frac{\partial \ln VC}{\partial \ln P_i} = \frac{\partial VC}{\partial P_i}\frac{P_i}{VC} \qquad i = L, M \tag{7}$$

Equation set (4) and (7) constitutes the solution to what can be defined as the short-run equilibrium related to variable factors, given the amount of Y, K and H.[3] In other words, the preceding functions, and consequently the short-run solution, are not independent of the stock of the quasi-fixed factor and human capital.

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[2] The use of a cost function to analyse the effect of human capital must be understood as parallel to the common practice in economic growth literature of using a production function aggregated with the stock of human capital (see for instance Topel, 1999). Both frameworks lie on the same idea that a higher endowment of human capital in the economy may imply higher productivity growth. In the cost function, this result implies that additional investment in human capital results in a downward shift in the aggregate cost function. According to Morrison and Siegel (1997) the use of the duality theory provides more broad-based information about the returns to variable, quasi-fixed and external factors.

[3] Either demand functions or factor share functions may be used. So, alternatively, we could talk about set (4) and (6).

On the other hand, the long-run demand for the quasi-fixed factor is given by minimizing total short-run cost function in (5) with respect to K (the envelope condition):

$$\frac{\partial SC}{\partial K} = \frac{\partial VC}{\partial K} + P_K = 0$$

$$-P_K = \frac{\partial VC}{\partial K} \qquad (8)$$

The fixed factor is at its static equilibrium level if and only if the cost savings it generates (shadow price) equal the market rental prices. Solving (8) for capital we obtain its equilibrium stock:

$$K^* = G(P_L, P_M, P_K, Y, H) \qquad (9)$$

The optimal demand for K depends not only on its own price but on the prices of variable inputs, the level of output and the fixed quantity of human capital. Thus, equations (4), (6) — or (7)— and (9) characterize the long-run equilibrium.

By substituting (9) into (5) we obtain the long-run cost function, equivalent to that in the full static equilibrium:[4]

$$C = VC(P_L, P_M, Y, K^*, H) + P_K \cdot K^* = C(P_L, P_M, P_K, Y, H) \qquad (10)$$

From the functions previously described, a set of measures in relation with the effects of human capital investments can be obtained, as will be shown in section 4.

2.2 Empirical specification

The functional form chosen for the empirical work is based on a translog cost function, a general second degree polynomial in logs, with the following form:

$$\begin{aligned}
\ln(VC/P_M) = {} & \beta_0 + \beta_L \ln\frac{P_L}{P_M} + \beta_Y \ln Y + \beta_K \ln K + \beta_H \ln H + \beta_T t + \\
& 0.5\left[\beta_{LL}\ln^2\frac{P_L}{P_M} + \beta_{YY}\ln^2 Y + \beta_{KK}\ln^2 K + \beta_{HH}\ln^2 H + \beta_{TT} t^2\right] \\
& + \beta_{LY}\ln\frac{P_L}{P_M}\ln Y + \beta_{LK}\ln\frac{P_L}{P_M}\ln K + \beta_{LH}\ln\frac{P_L}{P_M}\ln H + \beta_{LT}\ln\frac{P_L}{P_M}\, t \\
& + \beta_{YK}\ln Y \ln K + \beta_{YH}\ln Y \ln H + \beta_{YT}\ln Y\, t + \beta_{KH}\ln K \ln H + \beta_{KT}\ln K\, t + \beta_{HT}\ln H\, t
\end{aligned} \qquad (11)$$

[4] It is evident that the FSE can be understood as a specific case of the general model of partial equilibrium; a model in which the quasi-fixed inputs are to be found at all times in their equilibrium quantities.

where t is a time trend which summarizes technological change. For ease of notation, variables in equation (11) onwards do not carry subscripts referring to the observations.

This functional form permits the consideration of a wide range of substitution possibilities and can be accommodated within any production technology without the need to impose a priori restrictions on returns to scale. Intermediate prices are included as a relative factor to ensure that the function is homogeneous of degree one in factor prices and symmetry conditions are imposed (Berndt, 1991). Besides, no kind of a priori returns to scale is imposed.

The share equations for variable inputs on variable costs are obtained through the differentiation of equation (11) with respect to variable input prices, $\partial VC(\cdot)/\partial P_i$, with i=L, M. For the two variable factors we consider here, only one equation is independent, given that factor shares sum to one. Thus, we have:

$$S_L \equiv \frac{P_L \cdot L}{VC} = \frac{\partial \ln VC}{\partial \ln P_L} = \beta_L + \beta_{LL} \ln \frac{P_L}{P_M} + \beta_{LY} \ln Y + \beta_{LK} \ln K + \beta_{LH} \ln H + \beta_{LT}\, t$$
$$S_M \equiv 1 - S_L \qquad (12)$$

On the other hand, if fixed inputs are in their long-run equilibrium condition, the following condition holds:

$$-S_K \equiv -\frac{P_K \cdot K}{VC} = \frac{\partial \ln VC}{\partial \ln K} = \beta_K + \beta_{KK} \ln K + \beta_{LK} \ln \frac{P_L}{P_M} + \beta_{YK} \ln Y + \beta_{KH} \ln H + \beta_{KT}\, t \qquad (13)$$

In this situation, the marginal reduction in variable costs due to increases in capital equals this input price, $-\partial VC(\cdot)/\partial K = P_K$.

Finally, differentiating logarithmically the function of VC(·) with respect to Y and introducing the condition of equality between the price of the output and the marginal cost, we obtain

$$S_Y \equiv \frac{P_Y \cdot Y}{VC} = \frac{\partial \ln VC}{\partial \ln Y} = \beta_Y + \beta_{YY} \ln Y + \beta_{LY} \ln \frac{P_L}{P_M} + \beta_{YK} \ln K + \beta_{YH} \ln H + \beta_{YT}\, t \qquad (14)$$

The set of expressions (11)-(14) would comprise the framework of the full static equilibrium. By contrast, using the model of partial static equilibrium, the parameters in (13) would not correspond with those in (11).

2.3 The effect of human and physical capital

The effect of human capital on production can be defined as the elasticity of output with respect to this factor, and can be calculated in the context of the cost system using the envelope theorem (Chambers, 1988) as:

$$\varepsilon_{Y,H} = \frac{\partial \ln Y}{\partial \ln H} = \frac{-\frac{\partial VC}{\partial H}}{\frac{\partial SC}{\partial Y}} \frac{H}{Y} \tag{15}$$

The return to human capital in (15) can be estimated by using the parameters estimated in the cost system and the corresponding values for the variables involved. However, in the case of human capital it is more intuitive to analyse the impact on production of one additional year of education, and therefore return to human capital is defined as the increase in production caused by an increase of one year in the average educational attainment of the employees. In other words, the semi-elasticity of output with respect to human capital:

$$RTN_H = \frac{\partial \ln Y}{\partial H} = \varepsilon_{Y,H} \frac{1}{H} \tag{16}$$

At the same time, to make it easier to compare returns to human capital with returns associated with the accumulation of alternative factors, returns to physical capital can be calculated, defined as its product elasticity, in a similar way to (15), that is, as the percentage variation in the product as a result of varying the stock of physical capital by 1%.

Finally, and having in mind that the main objective is to analyse to what extent human capital exerts an stimulus on the investment in physical capital, we define the semi-elasticity of the optimum demand of physical capital with respect to human capital as follows:

$$\text{Semi} - \varepsilon_{K^*H} \equiv \frac{\partial \ln K^*}{\partial H} = \varepsilon_{K^*H} \frac{1}{H} = -\beta_{KH} \frac{1}{S_K H} \tag{17}$$

This measure indicates the percentage change in the stock of optimum capital with respect to a one-year increase in the average education level.

3. DATABASE

3.1 Database and variables

The spatial units considered here correspond to the 17 Spanish NUTS II regions[5] and the period analyzed runs from 1980 to 2000. Thus, as stated above we shall consider the influence of human capital on physical capital in the private productive sector of the Spanish regions during a period in which there was a marked accumulation of education and physical capital in all the regions, in conjunction with the modernization of the Spanish economy and its opening up to the exterior following integration into the European Union.

The measure used for human capital in this study combines the average number of years in each level of education with the percentage of the population in each of these levels, thereby producing an attractive synthetic indicator of human capital, like that of the average number of years of education of an economy. This type of indicator has been constructed for various samples of economies by, among others, Kyriacou (1991), Barro and Lee (1993, 1996, 2001), and has been used to analyze the contribution of this factor to growth in, for example, Benhabib and Spiegel (1994), Temple (1999), de la Fuente and Doménech (2001, 2006a), del Barrio *et al* (2002).[6] The information required for constructing the indicator was drawn from Mas *et al* (2002).

We have information for five levels of education: illiterates, primary education, secondary education, first level of higher education, and second level of higher education. Given that this information is tabulated for, among other groups, the workers employed in each period, it is possible to obtain the percentage of workers for each of these levels of education, for the period 1964 to 2001. We have followed Serrano (1996) by designating 0 years to illiterates, 3.5 years to the group with primary education studies, 11 years to those having completed secondary education, 16 years to those workers with a first level of higher education and 17 years to those with a second level of higher education.

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[5] NUTS is the French acronym for Nomenclature of Territorial Units for Statistics, a hierarchical classification established by EUROSTAT to provide comparable regional breakdowns of EU Member States. In the case of Spain, the NUTS II regions correspond to the 17 Autonomous Communities, historical and administrative regions with a high level of political and financial autonomy.

[6] Alternatives, such as the rate of schooling or the literacy rate have been subjected to considerable criticism due to their clear limitations when approximating an economy's human capital stock. They have, however, been used in several studies because of the impossibility of obtaining detailed information about the levels of education of the population.

The remaining statistical information has been taken from the BD.MORES database prepared by the Spanish Ministry of Economy and Finance. Specifically, of the data provided by the BD.MORES database, we have used the series relating to Gross Added Value at factor prices, employment, wages, private physical capital stock and its cost and intermediates. The output variable chosen is the production value, which is obtained by summing intermediates to value added. The time period for all these series runs from 1980 to 2000.

3.2 Descriptive analysis of human and physical capital in Spain

Table 1 shows the evolution of some of the variables of interest. Human capital, that is, the average years of schooling of workers in the private productive sector of the Spanish economy increased notably throughout the period (H). In particular, in two decades there was an increase of more than four years, reaching 9.32 years in 2000. However, it is interesting to highlight that the growth rate has decelerated with time, so that it is not expected to continue with the same strength. As for physical capital (K), we also observe positive growth rates throughout the period under analysis, although the interesting point here is that the process has accelerated considerably in the last five years. This way, the analysis of the ratio K/H leads to the conclusion that it has decreased along time with the exception of the last five years, when it has increased notably. This would imply that the increases of human capital have been higher during all the years except in the five last ones when the reverse has occurred.

[Insert Table 1 around here]

Table 2 shows some interesting ratios and variables in the analysis for the regions. In the case of human capital, we observed that marked differences persist in the regional endowment of human capital education. Specifically, it can be seen how the regions over the average in the number of years of schooling are Madrid, País Vasco, Catalunya, Navarra and Valencia. On the contrary, those regions are precisely those that present a lower ratio of physical and human capital, in other words, their stock of physical capital per year of schooling is much lower than in the rest of regions.

[Insert Table 2 around here]

4. RESULTS

4.1. Estimate of the coefficients of the cost system

For purposes of empirical implementation the models discussed in section 2 have to be embedded within a stochastic framework. In order to do this we consider errors in variable costs —eq. 11— and variable factor demands —eq. 12— as being due to errors in optimization in the short-run, while those for the equilibrium relationships (for physical capital —eq. 13— and output —eq. 14) represent unanticipated information that becomes available once the investment and output decision have been taken. To allow for separate elasticities across groups of regions we have included two dummy variables interacting with the linear terms of the variable factor prices, the stock of physical capital and output. Correspondingly, those dummies have been included as well in the factor share equations and in those for the equilibrium conditions of physical capital and output. The first of these dummies (D1) controls for the size of the regional economy, in terms of the share of its output over the one of the country. The second (D2) is included to account for the situation in some regions in which the ratio of physical to human capital was fairly low. The models specified both in the short and long-run are estimated using the iterative Zellner technique for seemingly unrelated regression equations, which converge to the maximum likelihood estimator for models of this type.

To choose the framework for use in computing the elasticities in the section above, we need to determine whether the observed levels of physical capital correspond with their long-term optimal levels. This will allow us to determine the type of framework (FSE or PSE) which best fits the sample under consideration, without any a priori decision as is usually the case in the literature. Therefore, the fixity assumption of K is explicitly tested by applying the test developed by Schankerman and Nadiri (1986).[7] The result of this contrast is shown in the lower panel of Table 3. The result is conclusive: for the sample of Spanish regions in the period between 1980 and 1995, the model that best captures the behaviour of the production technology of the private sector is that of partial static equilibrium. In other words, the assumption that capital stock in this sector adjusts at all times to the optimum in function of the existing production technology is clearly rejected. Consequently, we estimate the PSE

[7] In brief, the null hypothesis of long-run equilibrium is tested by applying a standard likelihood ratio test, which in essence compares the estimates from the specification that imposes the constraints in the coefficients across equations with those from the short-run equilibrium model that does not impose any restriction. The constrained estimator is consistent under the null but not under the alternative hypothesis, while the unconstrained estimator is consistent under both the null and the alternative.

model and calculate the effects of interest to us here on the basis of these parameters. The results of the estimation are shown in Table 3 where, in addition, we show the results obtained from the likelihood-ratio test of the null hypothesis of which the matrix of covariances of the disturbance of the system of equations is diagonal - in other words, the contrast of the fit of the cost system as a model of apparently unrelated equations. The value obtained for the test statistic (108.8) lies clearly within the rejection zone of the null hypothesis, so that the Zellner estimation for the SURE-type model is adequate.

[Insert Table 3 around here]

It should be pointed out that it is unreasonable to undertake any kind of interpretation or structural analysis directly from the estimated parameters, given that we are using the translog approximation of the unknown functional form underlying the cost system. Similarly, it is worth stressing that convergence in the estimation was reached with a relatively small number of iterations and, more importantly from an economic point of view, that the coefficients of the terms that involve the dummy variables on the one hand, as well as all the variables that describe the effect of human capital, are together significant. Consequently, the Wald test confirms the existence of a significant effect of human capital on costs.

4.2. Has human capital stimulated physical capital?

According to the descriptive analysis above, if the increases of human capital would have stimulated the investments in physical capital, this could be due to the fact that the higher skill level of the workers would have allowed extracting a higher return from the investment in physical capital. Therefore, before computing the semi-elasticity of human and physical capital we analyse the returns obtained from the investments made in these two factors.

Los resultados obtenidos para estas medidas se recogen en las tres primeras columnas de la Tabla 4. Respecto a la media global, se observa como el rendimiento del capital humano es prácticamente igual que el del capital físico. Este resultado justificaría las subvenciones a la formación de capital humano, según Willis (1986), es decir a la educación de los individuos, dado que los recursos que se estarían desviando con este objetivo no resultarían menos rentables de lo que lo serían financiando las inversiones en capital físico. La importancia del capital humano sobre la producción que se deduce de ese resultado se corresponde con la obtenida por Serrano (1997), cuyos resultados indican que este factor habría sido responsable de entre un tercio y la mitad del crecimiento de la productividad del factor trabajo en la economía española en las últimas décadas.

Pero ese resultado global esconde una importante heterogeneidad regional. En efecto, el rendimiento del capital humano medio en el periodo es muy superior al del capital físico en Extremadura, Castilla y León, Castilla-La Mancha, Murcia, La Rioja y Asturias, a las que cabría añadir a Galicia para la que el rendimiento del capital físico es incluso negativo. Por el contrario, en Catalunya, Madrid, País Vasco y Navarra, las cuatro regiones con mayores productividades, el rendimiento del capital humano fue poco más de la mitad del obtenido a través del capital físico.

Otra circunstancia interesante por lo que respecta al rendimiento de ambos tipos de capital tiene que ver con su evolución a lo largo del periodo. En el caso del capital humano se produce un apreciado descenso en el rendimiento de forma que, al final del periodo, éste representaba poco más del 50% del que se daba en 1980. Si recordamos el continuo aumento en el stock de este factor, ese resultado apuntaría a un claro mecanismo de rendimientos decrecientes en la acumulación de capital humano. No obstante, al final del periodo el rendimiento de un año extra de educación sigue siendo considerable (próximo al 5.6%). Curiosamente, la evolución del rendimiento del capital físico es distinta. Aunque no de forma monótona, sí parece deducirse un aumento en su rendimiento a lo largo del periodo (de algo más de dos puntos porcentuales entre 1980 y 2000), a pesar de que también en este caso la economía española en su conjunto experimentó un aumento en el stock de dicho factor. Así, no parece que el mecanismo de rendimientos decrecientes a la acumulación de capital físico esté funcionando (al menos en términos netos). Una posible explicación a este fenómeno lo podríamos encontrar en la relación de complementariedad entre ambos tipos de capital. Lo que puede haber estado sucediendo en la economía española en el periodo considerado es que el ritmo de acumulación en capital humano haya superado con creces al del capital físico, produciendo una descompensación en la ratio, que haya contrarrestado a lo largo de todo el periodo el mecanismo de reequilibrio en la ratio de ambos capitales y con ello de los rendimientos decrecientes en la acumulación del físico, al elevar la productividad marginal de este factor (predicciones de los modelos de Uzawa, 1965 y Lucas, 1988)[8]. En esa misma circunstancia el rendimiento del capital humano habría descendido rápidamente.

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[8] En el modelo de Lucas, el output y la acumulación de capital humano se rigen por $Y = K^{\alpha}(uH)^{1-\alpha}$

Con el objetivo de confirmar esta intuición, los gráficos 1 y 2 muestran la relación entre la ratio capital físico/capital humano[9] y los rendimientos de ambos factores en la muestra. Para el caso del rendimiento del capital humano (Gráfico 1) se aprecia claramente como, cuando el capital físico es abundante en relación al humano, el rendimiento de este último es mucho más elevado que cuando el desequilibrio se produce a favor del stock educativo. El coeficiente de correlación entre ambas magnitudes toma un valor significativo de 0.74. El mismo fenómeno se produce en el caso del rendimiento del capital físico (Gráfico 2), donde la relación con la ratio de capitales es inversa y algo menos intensa, aunque igualmente significativa (correlación de –0.49).

Por su parte, los gráficos 3 y 4 proporcionan información adicional a la comentada anteriormente. El Gráfico 3 muestra el rendimiento del capital humano obtenido para las diversas combinaciones de capital físico y humano, mientras que el Gráfico 4 nos proporciona los resultados para el caso de los rendimientos del capital físico. La imagen que se desprende del último es mucho más nítida que la del primero y nos indica como, para un nivel dado de dotación de capital físico, su rendimiento aumenta claramente con el stock de capital humano. Ello nos sugiere una relación de complementariedad entre ambos factores que, dada la proporción existente entre ellos habría favorecido a la rentabilidad del capital físico.

En la última columna de la Tabla 4 se ofrece la medida de la semi-elasticidad del capital con respecto al capital humano. Se observa como esta medida es positiva en todos los casos, indicando que el capital humano parece haber estimulado al stock de capital físico que, además, resulta bastante importante dado que, en términos medios en el periodo, un año adicional de educación suponía un aumento de algo más de un 19% en el stock de capital óptimo. Un efecto que, siendo más marcado al inicio de los ochenta[10], se estabiliza desde la segunda parte de esa década en niveles próximos al 13%. La influencia del capital humano sobre la cantidad óptima de capital físico presenta una notable variabilidad regional. Destaca la respuesta en La Rioja, Galicia y Asturias donde un año adicional de escolarización aumenta

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$\dot{H} = BH(1-u) - \delta H$, donde u es la fracción de tiempo destinada a la producción de capital humano. En este modelo la productividad media del capital físico en la producción de bienes, su productividad marginal y su rendimiento dependen del ratio K/uH.

[9] En los gráficos el capital humano hace referencia al stock total de este factor en la economía y no al medio. Es decir es el stock medio, H, por el número de ocupados, L.

[10] De hecho el valor estimado para la media del año 1980 resulta demasiado elevado para resultar verosímil, por lo que cabría tomarlo con las debidas precauciones.

el stock físico óptimo en un 23 y 27%. De forma menos intensa pero aún por encima de la media se encuentran las respuestas en Murcia, Andalucía, Valencia y Navarra. Por el contrario, Extremadura y Baleares presentan las menores semi-elasticidades con más de cuatro puntos porcentuales por debajo de la media. En una situación similar se encuentran regiones con mayores niveles de desarrollo, aunque heterogéneas en sus estructuras productivas como Catalunya, Madrid y el País Vasco, y regiones con menores niveles de desarrollo como Aragón, Canarias, Cantabria y las dos Castillas. Por tanto, en el caso español no parece obtenerse ninguna conclusión clara respecto a que el efecto que el capital humano ejerce sobre el capital físico sea distinto según el nivel de desarrollo de las distintas regiones españolas.

En cualquier caso, de la evidencia presentada podemos derivar un claro estímulo por parte del capital humano hacia el capital físico. Es decir, dada la proporción existente entre el stock de ambos tipos de capital en las economías consideradas en la muestra, el capital humano habría estimulado la inversión en capital físico, revirtiendo incluso la tendencia al decrecimiento en el rendimiento a las inversiones en este tipo de capital. Ello tiene una repercusión importante a la hora de decidir la inversión en educación dado que, en la medida en la que a nivel individual no se percibirá su influencia indirecta sobre la productividad a través de la inversión inducida en capital físico, se producirá una infrainversión en capital humano. Dicho de otra forma, el resultado obtenido apoyaría desde un punto de vista estrictamente económico la subvención estatal de la adquisición de educación por parte de los individuos en el periodo analizado.

5. CONCLUSIONS

Para el periodo considerado en la economía española parece cumplirse la condición requerida para considerar las inversiones en capital humano como socialmente rentables: que su rendimiento social como mínimo iguale al rendimiento del capital físico. En caso contrario, los recursos destinados a financiar el capital humano hubiesen obtenido una mayor rentabilidad financiando al capital físico.

Asimismo, hemos obtenido evidencia acerca de un efecto indirecto del capital humano en el crecimiento económico a través del estímulo que ejerce sobre el capital físico. En concreto, aumentar en uno los años medios de educación de los ocupados supuso un incremento de un

19% en el stock de capital óptimo de la economía. De ello deducimos que el capital humano supone un estímulo a la inversión en capital físico, al aumentar su rentabilidad y contrarrestar el mecanismo de rendimientos decrecientes a su acumulación. Es interesante destacar como, mientras el rendimiento del capital humano disminuía progresivamente a medida que aumentaba el nivel educativo, el rendimiento del privado mostraba una tendencia casi opuesta. Finalmente, no parece obtenerse ninguna conclusión clara respecto a que el efecto que el capital humano ejerce sobre el capital físico sea distinto según el nivel de desarrollo de las distintas regiones españolas.

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Figure 1. Return of human capital and ratio K/H

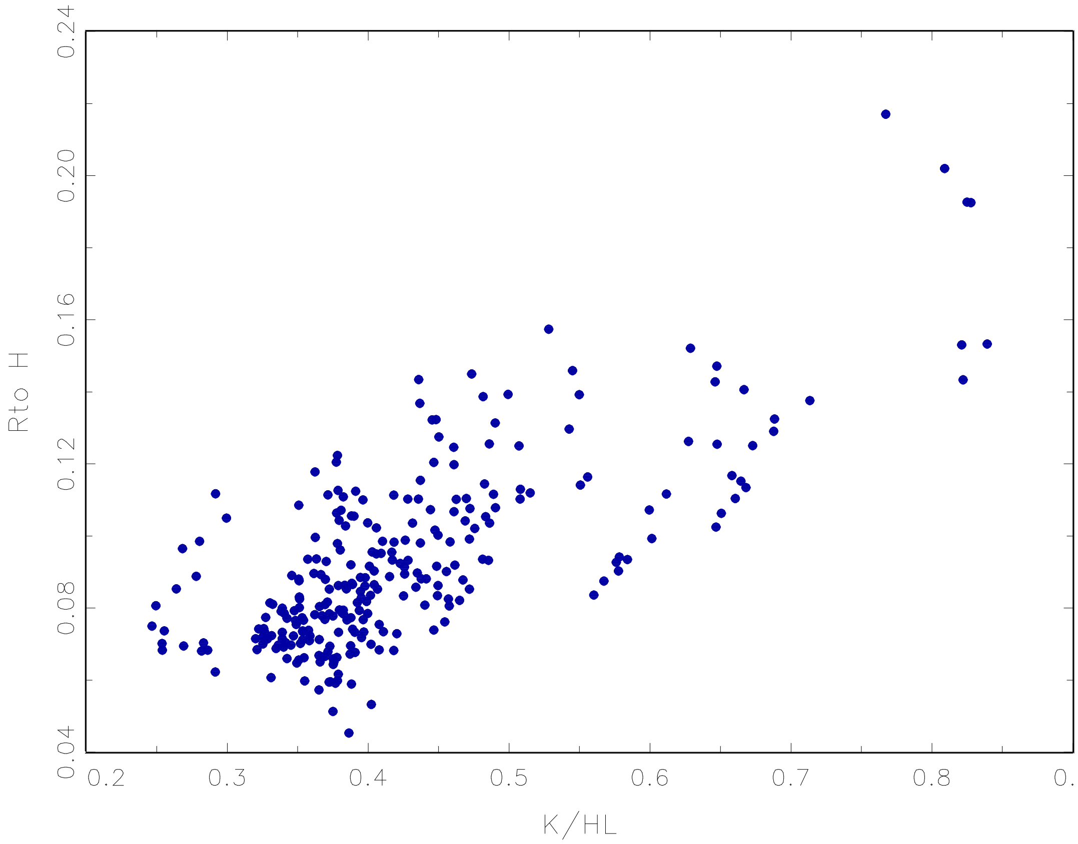

Figure 2. Return of physical capital and ratio K/H

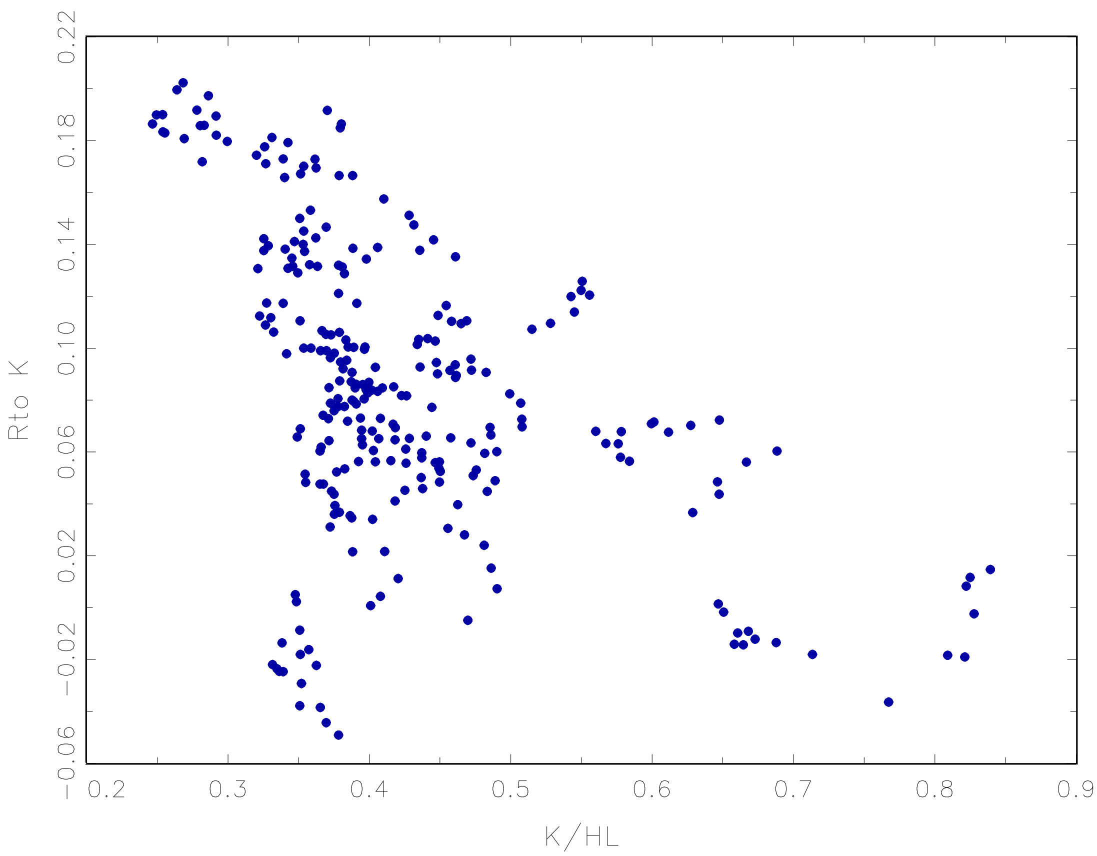

Figure 3. Return of human capital and the stocks of physical and human capital

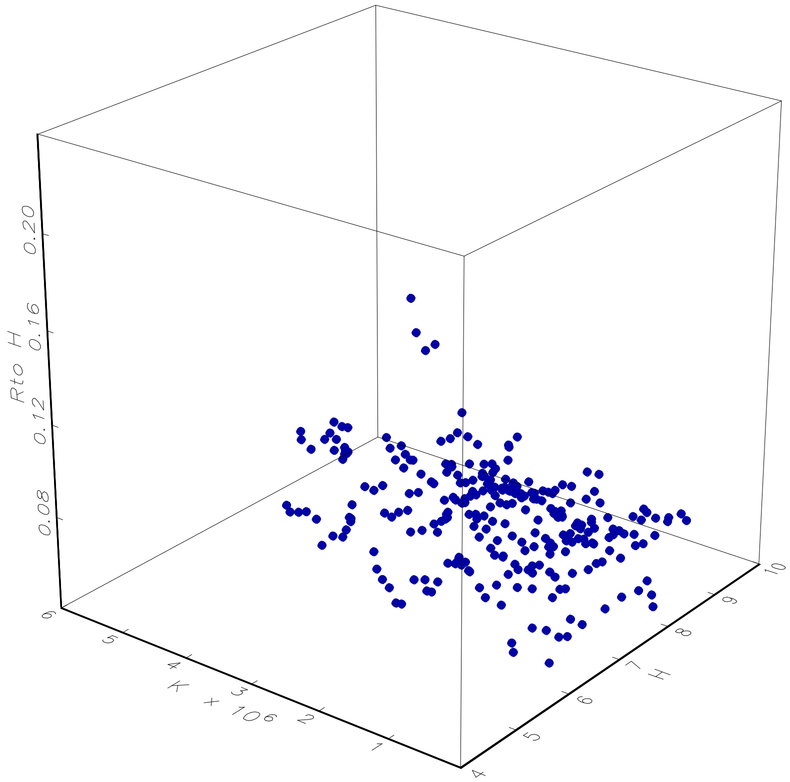

Figure 4. Return of physical capital and the stocks of physical and human capital

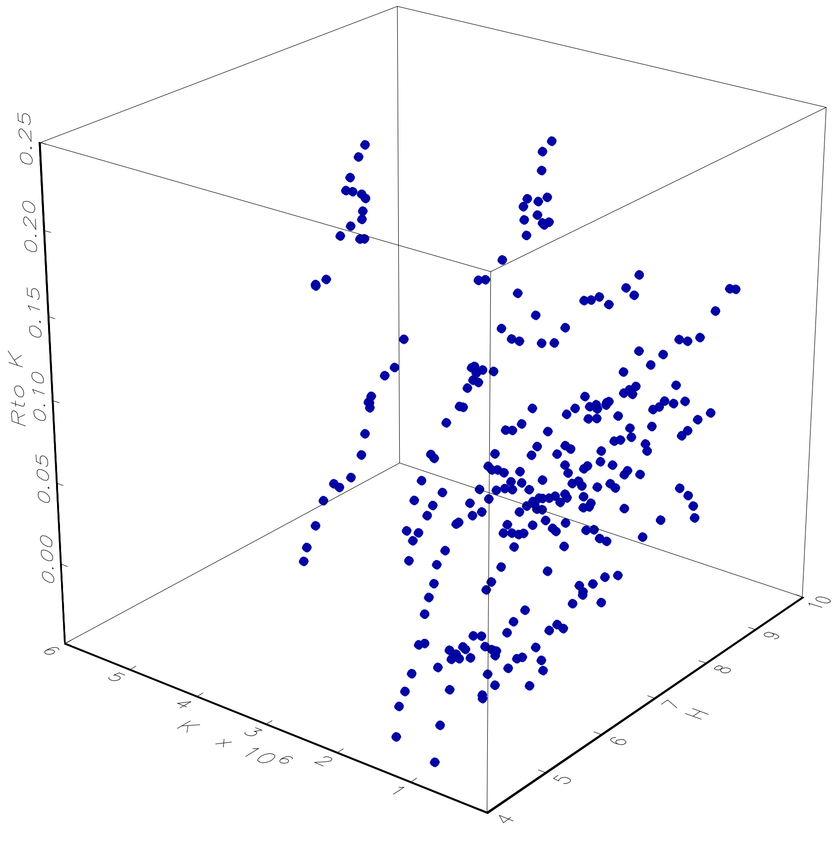

Table 1. Time evolution of human and physical capital (Spain)

	K	Y/L	K/Y	K/L	H	K/H
1980	22017847	2.51	0.87	2.19	5.06	255423
1981	22499966	2.56	0.91	2.32	5.18	255301
1982	22854075	2.58	0.93	2.39	5.38	249971
1983	23167361	2.64	0.93	2.45	5.59	243311
1984	23284175	2.77	0.92	2.54	5.74	237960
1985	23376304	2.82	0.90	2.53	5.91	231440
1986	23678050	2.86	0.89	2.53	6.16	225343
1987	24246605	2.89	0.86	2.49	6.42	221796
1988	25043141	2.96	0.84	2.49	6.62	221658
1989	26117319	3.03	0.83	2.53	6.90	221589
1990	27200248	3.05	0.84	2.55	7.12	224177
1991	28269177	3.09	0.86	2.64	7.32	227057
1992	29236942	3.16	0.89	2.80	7.51	228736
1993	29736355	3.19	0.93	2.97	7.73	225756
1994	30322707	3.32	0.91	3.03	7.98	222601
1995	31219910	3.37	0.91	3.07	8.18	222909
1996	32142264	3.41	0.92	3.12	8.45	221927
1997	33247770	3.43	0.91	3.13	8.64	224033
1998	34560969	3.47	0.90	3.12	8.86	227211
1999	36175191	3.49	0.90	3.14	9.08	231695
2000	38117427	3.53	0.90	3.19	9.32	237483
Annual growth [(1)]						
1980-1985	1.20	2.40	0.48	2.89	3.17	-1.95
1986-1990	2.81	1.28	-1.06	0.18	2.95	-0.10
1991-1995	2.01	1.76	1.28	3.06	2.24	-0.37
1996-2000	3.47	0.69	-0.24	0.46	1.99	1.36
1980-2000	2.78	1.73	0.17	1.90	3.10	-0.36

[(1)] Annual Accummulated growth rate

Table 2 . Some interesting ratios in the analysis. Averages 1980-2000

	Y/L	Y/K	K/L	H	Y/H	K/H
ANDALUCIA	91.8	93.2	98.6	92.6	96.5	103.7
ARAGÓN	110.6	89.4	123.1	102.7	105.9	117.7
ASTURIAS	117.9	113.9	104.4	98.7	118.1	104.2
BALEARES	100.7	85.6	117.7	101.8	95.9	112.1
CANARIAS	88.2	82.8	106.8	96.2	88.6	107.9
CANTABRIA	111.5	100.3	110.6	104.7	104.7	103.9
CAST. Y LEON	102.9	87.6	116.7	96.0	105.5	119.8
CAST.-LA MANCHA	87.1	69.1	125.7	89.3	95.9	138.3
CATALUÑA	109.2	111.9	97.5	110.4	96.8	86.3
VALENCIA	87.3	100.4	87.5	100.5	84.4	85.0
EXTREMADURA	80.7	54.6	146.5	85.3	93.0	168.9
GALICIA	76.0	96.1	79.3	85.3	87.8	91.5
MADRID	110.3	128.7	86.9	121.2	89.0	70.7
MURCIA	90.3	94.7	95.7	93.6	93.4	99.2
NAVARRA	122.2	122.6	100.1	109.8	109.4	89.6
PAIS VASCO	127.4	113.0	112.4	113.8	109.9	96.9
LA RIOJA	124.5	129.1	97.0	98.2	124.6	97.2
VALUE FOR SPAIN	3.053[(1)]	1.122	2.725[(1)]	7.102	0.437[(2)]	0.39[(2)]

Note: the values for the regions correspond to their percentage with respect to the value in Spain
(1) En millions of pesetas per worker (2) In millions of pesetas per education year

Table 3. Estimates of the partial static equilibrium model

	Dependent var. : VC, S_L, S_Y		Dependent var.: $-S_K$	
Coefficient	**Estimate**	**t-Ratio**	**Estimate**	**t-Ratio**
β_0	-3.484	-5.231	0.160	1.976
β_L	0.338	3.688		
β_Y	-0.483	-4.093		
β_K	1.866	13.954		
β_H	1.830	3.836		
β_T	-0.089	-5.242		
β_{LL}	0.132	11.259		
β_{YY}	0.012	1.848		
β_{KK}	-0.041	-4.482	-0.062	-11.573
β_{HH}	-0.900	-6.869		
β_{TT}	-0.001	-3.324		
β_{LY}	-0.152	-12.269		
β_{LK}	0.171	15.484	0.011	0.546
β_{LH}	-0.067	-2.487		
β_{LT}	-0.005	-4.101		
β_{YK}	0.012	0.951	0.120	9.369
β_{YH}	0.659	19.873		
β_{YT}	-0.015	-12.036		
β_{KH}	-0.639	-14.075	-0.120	-4.776
β_{KT}	0.015	9.421	-0.002	-1.815
β_{HT}	0.060	6.829		
$D_1\beta_L$	0.007	0.718		
$D_1\beta_Y$	-0.064	-5.590		
$D_1\beta_K$	0.066	5.537		
$D_2\beta_L$	0.008	0.857		
$D_2\beta_Y$	0.040	3.317		
$D_2\beta_K$	-0.042	-3.311		
D_1			0.0112	1.247
D_2			-0.003	-0.374

R^2 Cost function	0.997	
R^2 Labor share	0.676	
R^2 Capital share	0.580	
R^2 Price = Marginal Cost Equation	0.755	
# observations	272	
# iterations	11	
LR Test of SURE –$\chi^2(6)$ –	108.8	p-val: 0.000
Wald Test:		
Significance of regional dummies –$\chi^2(8)$ –	40.8	p-val: 0.000
Significance of human capital –$\chi^2(7)$ –	818.1	p-val: 0.000
Shankerman & Nadiri Test –$\chi^2(27)$ –	534.8	p-val: 0.000

Table 4. Return of human and physical capital

	ε_{YH}	Rto H	ε_{YK}	Semi-ε_{K*H}
Average	0.507	0.073	0.076	0.191
Time evolution				
1980	0.5098	0.1004	0.0619	0.6276
1981	0.4861	0.0936	0.0661	0.3363
1982	0.4922	0.0912	0.0750	0.2510
1983	0.5039	0.0898	0.0822	0.2657
1984	0.4622	0.0801	0.0817	0.1844
1985	0.4547	0.0763	0.0819	0.2069
1986	0.4890	0.0793	0.0716	0.1720
1987	0.4808	0.0749	0.0722	0.1382
1988	0.4859	0.0731	0.0726	0.1623
1989	0.4892	0.0707	0.0766	0.1376
1990	0.4973	0.0696	0.0756	0.1262
1991	0.5105	0.0697	0.0726	0.1264
1992	0.5232	0.0696	0.0693	0.1206
1993	0.5508	0.0712	0.0721	0.1352
1994	0.5435	0.0680	0.0751	0.1351
1995	0.5245	0.0641	0.0792	0.1188
1996	0.5376	0.0637	0.0808	0.1234
1997	0.5358	0.0620	0.0820	0.1432
1998	0.5260	0.0594	0.0788	0.1489
1999	0.5184	0.0571	0.0793	0.1565
2000	0.5182	0.0556	0.0879	0.2016
Regional averages				
ANDALUCIA	0.4238	0.0659	0.0666	0.2020
ARAGON	0.5911	0.0843	0.0939	0.1670
ASTURIAS	0.4466	0.0645	0.0414	0.2345
BALEARES	0.5713	0.0816	0.0994	0.1459
CANARIAS	0.5182	0.0782	0.0748	0.1646
CANTABRIA	0.5635	0.0782	0.0829	0.1852
CAST. y LEON	0.5344	0.0812	0.0525	0.1895
CAST. – LA MANCHA	0.4995	0.0814	0.0555	0.1719
CATALUÑA	0.5790	0.0765	0.1506	0.1739
VALENCIA	0.4933	0.0706	0.0971	0.1953
EXTREMADURA	0.5650	0.0976	0.0099	0.1503
GALICIA	0.3054	0.0504	-0.0214	0.2722
MADRID	0.6389	0.0762	0.1661	0.1679
MURCIA	0.4091	0.0627	0.0447	0.2055
NAVARRA	0.5093	0.0674	0.1214	0.1975
PAIS VASCO	0.6166	0.0790	0.1282	0.1694
LA RIOJA	0.3480	0.0505	0.0271	0.2598