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HUMAN CAPITAL AND REGIONAL ECONOMIC GROWTH. EVIDENCE FROM THE DUAL APPROACH.

Preliminary version.

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1. INTRODUCTION

The effect that education can have on the whole of society, as a mechanism that generates human capital, has meant that today the principal motivation underpinning human capital theory has been extended from simply accounting for wage differentials between individuals to that of explaining economic growth (Willis, 1986). The macroeconomic evidence presented to-date has been based on the analysis of the social or aggregate return to human capital, though no definite conclusions have yet been drawn. This evidence has been obtained through the application of a range of specifications centered on this primal focus - in other words, basing the analysis within a production function framework, despite the fact that this approach has given rise to considerable methodological difficulties, including most importantly problems of endogeneity, errors in measurement, and the failure to consider within the return estimates the indirect effects of human capital manifest in other factors.

In fact, the inconsistency between part of the empirical evidence obtained through the use of aggregate analyses and the evidence derived from the predictions of a range of theoretical models of economic growth (e.g. Lucas, 1988) has given rise to many empirical exercises linking aggregate productivity and growth with an economy's human capital endowment. In this context, a distinction has been drawn between the so-called *level effect* of human capital, i.e. a direct effect whereby the accumulation of human capital leads to productivity growth (an assumption that is made for the accumulation of other types of capital) and a *rate effect*. The latter implies the identification of certain indirect effects of human capital, based on the idea that the factor stimulates the generation and absorption of technology (Nelson & Phelps, 1966). While many of the results reported to-date question the significance of the level effect, the evidence clearly seems to point to the existence of the rate effect of human capital. Yet despite this, and despite recent findings that lend support to a level effect based on the use of what is more refined human capital data (de la Fuente & Doménech, 2000), the debate is by no means settled and the evidence from an aggregate perspective on the effects of education on growth remains unclear (Temple 2001a).

A possible approach to analyzing the aggregate effect of human capital - and one that is virtually unexplored - is one based on duality theory. Morrison & Siegel (1997) is, to the best of our knowledge, the only study to analyze some of the effects of human capital endowment on production activity by adopting this approach, in a more general context of the study of the effects of the accumulation of knowledge.[1] Yet, this study does not explore the possibility of obtaining an estimate of the return to human capital, or, for that matter, of any other measures of interest in the study of the effect of human capital. The dual approach allows us to avoid, or at least mitigate, the impact of some of the drawbacks described above when adopting this primal focus - most specifically questions concerning the endogeneity of human capital and the imposition of restrictions concerning its effects.

Many studies have not only identified human capital as being a major factor in determining a significant part of the differences in levels of productivity and per capita income between regions with highly integrated economies (refs??????), but they have also identified human capital as being a key element in strengthening the effect of other factors considered essential for their economic growth, such as investment in technology (refs??????). It is of little surprise that financing the accumulation of human capital in the least developed regions has been one of the main measures of regional development policy over the last few decades (Rodríguez-Pose & Fratesi, 2004). However, the effectiveness of this policy depends in large measure on the investment returns to educational human capital in each of these regions. We would expect this return to be homogenous in all regions in the case that these regions were also homogenous in other aspects, such as in their productive structure, in their propensity to generate and adopt innovations and in their engagement in trade. Were this not the case, it is possible that the return to human capital would differ between regions, which means that an appraisal of its value as a tool for use in regional policy would be particularly useful if information about the regional distribution of this return were available.

[1] The use of the dual approach has been much more frequent in analyzing the effects of investments in infrastructure and public capital (Seitz and Licht, 1995; Morrison and Schwartz, 1996; Moreno *et al*, 2002; Boscà *et al*, 2004).

In this context, the main aim of this study is to provide evidence concerning the contribution of human capital, acquired in the formal education system, to the growth of the Spanish regions over the last few decades. The use of the dual framework means that measures can be easily derived enabling us to describe the effect of the accumulation of human capital on growth. Thus, in addition to the traditional measure of its return for each of the regions and time periods considered, we can also obtain its shadow price, defined as the price that that the firms would have been prepared to pay for an additional year of education for their employees. By obtaining this measure, which to the best of our knowledge has not been reported before, we are able to undertake an analysis of the social profitability of investment in human capital. Finally, the possibility of obtaining estimations of these effects for each of the regions throughout the period of study, combined with the fact that at the same time a continuous process of capitalization would have been in progress, enables us to empirically evaluate the hypothesis of diminishing returns to the accumulation of human capital.

We believe that the situation in Spain might be paradigmatic when it comes to evaluating the contribution of this type of factor to economic development and to the evolution of regional imbalances. This belief is based on various ideas including the spectacular increase in the level of education in all of the regions of Spain, albeit that significant inter-regional differences remain; the fact that this has coincided with a virtually uninterrupted process in which these regions have been opened up to and exposed to competition; and the modernization of the productive and institutional structures which, to a greater or lesser degree, has had an impact on all the regions of Spain. Thus, we believe that the setting is ideal for assessing whether human capital really can promote economic growth when this occurs in combination with other elements that might allow both individuals and economies to use this capital in productive activities for which they receive their corresponding return.

The rest of this paper is organized as follows. In the second section we undertake a brief review of the literature on the effects of human capital in an aggregate context. In the third section, we analyze further the aggregate effect of human capital, defending its social returns and presenting the dual framework as a suitable means for its estimation.

The empirical framework and the data base are described in the fourth section, while the results are reported in the fifth. The sixth section concludes.

2. HUMAN CAPITAL AND PRODUCTIVITY. A BRIEF SUMMARY

The aggregate or macroeconomic context is a suitable one in which to measure the social return of education through its effect on human capital and, in its turn, on economic growth. Analyses of this kind are not new. Schultz (1960, 1961) drew the conclusion that a very significant part of growth was due to improvements in a country's human capital endowment, obtained via investment in education. Such studies have considered two distinct possibilities when examining the effect of human capital. On the one hand, the first line of research has considered it as it would any other reproducible productive factor (similar in the essence of its mechanism to that of physical capital), so that its accumulation positively affects growth, in what has become known as the *level effect* of human capital. On the other hand, it has been considered as a factor that facilitates the generation and adoption of technology, so that a positive relation is expected between capital stock and the growth in productivity, in what has become known as the *rate effect* of human capital.

Given that the level effect models, such as that devised by Lucas (1988), predict that investment in human capital is directly transferred productivity growth and, under certain circumstances, to growth in per capita income, growth-accounting exercises allow us to measure its contribution in the same way as the contribution of other productive factors can be measured. Thus, Griliches (1997) shows that a third of the productivity of the United States since the post-war is due to improvements in education. Similar conclusions are drawn by Maddison (1987) for a number of western economies and by Young (1995) for a group of rapidly growing Asiatic countries. However, it should be pointed out that such growth-accounting exercises have certain limitations when it comes to capturing the effect of human capital if, for example, this factor interacts with the accumulation of physical capital or it comes to intervene in the generation of technical progress. A further option consists in estimating its effect in the context of a growth equation. Adopting this line of thinking, Mankiw *et al* (1992) concluded that 80% of the variability in per capita income in a wide sample of countries can be explained by the accumulation of productive factors, especially human capital. In this particular study, the growth over a long time period in the sample of countries was found to depend, among other factors, on the rate of investment in human capital measured using a schooling rate.

But these results supporting the level effect of human capital came in for criticism in other studies. Perhaps the most significant were Pritchett (1996) and Benhabib & Spiegel (1994), who failed to find a significant effect of investment in human capital on growth rates, and even in some specifications reported a negative relation. Later studies corroborated these surprising results and lent support to those who favored a rate effect of human capital. The idea that human capital serves to stimulate the generation and adoption of technology was initially proposed by Nelson & Phelps (1966) and has more recently been incorporated, for example, in Romer (1990). The argument is an attractive one because, among other reasons, it provides an explanation as to why the diffusion of technology occurs basically between economies with similar levels of development and, above all, with certain levels of human capital endowment of their population. Empirically, studies have sought to determine whether the initial level of human capital (measured by the percentage of the population with a given level of education or the mean number of years of education of this population) has a significant and positive effect on growth, once certain conditioning variables are included. For example, Barro (1991, 1998) detected a fairly marked positive effect. However, a number of authors including Topel (1999) claim that the estimated effect in these studies is too high to be credible.

The argument exists that the non significance of the level effect might be caused by an exacerbation of the harmful effects of the errors of measurement when using the growth of human capital indicators (Krueger & Lindahl, 2001), and this has seen a reemergence in recent years of arguments in favor of the level effect. In this debate, the improvement in education data bases as well as the detection of some anomalous cases that apparently distorted earlier results have been influential (Vasudeva & Chien, 1997; de la Fuente & Doménech, 2000; Temple, 1999; Englebrecht, 1997; del Barrio *et al*, 2002). Bassanini & Scarpeta (2001 and 2002) reached the conclusion that, in a sample of OECD countries, an additional year of education in the population increases per capita product by 6%. Despite this, and in comparison with the overwhelming microeconomic evidence concerning private returns, the evidence regarding the level effect remains flimsy (Temple, 2001).

In the case of the Spanish economy, the availability of data concerning the product and the productive factors over a long time period, and in a format that is disaggregated territorially, has enabled us to assess the contribution of human capital (both in terms of it level and rate effects) to the growth experienced over the last few decades. Studies undertaken to date have used as their frame of reference a production function expanded to include human capital with somewhat contradictory results, in keeping it should be said with findings internationally. Thus, Serrano (1996) obtained a non significant level effect when using the mean number of years in education but a significant one when the variable used as a proxy for human capital was the percentage of the population employed with a secondary education. In a later study, the same author was able to confirm this significant and positive effect, even in the case of the mean number of years in education, when using data by sector (Serrano, 1997). On the other hand, Gorostiaga (1999) reported the negative effect of the accumulation of human capital on growth rates between 1964 and 1991, a finding attributed by Freire-Serén (2002) to the fact that the simultaneous nature of the relationship between product growth and the accumulation of capital was not considered. The latter estimated a simultaneous model concluding that the product affects positively the accumulation of human capital and that this, in turn, leads to product growth.

Most of the studies discussed above have considered a Cobb-Douglas production function that incorporates human capital as an additional factor. But this specification carries with it the imposition of elasticities of substitution between constant and unitary factors, which can at times be fairly restrictive, particularly in the case of human capital. Furthermore, a rigid relationship is established between human capital and productivity (loglinearity and homogeneity in the coefficient). The primal focus of the analysis, when considering the estimation of a production function or its transformation, has given rise to additional concerns, including the possible bias of endogeneity described above, due to the possible influence of the product on decisions concerning the accumulation of education, the lack of robustness of the results obtained when choosing the set of regressors for the growth equations, and the failure to consider the possible nonlinearity of the human capital effect (Sianesi & Van Reenen, 2000).

In this study, however, we estimate the effect of human capital via the framework established by the duality theory, using the estimation of a system of costs. The consideration of the dual framework, using a sufficiently flexible cost function allows us to overcome in some cases and to reduce in others some of the limitations described above in the case of studies based on the prime focus. Moreover, it allows us to define and obtain interesting measures that cannot be obtained from the primal framework, such as the shadow price of human capital, in other words, what the firms that operate in the economy would be prepared to pay for its provision. Yet at the same time the typical measures from the primal focus can still be obtained, namely the factor return or the returns to scale of the production technology.

3. MEASUREMENT OF THE EFFECTS OF HUMAN CAPITAL WITHIN THE DUAL FRAMEWORK.

Duality theory assumes that the optimization problem faced by all firms involves choosing inputs so that production costs are minimized, given certain input prices, a level of output and a production function (Chambers, 1988). The solution to this optimization problem lies in a cost function which is dual to the production function. In this framework human capital is introduced in order to take into consideration the effect that this factor has on a firm's production costs.

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 the firm 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:[2]

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

[2] A detailed description of cost function properties can be found in Chambers (1988).

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).

Therefore, here, we consider 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:

$$VC = VC\,(P_1,...P_s, Y, Z_1,...Z_m) \qquad (3)$$

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 the firm is to minimize total costs in (2), in a PSE situation, the firm's 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. Since the purpose of this paper is to obtain human capital elasticities, here we focus our attention on a production function aggregated with this type of capital. This aspect must be taken into account when obtaining the corresponding PSE model, which presents an associated variable cost function as follows:

$$VC = VC(P_L, P_M, Y, K, H) \qquad (4)$$

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; and 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 human capital stock can lead to shifts in cost curves. After increasing or improving human capital endowment, firms adjust their decisions concerning the amounts of the different variable inputs used in the production process according to their substitutive or complementary relationship with human capital, given the existing amount of quasi-fixed inputs.

Since firms pay for the human capital factor of their employees through their wages, but do not pay for the rest of human capital available in the economy, the short-run cost function is the sum of the variable cost and the cost of the services provided by the existing capital:

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

Assuming that variable input prices are exogenous to the producer and 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.

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

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

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

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

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:

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

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:[4,5]

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

From the functions previously described, a set of measures in relation with the effects of human capital investments can be obtained. Specifically, the traditional elasticity of output to human capital usually obtained in growth studies related to human capital can be recovered from the dual approach thanks to the envelope theorem (see Chambers, 1988):

$$\varepsilon_{Y,H} = \frac{\partial \ln Y}{\partial \ln H} = \frac{-\frac{\partial VC}{\partial H}}{\frac{\partial SC}{\partial Y}} \frac{H}{Y} \quad (11)$$

This relationship provides the connection between the primal (via the production function) and the dual (via the cost function) measurement of the productivity impact of capital stocks. However, in the case of human capital it is more intuitive to analyze the impact of an additional educational year on output. We can define the return of human capital as the increase in output given an increase of one year in the average level of the education of workers. This semi-elasticity of output with respect to human capital is given by:

[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.
[5] Note that human capital will have a direct effect on the cost of production through its influence on variable costs, and an indirect one through the effect that it may exert on the equilibrium stock of capital.

$$R_H \equiv \frac{\partial \ln Y}{\partial H} = \varepsilon_{Y,H} \frac{1}{H} \tag{12}$$

In addition to these measures, the dual approach allows us to obtain the change in costs due to a marginal addition to the stock of human capital, defined as:

$$\varepsilon_{SC,H} \equiv \frac{\partial \ln SC}{\partial \ln H} = \frac{\partial SC}{\partial H}\frac{H}{SC} = \frac{\partial VC}{\partial H}\frac{H}{SC} \tag{13}$$

If firms obtain cost reductions due to human capital, it can be considered that they will be willing to pay for its endowment up to an amount equal to the savings in cost that this endowment implies. Hence, it is possible to obtain a measure of the implicit willingness of manufacturers to pay for human capital - that is, the *shadow price of human capital*:

$$Z_H \equiv -\frac{\partial VC}{\partial H} = \varepsilon_{VC,H}\left(-\frac{VC}{H}\right) \tag{14}$$

where $\varepsilon_{VC,H}$ denotes the elasticity of variable costs with respect to human capital ($\varepsilon_{VC,H} \equiv \frac{\partial \ln VC}{\partial \ln H} = \frac{\partial VC}{\partial H}\frac{H}{VC}$). The shadow price is defined as the reduction in variable costs due to an increase in the human capital stock.[6] As long as this value is positive, human capital will maintain, to a greater or lesser extent, a net substitutability relationship with variable factors, so that investments in this type of capital will imply improvements in efficiency, the latter understood as net savings as a result of decreases in variable input utilization and thus in variable costs.

4. EMPIRICAL MODEL AND DATABASE

4.1. Empirical model

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:

[6] In this framework we assume that firms do not pay directly for the human capital stock available in the economy in which they operate, but only the human capital offered by their workers through their wages. From this perspective, the shadow price obtained when applying this theoretical model will tend to exaggerate the social impact of human capital.

$$\ln(VC/P_M) = \beta_0 + \beta_L \ln\frac{P_L}{P_M} + \beta_Y \ln Y + \beta_K \ln K + \beta_H \ln H + \beta_T t +$$
$$0.5\left[\beta_{LL}\ln^2\frac{P_L}{P_M} + \beta_{YY}\ln^2 Y + \beta_{KK}\ln^2 K + \beta_{HH}\ln^2 H + \beta_{TT} t^2\right] \quad (15)$$
$$+\beta_{LY}\ln\frac{P_L}{P_M}\ln Y + \beta_{LK}\ln\frac{P_L}{P_M}\ln K + \beta_{LH}\ln\frac{P_L}{P_M}\ln H + \beta_{LT}\ln\frac{P_L}{P_M}\, t$$
$$+\beta_{YK}\ln Y \ln K + \beta_{YH}\ln Y \ln H + \beta_{YT}\ln Y\, t + \beta_{KH}\ln K \ln H + \beta_{KT}\ln K\, t + \beta_{HT}\ln H\, t$$

where t is a time trend which summarizes technological change. For ease of notation, variables in equation (16) 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 (16) 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:

$$S_L \equiv \frac{P_L \cdot L}{VC} = \frac{\partial \ln VC}{\partial \ln P_L} = \beta_L + \beta_{LL}\ln\frac{P_L}{P_M} + \beta_{LY}\ln Y + \beta_{LK}\ln K + \beta_{LH}\ln H + \beta_{LT} t$$
$$S_M \equiv 1 - S_L \quad (16)$$

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

$$-S_K \equiv -\frac{P_K \cdot K}{VC} = \frac{\partial \ln VC}{\partial \ln K} = \beta_K + \beta_{KK}\ln K + \beta_{LK}\ln\frac{P_L}{P_M} + \beta_{YK}\ln Y + \beta_{KH}\ln H + \beta_{KT} t \quad (17)$$

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

$$S_Y \equiv \frac{P_Y \cdot Y}{VC} = \frac{\partial \ln VC}{\partial \ln Y} = \beta_Y + \beta_{YY}\ln Y + \beta_{LY}\ln\frac{P_L}{P_M} + \beta_{YK}\ln K + \beta_{YH}\ln H + \beta_{YT} t \quad (18)$$

The set of expressions (15)-(18) would comprise the framework of the full static equilibrium. By contrast, using the model of partial static equilibrium, the parameters in (17) would not correspond with those in (15), since this expression would not be the result of the differentiation of the latter expression.

4.2 Database

The spatial units considered here correspond to Spain's Autonomous Communities (NUTS II level), while the period analyzed ran from 1980 to 1995. Thus, we shall consider the influence of human capital in the private productive sector of the Spanish regions during a period in which there was a marked accumulation of education 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 mean 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 mean number of years of education of an economy. This type of indicator has been constructed for various samples of economy by, among others, Kyriacou (1991), Barro & Lee (1993, 1996, 2001) and de la Fuente & Doménech (2000), and has been used to analyze the contribution of this factor to growth in, for example, Benhabib & Spiegel (1994), Temple (1999), de la Fuente & Doménech (2001) and del Barrio *et al* (2002).[7] The information required for constructing the indicator was drawn form Mas *et al* (2002). We have information for five levels of education: illiterates, those with primary education or without any schooling at all (fewer than eight years of schooling), secondary schooling (from eight to ten years of education), pre-higher education (at least fifteen years of schooling), and higher education (seventeen years of study). 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.

[7] Alternatives, such as the rate of schooling or the literacy rate have been subjected to considerable criticism owing to their clear limitations when adequately 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.

Graph 1 illustrates the evolution in the education of the population engaged in the private productive sector of the Spanish economy. It clearly reveals the marked growth in the level of education of the working population described above. It can be seen that the number of illiterate workers virtually disappears and how primary education - the preponderant level for much of this period for which data are available - is supplanted by secondary education. It can also be seen that, at the end of the XX century, the typical worker in the Spanish economy was an individual who had completed between eight to ten years of education. Although smaller in number, the increase in the percentage of workers with university studies is notable (studies up to higher education and higher education).

[Insert Figure 1 around here]

As discussed above, by combining the mean number of years in each level of education with the percentage of the population that has completed each of these levels, we obtain an attractive synthetic indicator of human capital: that of the mean number of years of education. In so doing, we have followed Serrano (1996 and 1997) by designating 0 years to illiterates, 3.5 years to those with primary education studies or without any schooling at all, 11 years to those having completed secondary education, 16 years to those workers with studies up to higher education and 17 years to those with higher education. Graph 2 illustrates the evolution in this indicator for the whole of the Spanish economy. The graph needs few additional comments: throughout the period the mean number of years of schooling in the private productive sector increased notably. In particular, the increase during the period in which this study is focused was even more intense than in earlier periods. Thus, in a decade and a half there was an increase of more than three years in the mean schooling rate, reaching 8.34 years in 1995. Although the period following this year is not included in the analysis undertaken here, it should be pointed out that this trend shows no sign of weakening.

[Insert Figure 2 around here]

The results obtained for Spain as a whole are by and large reproduced in the case of all the Autonomous Communities, although marked differences persist in the regional endowment of human capital education at the end of the period. Specifically, Graph 3 shows the mean number of years of education of those employed in the private sector in 1980 and in 1995, i.e. the first and last years of the period analyzed in our subsequent study. It can be seen how, despite the convergence in the levels of human capital that have taken place in the period (see, for example, Mas *et al*, 1996 or Serrano *et al*, 2002) marked differences persist between the regions. Thus, compared to the mean of 9.6 years in Madrid in 1995, Galicia and Estremadura do not reach 7 years.

Therefore, the increase in the education stock of the workforce in all the regions and the existence of marked variability among them should provide us with substantial information for comparing the effect that educational human capital has on aggregate productivity and economic growth which, as discussed above, will enable us to draw conclusions as to the social return to investment in education.

[Insert Figure 3 around here]

The remaining statistical information has been taken from the BD.MORES data base prepared by the Spanish Ministry of Economy and Finance.[8] Specifically, of the data provided by the BD.MORES database, we have used the series relating to Gross Added Value to factor costs, workforce, income for work, capital stocks stock and the cost of using private productive capital. Similarly, the data referring to the intermediate consumer goods are taken from Díaz (1998), so that the output variable chosen is the production value, which is obtained by summing the intermediate consumer goods to the added value. The time period for these series runs from 1980 to 1995.

5. RESULTS

5.1. Estimate of the coefficients of the cost system

For purposes of empirical implementation the models have to be embedded within a stochastic framework. In order to do this we consider errors in variable costs —eq. 15— and variable factor demands —eq. 16— as being due to errors in optimization in the short-run, while those for the equilibrium relationships (for physical capital —eq. 17— and output —eq. 18) represent unanticipated information that becomes available

[8] See Dabán et al (1998) for a description of the series included and the methodology employed to construct this data base.

once the investment and output decision have been taken. 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.[9]

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).[10] The result of this contrast is shown in the lower panel of Table 1. 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 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 1 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 (Greene, 2001???). The value obtained by 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 1 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

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[9] This is true given that the Oberhofer-Kmenta (1974) conditions are fulfilled in the case of seemingly unrelated equation models (see, for instance, Greene, 2001).

[10] In brief, the null hypothesis that firms are in 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.

translog approximation of the unknown functional form underlying the system of costs. Similarly, it is worth stressing that the convergence in the estimation was reached with a relatively small number of iterations and, more importantly from an economics point of view, that the fictitious variables that control for regional differences in the exogenous demands for factors and marginal costs on the one hand, as well as all the variables that describe the effect of human capital, are together significant. Consequently, Wald's test confirms the existence of a significant effect of human capital on costs .

5.2. Estimate of the returns and the shadow price of human capital

In order to be able to quantify and evaluate the contribution of human capital we first need to obtain the various measures defined above in Section 3, using for this purpose the estimation obtained for the parameters of the system of costs. Table 2 summarizes the results, providing the global mean for the set of regions throughout the period considered.[11] It can be seen that the results obtained for the estimation of the returns on human capital were positive and of a sizeable magnitude in all the regions, with a regional mean slightly greater than 9%. In other words, for the mean of the period under consideration and in a typical Spanish region, an increase in one year in the mean level of education of the workforce gave rise to an increase of 9% in production. This result would therefore justify subventions being made to the training of human capital, that is the education of individuals, given that the resources that are diverted for this purpose would be profitably spent, even in comparison with profitability levels of alternative investments.[12] Yet this global result hides an important regional heterogeneity. Indeed, the mean return in the period on human capital is very high in the cases of the regions of Aragon, Castile-Leon, Castile-La Mancha, Estremadura and Cantabria. By contrast, in Andalusia, Galicia, Catalonia, Valencia, Madrid, Murcia, Navarre and La Rioja the return on human capital was considerably lower. Note, for example, that the return in the region in which investments in human capital were socially most productive (Estremadura) more than double the region with the lowest return (La Rioja). This suggests that the return could be related to the level of development attained by each regional economy as well as the existing endowment of human capital. In order to

[11] The set of effects for each of the regions in each of the years are available on request.

[12] By way of example, estimations of the return on investments in private productive capital on the Spanish economy in a similar period stand at around 3% (e.g. 2.8% in Moreno et al, 2003, and 4.2% in Boscà et al, 2004).

analyze these questions, Graphs 4 and 5?????? show the relationship between the estimation of return on human capital in each region and its productivity and stock of human capital respectively.

[Insert Figures ¿??? around here]

In keeping with the results obtained for its return, the improvements in the endowment of human capital gave rise to a saving in the total production costs ($\varepsilon_{SC,H} < 0$), which is true in all the Spanish regions. This confirms that human capital contributed positively to the returns to scale of the private productive activity. Specifically, its shadow price, Z_H, that is what the firms in a typical Spanish region would have been prepared to pay for an additional year in education for all its workers, reaches a mean value for the period of more than 1,800 million €. If we calculate this figure for the number of employees in each regional economy (Z_H/L), we find that the firms on average would have been prepared to pay more than 3,000 € for an additional year's education for any one of its workers. This figure represents the savings in variable costs for an additional year's education for the average worker. Finally, and as occurred with the return, we should highlight the significant regional variability in the unit shadow price of human capital (its standard deviation being greater than 570€). Thus, while Aragon, Cantabria and Estremadura exceeded 3,900 €, Galicia did not reach 2,100 €.

In short, the investments in human capital in all the regions of Spain presented far from negligible social or aggregate profitability levels, given that they contributed significantly to reducing production costs, that is, to increasing the returns of the private productive sector. But the magnitude of this effect was far from homogenous throughout all the regions, given that a tendency was noted for the regions with the greatest/lowest??? levels of productivity to benefit most from the accumulation of this factor. Similarly, the positive/negative?? relationship of the return with the existing stock of human capital points to a possible conflict between the objectives of efficiency and equity in the financing of education in the Spanish regions/suggests that no conflict was caused when using the stimulus for investment in education in the less developed regions as a regional policy measure, given that the objectives of efficiency and equity are simultaneously met. TBC¿???

[Insert Table 2 around here]

5.3. Temporal profile of the returns to human capital

From the above results it can be deduced that, for the whole period under review, investments in human capital were on average profitable in all the Spanish regions. However, under the assumption of diminishing returns for the accumulation of this capital, the continuous increase in its stock throughout the period, as described in Section 4 (Figure 2), should have brought about a decreasing trend in returns, which could even have led to the exhaustion of this resource as a factor that strengthens growth in the Spanish regions at the end of this period. In order to verify this, we calculated the return for each region in each of the years under consideration and that corresponding to the regional mean. For reasons of space, Table 3 alone provides information about this analysis.[13] Similarly, Graph 4 shows the relation between the return in each region and year and the corresponding ratio of the human capital stock to physical capital.

As expected under an assumption of decreasing returns, the most notable feature in the results in Table 3 is the large fall in the returns to human capital. Thus, at the end of the period these returns represented slightly more than 50% of those observed in 1980. Hence, it could be said that while human capital in the Spanish regions has played a significant role during the period analyzed, this significance has decreased over time in line with the continuous increase in its stock, and its importance is unlikely to persist with the same strength into the future. This is confirmed by Figure 4, which illustrates the clearly negative relationship between returns and human capitalization, supporting the hypothesis of decreasing returns to education investments.

However, as can be seen from the results in Table 3 for the last year under analysis, the return of an extra year's education at the end of the period maintained its importance (almost 7%). Thus, investments in human capital seemed to be a highly effective means of increasing productivity and, hence, promoting economic growth even in the mid-nineties. And considering the trend in returns and the current existing stocks, we predict

[13] The same temporal profile was recorded in each of the Spanish regions. Results are available on request.

that there is still room for significant returns to human capital investments, particularly in those regions with the smallest endowments.

[Insert Table 3 around here]

[Insert Figure ¿??? around here]

6. CONCLUSIONS

The main objective we set ourselves in undertaking this paper was to furnish evidence concerning the contribution of educational human capital to Spain's economic growth over the last few decades. Under certain conditions, and from a purely economic perspective, the identification of a positive effect would justify the use of public resources for financing a population's education. Similarly, our results should enable us to assess the use of the formal education system as a tool for promoting regional economic development, which is tantamount to saying, the use of education as a tool in economic development policy.

Having reviewed earlier contributions to the literature and having implemented an analytical strategy based on the framework supplied by duality theory, our results point to the fact that returns to education in Spain do not differ from those obtained in other OECD countries. We have seen how the return to human capital is positive throughout the period studied. This finding would justify the subsidizing of human capital, in other words financing the education of individuals, given that the resources commandeered for this purpose would prove profitable. We can affirm, therefore, that it is socially justifiable to dedicate resources to the financing of the accumulation of human capital given that it results in increases in productivity and, consequently, in greater economic growth.

The conclusion from a social perspective is undoubtedly the confirmation that educational policy has played and should continue to play a key role in economic development. Used correctly and in combination with other incentives, it should allow greater levels of productivity and income in the Spanish economy, together with a greater development of the least favored regions. In this regard, and bearing in mind the results obtained concerning the return to investments in public infrastructure in Boscá *et al* (2002) and Moreno *et al* (2002), the redistribution of resources for financing both types of capital in the least favored regions seems to be entirely reasonable.

Whatever the case, there are a number of aspects arising from this study which need to be analyzed in greater detail in future studies. For example, it would be of considerable interest to obtain measures of the profitability of investment at different levels of education. Here, we have considered the shadow price as being homogenous for all levels of education; however, there is evidence in the literature that the effects may differ significantly from one level to another.

References

TBC

Figure 1. Employment by education levels in Spain

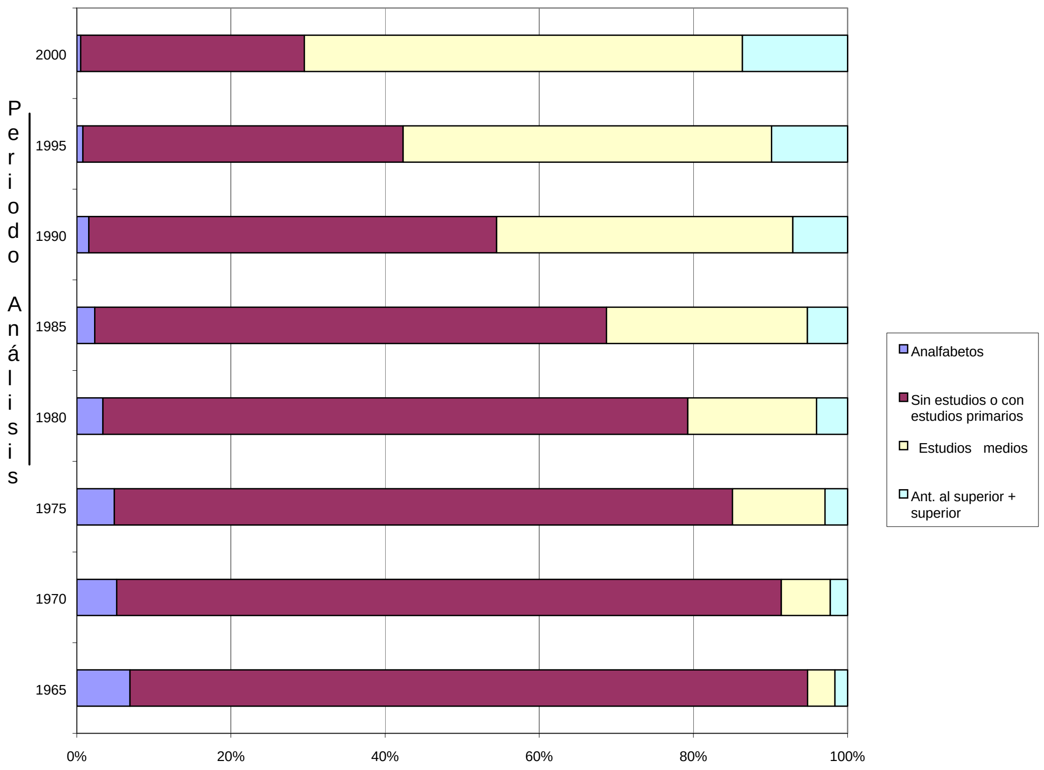

Figure 2. Evolution of the average years of education of employment in Spain

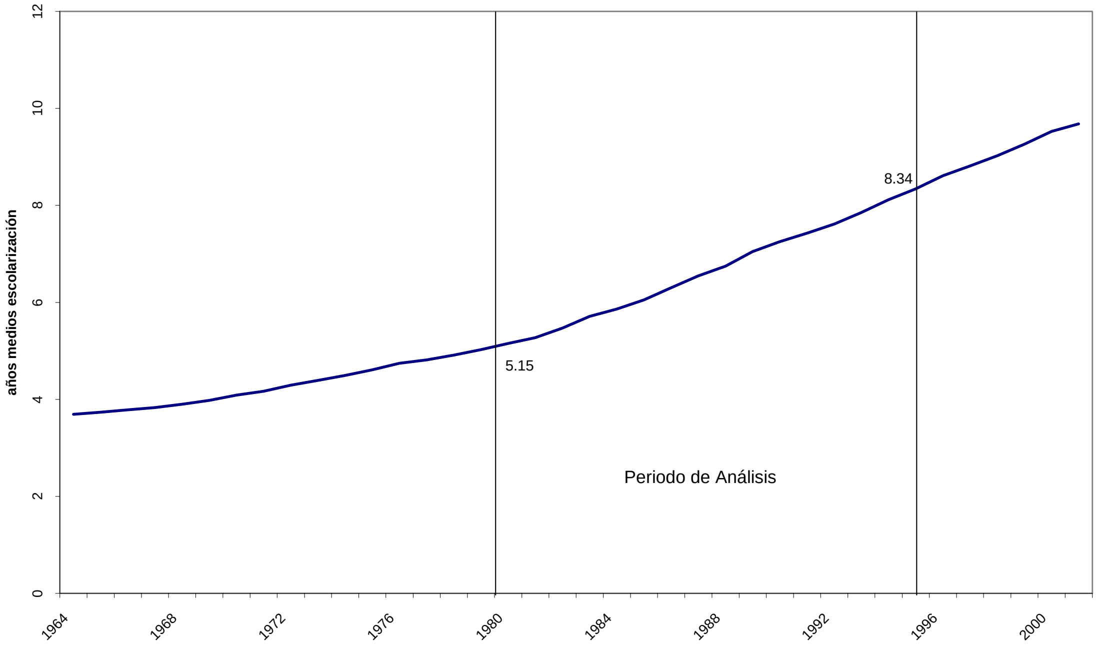

Figure 3. Average years of education in the Spanish regions

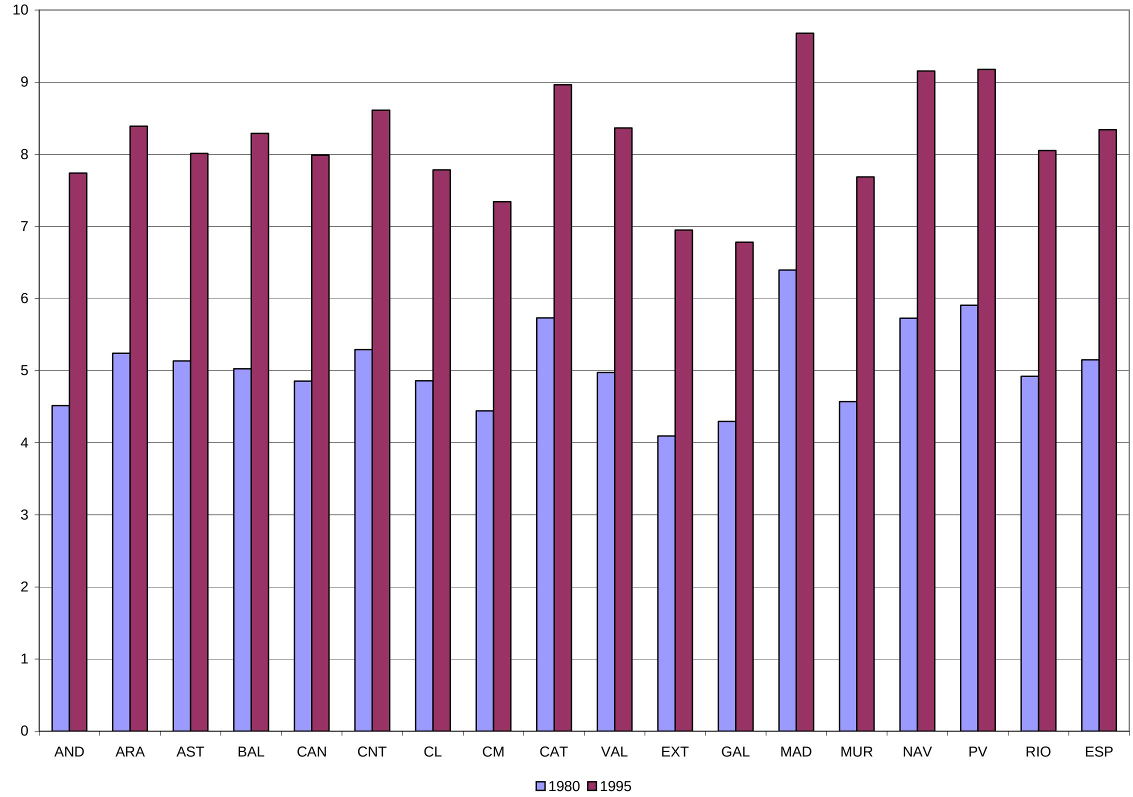

Table 1. Estimates of the partial static equilibrium model

	Var. dep. : CV, S_L, S_Y		Var. dep.: $-S_K$	
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		
$F_1\beta_L$	0.007	0.718		
$F_1\beta_Y$	-0.064	-5.590		
$F_1\beta_K$	0.066	5.537		
$F_2\beta_L$	0.008	0.857		
$F_2\beta_Y$	0.040	3.317		
$F_2\beta_K$	-0.042	-3.311		
F_1			0.0112	1.247
F_2			-0.003	-0.374

R^2 Cost function	0.997	
R^2 Labour share	0.676	
R^2 Capital share	0.580	
R^2 Price = Marg Cost Equation	0.755	
# observations	272	
# iteracions	11	
LR Test of SUR –$\chi^2(6)$ –	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 2. Regional effects of human capital

	Rto H	ε_{SCH}	Z_H	Z_H/L	ε_{YH}	RTS
Media Total	0.093	-0.652	302688.301	0.544773	0.588	0.910
ANDALUCIA	0.081	-0.496	593880.724	0.433023	0.473	0.954
ARAGON	0.106	-0.791	227841.294	0.672515	0.696	0.879
ASTURIAS	0.091	-0.637	166979.883	0.553046	0.581	0.911
BALEARES	0.092	-0.678	115640.783	0.553829	0.594	0.876
CANARIAS	0.092	-0.620	161217.674	0.479670	0.565	0.911
CANTABRIA	0.100	-0.767	93573.651	0.670221	0.669	0.872
CAST. y LEON	0.104	-0.668	399437.183	0.585630	0.640	0.957
CAST– LA MANCHA	0.114	-0.668	241670.240	0.595673	0.639	0.956
CATALUÑA	0.085	-0.729	981093.716	0.553841	0.607	0.832
VALENCIA	0.085	-0.599	467510.044	0.451280	0.542	0.906
EXTREMADURA	0.144	-0.726	149967.334	0.665719	0.754	1.037
GALICIA	0.078	-0.404	301521.541	0.345172	0.423	1.046
MADRID	0.080	-0.800	620221.407	0.523010	0.638	0.797
MURCIA	0.081	-0.508	106744.125	0.428500	0.479	0.943
NAVARRA	0.086	-0.748	94939.109	0.596046	0.613	0.820
PAIS VASCO	0.091	-0.795	382568.680	0.644969	0.673	0.846
LA RIOJA	0.062	-0.439	40893.732	0.508994	0.398	0.907

Table 3. Evolution of the effects of human capital

	Rto H	ε_{SCH}	Z_H	Z_H/L	ε_{YH}	RTS
Media Total	0.093	-0.652	302688.301	0.544773	0.588	0.910
1980	0.131	-0.708	167955.194	0.297348	0.657	0.938
1981	0.121	-0.676	187939.700	0.344965	0.625	0.932
1982	0.115	-0.672	209174.957	0.389317	0.615	0.923
1983	0.112	-0.686	233431.672	0.438052	0.621	0.914
1984	0.100	-0.638	245247.676	0.473231	0.574	0.908
1985	0.095	-0.628	251839.173	0.479153	0.562	0.903
1986	0.096	-0.649	270993.939	0.517169	0.588	0.912
1987	0.089	-0.629	287837.269	0.530509	0.566	0.906
1988	0.086	-0.632	302941.218	0.541758	0.567	0.904
1989	0.082	-0.632	330984.314	0.575878	0.562	0.897
1990	0.079	-0.630	355576.319	0.604498	0.560	0.897
1991	0.078	-0.640	378461.997	0.643690	0.573	0.901
1992	0.076	-0.633	396305.986	0.688500	0.569	0.905
1993	0.078	-0.671	403719.996	0.723631	0.603	0.906
1994	0.074	-0.664	407544.764	0.734569	0.592	0.899
1995	0.069	-0.632	413058.646	0.734100	0.562	0.896

Figure 4. Returns to human capital and physical-human capital ratio