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A proposal to estimate human capital depreciation: Some evidence for Spain *

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Abstract

This article formulates an empirical model for salary determination, which permits the identification of the depreciation rate of the stock of professional qualifications. The analysis is implemented using the 1994 European Community Household Panel data referring to Spanish salaried males. The depreciation rate of the stock of qualifications is estimated at a narrow interval centred at 1 percent. Empirical evidence also suggests that although the depreciation rate does not vary according to the level of education, it does so depending on unemployment spells endured by the worker in recent years and on whether the worker has undertaken training courses.

Keywords: human capital, depreciation, experience-earnings profiles.

JEL classification: J24, J31.

1. Introduction

The Human Capital Theory developed by Becker (1964) and Ben Porath (1967) is one of the most important contributions of the last 35 years in the fields of labor and education economics. Its basic merit lies in the fact that it permits an analytical management of the heterogeneity of the labor factor and the investment process throughout time that generates this heterogeneity. The human capital production model transforms the different knowledges and skills that individuals have in homogeneous units.

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From this theory as a starting point, an extensive empirical literature on wage equations has evolved on the returns from investments in human capital or on age-earnings profiles throughout the working life of individuals [1]. Empirical evidence is consistent with the existence of a process of human capital depreciation, the professional qualifications acquired by the individual depreciate, and, thus, his human capital depletes. The fact that individuals' earnings profiles reach a maximum before the age of retirement can only be explained if human capital depreciates. Therefore, without analysing this phenomenon, it is not possible to have a complete view of how the human capital investment process takes place throughout the individual's life cycle.

De Grip and Van Loo (2002) consider that, from an economic point of view, two types of depreciation may be distinguished, *technical* depreciation that refers to the worker's loss of human capital, and *economic* depreciation that refers to the loss of market value of the worker's qualifications. Among the first type, they include the depreciation directly attributable to the worker's physical deterioration and that due to atrophy of skills due to the lack of or insufficient use of skills (unemployment spells or inactivity, jobs for which the worker is over qualified,...). As for economic obsolescence they distinguish three causes, job specific skills obsolescence due to technological or organizational developments, obsolescence related to shifts in the sector structure of employment and firm-specific skills obsolescence.

Surprisingly, despite the undoubted relevance of human capital depreciation and that many theoretical studies since the seminal papers of Becker and Ben Porath consider its existence, very few studies have dealt with it empirically [2]. This void is probably due to the fact that the reference model in most human capital empirical works is the one proposed by Mincer (1974), where the depreciation rate cannot be identified. Even so, there are some studies based on Mincer's wage equation, which have attempted to estimate the depreciation rate, under certain identification assumptions.

Examples of this approach are the works focussing on the process of human capital accumulation and age-earnings profiles of females, and the depreciation (the atrophy of skills due to career interruptions) effect associated with exits from the labor market of this social group. Some seminal papers on this area are Mincer and Polacheck (1974) and Mincer and Ofek (1982). In this line of research, more recent papers such as Albrecht *et al.* (1999) and Welch and Ureta (2002) analyse the effect of labor market exits for men.

Carliner (1982) also uses the mincerian equation to look at the human capital depreciation process when studying the evolution of the salaries of U.S. males close to retirement, however, this paper concentrates in depreciation due to worker's physical deterioration.

Also, based on Mincer's model, Neuman and Weiss (1995) analyse the depreciation of human capital for the Israeli case. These authors try to identify depreciation due to the worker (technical) from economic depreciation caused by technological or organizational changes that affect the economic sector in which the worker develops his/her activity. They extend the mincerian model to include depreciation specifically due to education or «vintage effect». Rosen (1976) states that both types of depreciation are undistinguishable but Neuman and Weiss, maintain that since the «vintage effect» is not the same in all sectors

while technical depreciation is, it is possible to identify both of them by comparing data from high and low technology sectors [3].

Another study that tries to measure the obsolescence of sector or firm-specific human capital due to worker displacement, through the estimation of extended mincerian equations, is Jacobson, LaLonde and Sullivan (1993). They employ data combining workers' earning histories with information about their firms to estimate the magnitude and temporal pattern of displaced workers' earnings losses.

A limitation of the literature that applies mincerian equations, where depreciation is not identified, to measure the wage effects of human capital depreciation, is how to isolate this effect from the effects of other factors that influence workers' wages. In the context described above, this paper proposes a different analytical framework to that of Mincer's, which permits the estimation of the depreciation rate of qualifications accumulated over time, either through formal education or from on-the-job experience. Under this setting, depreciation is understood to be the loss of units of human capital and, therefore, of the capacity to produce income. The model does not try to identify the sources of this depreciation since it is difficult to distinguish the wage effects of different causes of skills obsolescence.

Section two presents the model. The third section discusses the main empirical results paying special attention to the effects of unemployment spells on the human capital depletion phenomenon. Conclusions and final remarks are placed in section four.

2. A proposal for the analysis of human capital depreciation

It may be regarded that individuals increase their human capital in a different way during their youth and infancy than once they have entered the job market. The difference between these two ways of increasing human capital is not only linked with the moment of the life cycle in which they occur, but also with the fact that while the former is basically identified with the individuals' formal education, the latter is related to the increase in skills caused by the use of that formal education in their jobs, i.e. professional experience.

Consider an individual who has finished his formal education and has joined the labor market. Let I_{it}^{*} be the gross post-school increases in skills of individual i with t years of experience. Then, the stock of professional qualifications, K_{it}, accumulated by individual i after t years of experience is given by I_{it}^{*} plus the stock he possessed in the previous period K_{it-1}, minus what this may have depreciated δK_{it-1}, δ being the depreciation rate. Formally,

$$K_{it} = I_{it}^{*} + (1-\delta)\cdot K_{i\,t-1} \qquad [1]$$

Depreciation implies a loss of units of human capital and/or losses of these units market value and, as a consequence, a loss in the capacity to generate income. By substituting this recursively, the *stock* of qualifications of an individual can be expressed as the sum of all

past post-school increases of skills and an initial *stock* acquired during the formal education stage:

$$K_{it} = \sum_{j=0}^{t-1} (1-\delta)^j \cdot I^*_{i\,t-j} + (1-\delta)^t \cdot K_{i0} \qquad [2]$$

Let us assume, as is usual in this literature, that earnings are an exponential function of K_{it}. Under this setting, the earnings of individual i with t years of experience are given by:

$$Y_{it} = W \cdot e^{\beta_K K_{it} + \beta_Z Z_{it} + u_{it}} \qquad [3]$$

where β_K is the rate of return on the stock of qualifications, Z_{it} are a group of observable variables, which have an influence on job earnings and β_Z a vector of parameters. In general, Z_{it} are socio-economic features such as working sector, region of residence, etc. W is the rental price per equivalent unit of human capital, which is assumed to be constant over time, and u_{it} represents other random influences in wages. By substituting [2] into [3], we obtain:

$$Y_{it} = W \cdot e^{\beta_K \left[\sum_{j=0}^{t-1} (1-\delta)^j \cdot I^*_{i\,t-j} + (1-\delta)^t \cdot K_{i0} \right] + \beta_Z \cdot Z_{it} + u_{it}} \qquad [4]$$

and by taking logarithms in [4] we have:

$$\ln Y_{it} = \ln W + \beta_K \cdot \left[\sum_{j=0}^{t-1} (1-\delta)^j \cdot I^*_{i\,t-j} + (1-\delta)^t \cdot K_{i0} \right] + \beta_Z \cdot Z_{it} + u_{it} \qquad [5]$$

It is worth noting that neither I^*_{it} nor K_{i0} are observable, so that if [5] is to be estimated, some identification restrictions must be introduced. In this respect, and as it is usual in this literature, it would seem appropriate to consider that the initial stock of professional qualifications is a function of the years of formal education, S_i, which will be approximated by a polynomial, $K_{i0} = \gamma_0 + \gamma_1 \cdot S_i + \gamma_2 \cdot S_i^2 + ...$ In addition, once the individual starts working, his increases of skills, I^*_{it}, will be a polynomial function of experience *t.* That is, $I^*_{it} = \alpha_0 + \alpha_1 \cdot t + \alpha_2 \cdot t^2 + ...$

Alternative expressions for the empirical equation [5] can be obtained depending on the order of the polynomials in t and S. Thus, assuming that K_{i0} is a quadratic function on S_i, leaving open the possibility that each year of formal education contributes differently to that stock, that I^*_{it} decreases linearly with experience, until it becomes zero at retirement, and some standard identification assumptions, K_{i0} and I^*_{it} can be formally expressed as

$$K_{i0} = S_i + \gamma \cdot S_i^2$$

$$I^*_{it} = \alpha - \frac{\alpha}{J - S_{i0}} \cdot t$$

where J is retirement age (generally 65) and S_{i0} is the age at which the individual begins working after completing his studies. Thus, from [5] we have:

$$\ln Y_{it} = \ln W + \beta_K \cdot \left\{ (1-\delta)^t \cdot (S_i + \gamma \cdot S_i^2) + \left[\frac{1-(1-\delta)^t}{\delta} \right] \cdot \left[\alpha + \frac{\alpha}{J - S_{i0}} \cdot \left(\frac{1-\delta}{\delta} \right) - \frac{\alpha \cdot t}{(J - S_{i0}) \cdot \delta} \right] \right\} + \quad [6]$$

$$+ \beta_Z \cdot Z_{it} + u_{it}$$

By making the usual assumptions on the model disturbances, this equation, unlike [5], can be estimated by non-linear techniques and constitutes the basis of the estimations presented in the third section. It should be noted that, unlike what happens with the traditional Mincerian earnings equation, the depreciation rate parameter is identified.

3. Estimation and results

The data used in the estimation of the reference model, summarized in equation [6], are drawn from the European Community Household Panel (ECHP) for 1994, carried out for Spain by the National Institute of Statistics. In the estimation of the model a sub-sample was selected, which was made up of the main core of the Spanish labor market, i.e. salaried males of working age (between 16 and 65) who work in the private sector and for whom all the necessary information to construct the variables employed is available. The number of individuals with full information on these characteristics is 1370.

According with the theoretical model, the main variables used in estimation are the following: the gross wage/hour expressed in 1994 euros; the education level reached by the individual measured in the number of years involved in the corresponding cycle —4 for individuals with primary studies, 8 for those with basic studies, 12 for those with medium grade studies, and 16 for those with university degrees—; and his experience measured in years. Other characteristics of the individual were represented by a set of dummy variables, including marital status, whether the individual had suffered unemployment spells in recent years, profession, region, size of firm and field of activity. Appendix I explains how these variables were constructed and in Appendix II the descriptive statistics of the most relevant variables are presented.

Table 1 presents the estimation results of the model summarized in [6] [4]. The estimation was carried out assuming that individuals retire at 65, (J=65) and that they do not begin working until they finish the maximum study level they declare to own. Moreover, in view of the legal restrictions in force concerning child labor, it is considered that none of the individuals started working before the age of 16. Estimation was carried out by Non-Linear Least Squares (NLLS) and standard errors robust to heteroskedasticity were used for inference purposes. As can be seen in column I, the depreciation rate of human capital estimated for working Spanish men reaches approximately 1.2 percent annually. This result is consistent with those obtained for the USA. For instance, Johnson and Hebein (1974) finds depreci-

ation rates between 1 percent and 3.5 percent, Heckman (1976) obtains depreciation rates between 0.7 and 4.7 percent and in Haley (1976) they were between 0.5 and 4 percent. For European economies, the only estimates available are those for Great Britain (11 percent) and the Netherlands (17 percent) reported by Groot (1998). However, as can be observed, his results are far removed from both, those obtained in the articles mentioned above for the U.S. and those reported for Spain in this paper.

Table 1
Estimation results of the proposed model in equation [6][1]

	I	II	III
Constant	0.593	0.503	0.517
	(0.087)	(0.121)	(0.083)
Parameter stock of qualifications (β_K)	0.055	0.059	0.050
	(0.015)	(0.025)	(0.015)
Square of years of formal education (γ)	–0.028	–0.010	–0.026
	(0.007)	(0.003)	(0.008)
Skill function (α)	0.574	0.682	0.766
	(0.159)	(0.280)	(0.235)
Depreciation rate (δ)	0.012	0.010	0.014
	(0.004)	(0.004)	(0.003)
Depreciation rate *x* Primary studies		0.006	
	—	(0.004)	—
Depreciation rate *x* Basic studies		0.006	
	—	(0.004)	—
Depreciation rate *x* Medium grade studies		0.004	
	—	(0.004)	—
Depreciation rate *x* Training		–0.010	–0.012
	—	(0.003)	(0.002)
Depreciation rate *x* Unemployed at least once in previous 5 years		0.009	0.009
	—	(0.003)	(0.003)
Depreciation rate *x* Long-term unemployment		0.017	0.017
	—	(0.007)	(0.006)
Unemployed at least once in previous 5 years	–0.097		
	(0.025)	—	—
Long-term unemployment	–0.118		
	(0.034)	—	—
Large size Firm	0.279	0.255	0.253
	(0.030)	(0.030)	(0.030)
Medium size Firm	0.209	0.203	0.204
	(0.023)	(0.023)	(0.023)
Agriculture+Fishery	–0.225	–0.231	–0.232
	(0.055)	(0.054)	(0.055)
Finance+Energy	0.227	0.219	0.219
	(0.044)	(0.042)	(0.042)
Household	–0.158	–0.173	–0.177
	(0.076)	(0.079)	(0.077)
Northeast+Madrid	0.227	0.230	0.229
	(0.024)	(0.023)	(0.023)
East	0.174	0.181	0.181
	(0.028)	(0.027)	(0.028)
South	0.089	0.086	0.086
	(0.031)	(0.030)	(0.030)

Table 1 (continued)
Estimation results of the proposed model in equation [6][1]

	I	II	III
Managerial and Professional staff	0.665	0.618	0.629
	(0.054)	(0.053)	(0.054)
Technicians	0.255	0.236	0.239
	(0.042)	(0.042)	(0.042)
Administrative staff	0.149	0.145	0.141
	(0.048)	(0.047)	(0.047)
Qualified workers	0.073	0.076	0.074
	(0.024)	(0.024)	(0.024)
Married	0.058	0.060	0.063
	(0.027)	(0.026)	(0.026)
Log likelihood	–490.70	–473.59	–475.94
Standard error	0.349	0.345	0.345

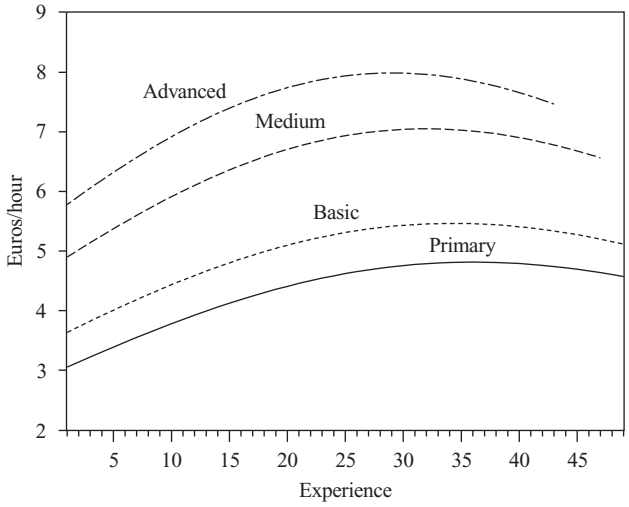
1. Description of model specification for depreciation:
I: constant depreciation rate regardless of personal peculiarities.
II: depreciation rate depending on level of education, on training and on unemployment status.
III: depreciation rate depending on training and on unemployment status.
Note: Number in parentheses indicates standard error robust to heteroskedasticity as proposed by White (1980).

In addition to the educational level and experience, there is a wide set of variables such as: productive sector, previous spells of unemployment, size of the firm, region of residence, type of occupation and marital status, which are significant in the determination of wages [5]. The results obtained for the variables reflecting past unemployment status are worth mentioning. Individuals who have been out of work at sometime in the previous five years earn, on average, less than those who have been employed in the same period of time. Furthermore, if these unemployment spells have been long (more than twelve months), earnings are even lower. One potential explanation for this outcome is that human capital is eroded away by both unemployment spells and by their length. In other words, work inactivity accelerates the rate at which human capital decays. Notwithstanding, to verify this hypothesis it would be necessary to allow for the possibility that the depreciation rate hinges, among other things, on the unemployment status of the individual. This will be considered in the next section.

On the basis of the estimation results shown above (Table 1 column I), the experience-earnings profiles per level of education attained by the average individual were obtained [6]. These experience-earnings profiles, taking into account the depreciation rate of human capital, are depicted in Figure 1.

As can be observed, these experience-earnings profiles show that the higher the level of education, the higher the wage for any level of experience. However, these experience-earnings profiles are not parallel: they separate at the beginning of the working life getting closer later on, as the individual reaches retirement age. Moreover, as suggested by Neuman and Weiss (1995), the years of experience at which the highest wage is reached vary with the worker's level of education. Thus, for those individuals with advanced studies, the highest

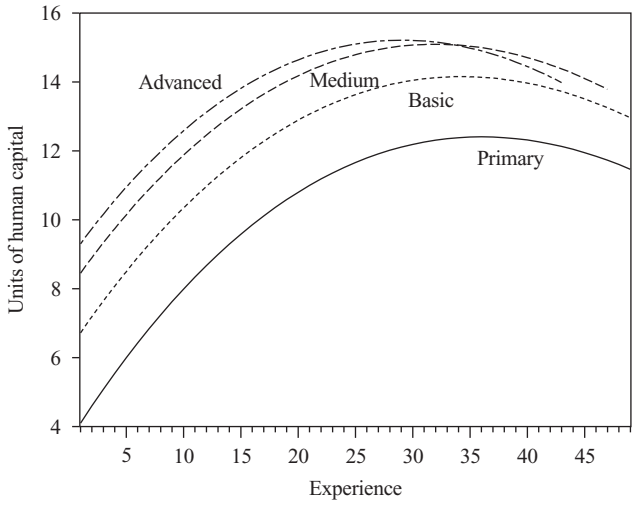
Figure 1. Experience-Earnings profiles



wage is reached after 29 years of experience, for those with medium grade studies (secondary school) this wage level is attained with 32 years of experience, for basic studies with 34 years and, finally, for elementary studies with 36 years. Even though the depreciation rate is the same regardless of the level of education, however, the higher the level of education, the higher the number of units of human capital eroded away per period as a result of depletion.

Likewise, departing from the estimation of our model, the stock of qualifications-experience profiles by level of education can also be derived. These profiles are depicted in Figure 2. As this figure shows, the stock of qualifications-experience profiles define a different evolution from the one corresponding to experience-earnings shapes. This is due to the existence of other factors, apart from the stock of qualifications, affecting wage formation. For example, as Figures 1 and 2 set out, a clear difference can be observed if we compare the wages and the stock of qualifications for individuals with medium and high studies. The existence of this gap indicates that a major part of wage differentials between these two groups is due to other factors apart from the stock of qualifications. This fact is mainly evident in the years before retirement.

Figure 2. Stock of professional qualifications



3.1. Differences in the rate of depreciation

Once we have estimated the depreciation rate for the stock of qualifications, it is interesting to check whether this rate is the same for all individuals or, on the contrary, it changes according to the characteristics of the worker. Authors such as Johnson (1970), Neuman and Weiss (1995), Groot (1998) and Ramírez (2002) point out that the depreciation rate of human capital may vary with the level of education. Nevertheless, there is a lack of consensus in the literature about the sign and the magnitude of this relationship between depreciation and personal educational attributes.

Although it could be thought that human capital accumulated by individuals with higher education depletes at a higher rate than that accumulated by workers with lower levels of education; this may not be the case, provided that the proportion of the human capital accrued by highly educated workers, corresponding to lower levels of education, decays at a lower rate. This line of reasoning implies that it is not evident that we have to observe in practice depreciation rates varying with education. Below, we test, for the Spanish case, whether the level of education is relevant or not in determining the rates of depreciation of human capital.

Authors such as Mincer and Polacheck (1974) and Mincer and Ofek (1982) have highlighted the implications that the interruptions in labor force participation might have on the magnitude of the rate of depletion of human capital. They find that the more continuous the participation, the lower the rate at which capital depreciates. Taking into account this conclusion together with our finding that unemployment spells affect negatively the average wages received by workers, in what follows we will also check the influence of the unemployment status of the individual on the depreciation rate of human capital.

Although there is not direct evidence of the impact of training on depreciation, there exist substantial evidence of the effect of training on workers' wages. For example, Booth (1993) examines the effects of different types of training on earnings and finds that workers reap substantial benefits from training. Her findings show that the training impact is reduced after controlling for endogeneity, however, some types of training nonetheless have a considerable impact on earnings [7]. A possible explanation of this effect is that training restores the human capital lost or diminishes the rate at which it gets eroded. Therefore, in this article we also test the effect of training over depreciation.

To verify the potential variation of the depreciation rate of human capital with the level of education attained by the worker, with the unemployment status of the individual and with the training received by the worker, we re-estimated the model making the depreciation rate to depend on these characteristics. Columns II and III in Table 1 present the results obtained from this re-estimation. The parameter associated with depreciation shows that there is no evidence that the depreciation rate of human capital differs by levels of education. To be precise, the hypothesis of equality of depreciation rates for all the levels of education considered cannot be rejected (p-value=0,29).

Column III (Table 1) shows the results once the restriction of equality in depreciation rates for all education levels has been imposed. As expected, unemployment spells enlarge the depreciation rate of human capital. The depreciation rate for those individuals who have been unemployed at some time in the last five years reaches 2.3 percent, which is remarkably higher than that for those who have been employed during the whole period (1.4 percent). In addition, if the unemployment spell has been long-term the depreciation rate is even higher (4 percent). Therefore, it seems that not only the existence of unemployment spells, but also the length of time of these periods of work inactivity accelerate the erosion of human capital. These results coincide with those obtained by Mincer and Polacheck (1974), Mincer and Ofek (1982), Albrecht *et al.* (1999) and Welch and Ureta (2002), who find that interruptions in labor force participation induce losses in human capital and wages beyond the losses just caused by the non-accumulation of years of experience.

In our data set (see Table 1, column III), those individuals who have received some type of training and have not been unemployed in the last few years, show a depreciation rate of only 0.2 percent; the depreciation rate for those who have endured unemployment spells and have received training is 1.1 percent, and if unemployment was long-term it is of 2.8 percent. To summarize, we can conclude that empirical evidence suggests that when workers receive training, the depreciation rate of human capital diminishes considerably (over 1 percent).

4. Summary of the main conclusions

This paper proposes an empirical model that allows the estimation of the depreciation rate of human capital. In this way, a mode of approach to the study of depreciation, novel in the literature, is presented. The empirical part of the study is a first approximation to an analysis of the depreciation rate in Spain, and although being aware of its limitations, we consider

that the results obtained are of enormous interest. The proposed model was estimated using 1994 data for Spain from ECHP referring to salaried males, and the human capital depreciation rate obtained was around 1 percent annually. It is therefore clear that any analysis of human capital or of the salary evolution of individuals throughout their working life should take into account human capital depreciation.

Furthermore, and unlike what other authors have suggested, it is found that the depreciation rate is the same for all education levels considered. In addition, the depreciation rate is higher for individuals enduring periods of unemployment, and higher still if that unemployment is long-term. However, it has been found that training courses reduce the rate of depreciation of human capital. This fact has significant economic policy implications as it implies that promoting training and vocational courses reduces the decay in knowledge and skills for unemployed and, therefore, compensates wage reductions for re-entrying the labor market. In addition, this paper also confirms that *refresher courses* and *retraining* at the place of work may help to compensate for human capital depletion.

Notes

1. For an overview of this literature see Cohn and Addison (1998) and Card (1999, 2001).
2. An overview of the depreciation literature can be found in De Grip and Van Loo (2002).
3. Ramírez (2002) carries out a similar study for Switzerland.
4. Although the initial stock of professional qualifications in the model was approximated by a 2nd order polynomial, it was tested against the alternative of a 3rd order polynomial, but the parameter associated with the 3rd order term was not significantly different from zero at a 10% significance level. Also, to relax the assumption that, once the individual starts working, I^*_{it} is linear in experience, linearity was tested against the alternative of quadratic in experience, but the linearity of I^*_{it} was not rejected.
5. As there were no significant differences between the parameters of some of these variables, it was proceeded to regroup them in a smaller number of variables (see Appendix I for more information).
6. The average individual for each level of education has been obtained from the sample by evaluating, for each level of education, the dummy variables at their mean.
7. Similar results are obtained in Lengermann (1996).

References

Albrecht, J. W., P. Edin, M. Sundstrom and S. B. Vroman (1999), "Career interruptions and subsequent earnings: a reexamination using Swedish data", *The Journal of Human Resources,* 34 (2): 294-311.

Becker, G. (1964), *Human Capital,* New York: National Bureau of Economic Research.

Ben-Porath, Y. (1967), "The production of human capital and the life cycle of earnings", *Journal of Political Economy,* 75: 352-356.

Booth, A. L. (1993), "Private sector training and graduate earnings", *The Review of Economics and Statistics,* 75 (1): 164-170.

Carliner, G. (1982), "The wages of older men", *The Journal of Human Resources,* XVII (1): 25-38.

Card, D. (1999), "The causal effect of education on earnings", in O. Ashenfelter and D. Card, *Handbook of Labor Economics,* 3: 1801-1863, Amsterdam: North-Holland.

Card, D. (2001), "Estimating the return to schooling: progress on some persistent econometric problems", *Econometrica,* 69 (5): 1127-1160.

Cohn, E., and J. T. Addison (1998), "The economic returns to lifelong learning in OECD countries", *Education Economics,* 6 (3): 253-307.

De Grip, A. and J. Van Loo (2002), "The economics of Skills Obsolescence: a Review", in De Grip, A., J. Van Loo and K. Mayhew, *Research in Labor Economics,* 21: 1-25.

Groot, W. (1998), "Empirical estimates of the rate of depreciation of education", *Applied Economics Letters,* 5: 535-538.

Haley, W. (1976), "Estimation of the earnings profile from optimal human capital accumulation", *Econometrica,* 44 (6): 1223-1238.

Heckman, J. (1976), "A life-cycle model of earnings, learning, and consumption", *Journal of Political Economy,* 84 (4): S11-S44.

Jacobson, L., R. J. LaLonde and D. G. Sullivan (1993), "Earnings losses of displaced workers", *American Economic Review,* 83 (4): 685-709.

Johnson, T. (1970), "Returns from investment in human capital", *American Economic Review,* 60: 546-560.

Johnson, T. and F. Hebein (1974), "Investment in human capital and growth of personal income 1956-1966", *American Economic Review,* 64 (4): 604-615.

Lengermann, P. A. (1996), "The benefits and costs of training: a comparison of formal company training, vendor training, outside seminars, and school based training", *Human Resource Management,* 35 (3): 361-381.

Mincer, J. (1974), *Schooling, experience and earnings,* New York: National Bureau of Economic Research.

Mincer, J. and S. Polachek (1974), "Family investments in human capital: earnings of women", *Journal of Political Economy,* 82: S76-S108.

Mincer, J. and H. Ofek (1982), "Interrupted work careers: depreciation and restoration of human capital", *The Journal of Human Resources,* XVII (1): 3-24.

Neuman, S. and A. Weiss (1995), "On the effects of schooling vintage on experience-earnings profiles: theory and evidence", *European Economic Review,* 39: 943-955.

Ramírez, J. (2002), "Age and schooling vintage effects on earnings profiles in Switzerland", in De Grip, A., J. Van Loo and K. Mayhew, *Research in Labor Economics,* 21: 83-99.

Rosen, S. (1976), "A theory of life earnings", *Journal of Political Economy,* 84 (4): S45-S67.

White, H. (1980), "A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity", *Econometrica,* 48: 817-838.

Welch, F. and M. Ureta (2002), "The Obsolescence of Skill", in De Grip, A., J. Van Loo and K. Mayhew, *Research in Labor Economics,* 21: 51-81.

Resumen

En este artículo se propone un modelo empírico de determinación salarial que permite identificar la tasa de depreciación del *stock* de cualificaciones de un individuo. Las estimaciones del modelo se realizan empleando datos de hombres asalariados españoles procedentes del Panel de Hogares de la Unión Europea para el año 1994. La tasa de depreciación estimada está alrededor del 1 por 100. Además la evidencia empírica sugiere que dicha tasa no varía por niveles educativos aunque sí que parece depender de si el individuo ha sufrido episodios de desempleo y de si ha seguido cursos de formación.

Palabras clave: capital humano, depreciación, perfiles salariales.

Clasificación JEL: J24, J31.

Appendix I: Description of variables

Taking as a starting point the information in the European Community Household Panel (ECHP), the variables used in the analysis are the following:

1) **Gross hourly-wage expressed in 1994 euros.** This variable is not available as such in ECHP, so that it was necessary to structure it from gross monthly salaries and hours worked which the cited survey does supply. In fact, the gross monthly salary found in ECHP was divided into the number of hours worked monthly, obtained by multiplying the weekly hours appearing in ECHP by 4.3452 (the approximate number of weeks in a month). It should also be pointed out that all the possible jobs held by each individual were taken into account.

2) **Level of study completed by individuals.** ECHP supplies information about the maximum level of studies completed by individuals. With this information, we have set up a variable that aimed to include the number of years of study: four for individuals with primary studies, eight for individuals with basic studies, twelve for those with medium grade studies, and sixteen for those with advanced studies.

3) **Experience.** This variable was set up by computing the difference between the individuals' age and the age at which they started working.

4) **Other characteristics of the individual.** ECHP supplies information on numerous characteristics of individuals. The following variables were considered:

— **Size of the firm.** Three possible sizes were considered: Small (under 50 employees), Medium (between 50 and 500 employees) and Large (over 500 employees).

— **Unemployment situation in the past five years.** This variable takes on a value of 1 for those individuals who have endured a period of unemployment in the past five years, and 0 if they have not.

— **Long-term unemployment.** This variable takes on a value of 1 for those individuals who have endured a period of unemployment in the past five years and which was long-term (over 1 year), and 0 otherwise.

— **Productive Sector in which the individual works.** At first, the following sectors were considered: Services, Household, Agriculture and Fishery, Building, Transport, Financial, Information Technology, Energy, Commerce and Industry. As there were no significant differences between the parameters associated with some of these variables, the sectors were reorganized in the final model as: Household, Agriculture and Fishery, Finances and Energy, and the remainder.

— **Region of residence.** At first, the seven regions included in the database were considered: the Canary Isles, Central Spain (Castile and Leon, Castile La Mancha and Extremadura), the North West (Galicia, Asturias and Cantabria), the North East (the Basque Country, Navarra, Rioja and Aragon), Madrid, the East (Catalonia, Valencia and the Balearic Isles) and the South (Andalusia and Murcia). As there were no significant differences between the average wage of some of these regions, they were regrouped in: Northwest and Madrid, the East, the South, and the remainder.

— **Professional status of the individual.** The nine large professional groups in ECHP were considered: Managers, Scientists and intellectuals, Technicians, Administrative staff, Sales people, Farmers, Qualified Workers, Qualified Machine operators, Unqualified workers. These categories were finally regrouped as: Managerial and Professional staff, Technicians, Administrative staff, Qualified workers, and the remainder.

— **Marital status:** A variable was set up with a value of 1 for those individuals who were married and 0 for those who were not.

— **Training:** A variable was set up with a value of 1 for those individuals who received any education or training in 1993.

Appendix II: Descriptive statistics

	Hourly wage (euros)		Experience (years)		Training (% individuals)		Number of individuals
	Mean	Standad Error	Mean	Standard Error	Yes	No	
Educational levels:							
Primary	4.529	1.889	26.567	12.348	4.7	95.3	508
Basic	4.973	2.625	18.339	11.961	15.1	84.5	410
Medium	6.762	4.328	16.256	10.355	24.4	75.6	172
Advanced	8.184	5.649	15.907	10.634	42.5	57.5	280
Total	5.689	3.781	20.631	12.541	18.0	82.0	1.370