The Dynamic Mincer Equation: Evidence and Theory

Corrado Andini [a b c]

[a] Universidade da Madeira, 9000-390 Funchal, Portugal
[b] CEEAplA, 9501-801 Ponta Delgada, Portugal
[c] IZA, D-53072 Bonn, Germany

ABSTRACT

The standard human-capital model is based on the assumption that earnings instantaneously adjust to human-capital productivity. We argue that this assumption is rejected by the ECHP data, and provide a theoretical interpretation of this empirical result. Both evidence and theory support a dynamic approach to the Mincer equation.

Keywords: Mincer Equation, Wages, Human Capital.
JEL codes: I21, J31.

Corresponding address:
Corrado Andini, Universidade da Madeira, 9000-390 Funchal, Portugal.
Tel: +351 291 70 50 53 Fax: +351 291 70 50 40 E-mail: andini@uma.pt

1. Introduction

In the standard human-capital model proposed by Mincer (1974), the logarithm of the hourly observed earnings of an individual is explained by schooling years, potential labor-market experience and experience squared. This section presents the theoretical foundations of the standard Mincerian equation as recently reported by Heckman et al. (2003). Therefore, we make no claim of originality at this stage and mainly aim at helping the reader with notations and terminology adopted in the next sections.

Mincer argues that potential earnings today depend on investments in human capital made yesterday. Denoting potential earnings at time t as E_t, Mincer assumes that an individual invests in human capital a share k_t of his/her potential earnings with a return of r_t in each period t. Therefore we have:

(1) $$E_{t+1} = E_t(1 + r_t k_t)$$

which, after repeated substitution, becomes:

(2) $$E_t = \prod_{j=0}^{t-1}(1 + r_j k_j)E_0$$

or alternatively:

(3) $$\ln E_t = \ln E_0 + \sum_{j=0}^{t-1}\ln(1 + r_j k_j) .$$

Under the assumptions that:

- schooling is the number of years s spent in full-time investment ($k_0 = ... = k_{s-1} = 1$),
- the return to schooling in terms of potential earnings is constant over time ($r_0 = ... = r_{s-1} = \beta$),
- the return to the post-schooling investment in terms of potential earnings is constant over time ($r_s = ... = r_{t-1} = \lambda$),

we can write expression (3) in the following manner:

(4) $$\ln E_t = \ln E_0 + s\ln(1 + \beta) + \sum_{j=s}^{t-1}\ln(1 + \lambda k_j)$$

which yields:

(5) $$\ln E_t \approx \ln E_0 + \beta s + \lambda\sum_{j=s}^{t-1}k_j$$

for small values of β, λ and k [1].

In order to build up a link between potential earnings and labor-market experience z, Mincer assumes that the post-schooling investment linearly decreases over time, that is:

$$(6) \qquad k_{s+z} = \eta\left(1 - \frac{z}{T}\right)$$

where $z = t - s \geq 0$, T is the last year of the working life and $\eta \in (0,1)$.

Therefore, using (6), we can re-arrange expression (5) and get:

$$(7) \qquad \ln E_t \approx \ln E_0 - \eta\lambda + \beta s + \left(\eta\lambda + \frac{\eta\lambda}{2T}\right)z - \left(\frac{\eta\lambda}{2T}\right)z^2 .$$

Then, by subtracting (6) from (7), we obtain an expression for net potential earnings, i.e. potential earnings net of post-schooling investment costs:

$$(8) \qquad \ln E_t - \eta\left(1 - \frac{z}{T}\right) \approx \ln E_0 - \eta\lambda - \eta + \beta s + \left(\eta\lambda + \frac{\eta\lambda}{2T} + \frac{\eta}{T}\right)z - \left(\frac{\eta\lambda}{2T}\right)z^2$$

which can also be written as:

$$(9) \qquad \ln npe_t \approx \alpha + \beta s + \delta z + \phi z^2$$

where $\ln npe_t = \ln E_t - \eta\left(1 - \frac{z}{T}\right)$, $\alpha = \ln E_0 - \eta\lambda - \eta$, $\delta = \eta\lambda + \frac{\eta\lambda}{2T} + \frac{\eta}{T}$ and $\phi = -\frac{\eta\lambda}{2T}$.

Finally, assuming that observed earnings are equal to net potential earnings at any time t (a key-assumption, as argued in the next section):

$$(10) \qquad \ln w_t = \ln npe_t$$

and, using expression (9), we get the standard Mincer equation:

$$(11) \qquad \ln w_t \approx \alpha + \beta s + \delta z + \phi z^2 .$$

2. Evidence: adjustment model

Following Heckman et al. (2003), the standard Mincerian framework seems to be characterized by two main features. First, it provides an explanation why the logarithm of the net potential earnings of an individual at time $t = s + z$ can be approximately represented as a function of s and z, i.e. expression (9). Second, it is based on the *assumption* that, at any time $t \geq s$, the logarithm of the observed earnings of an individual is equal to the monetary value of the individual net human-capital productivity, measured by his/her net potential earnings, i.e. assumption (10).

This paper does not question expression (9) and focuses on assumption (10). On the lines of Flannery and Rangan (2006), we argue that assumption (10) can be replaced by

[1] Note that the symbol of equality $(=)$ in expression (4) becomes a symbol of rough equality $(\approx)$ in expression (5). It happens because, if x is closed to zero, then $\ln(1 + x) \approx x$.

a more flexible assumption. Particularly, observed earnings can be seen as dynamically adjusting to net potential earnings, according to the following simple adjustment model:

$$(12) \qquad \ln w_t - \ln w_{t-1} = \rho(\ln npe_t - \ln w_{t-1})$$

where $\rho \in [0,1]$ measures the speed of adjustment.
If $\rho = 1$, then assumption (10) holds, the speed of adjustment is maximum, observed earnings instantaneously adjust to net potential earnings, and the standard Mincerian model (11) holds. If instead $\rho = 0$, then observed earnings are constant over time and do not adjust at all to variations of net potential earnings. In general, when the speed of adjustment is neither null nor maximum, replacing expression (9) into (12) gives:

$$(13) \qquad \ln w_t \approx (1-\rho)\ln w_{t-1} + \rho\left(\alpha + \beta s + \delta z + \phi z^2\right)$$

or alternatively:

$$(14) \qquad \ln w_t \approx \upsilon_0 + \upsilon_1 \ln w_{t-1} + \upsilon_2 s + \upsilon_3 z + \upsilon_4 z^2$$

where $\upsilon_0 = \rho\alpha$, $\upsilon_1 = 1-\rho$, $\upsilon_2 = \rho\beta$, $\upsilon_3 = \rho\delta$ and $\upsilon_4 = \rho\phi$.
Expression (14) is a dynamic version of the Mincer equation. Note that, when individual-level *longitudinal* data are available, the complement to one of the speed of adjustment $(1-\rho)$ can be estimated and the theory underlying (14) can be tested. The main requirement for the theory to be consistent with the data is to find that the coefficient υ_1 is significantly different from zero.
The Appendix presents estimates based on model (14). We use the ordinary-least-squares estimator to explore 1994-2001 data on male workers (aged between 15 and 65) from the European Community Household Panel (ECHP). Figure 1 uses the Appendix estimates to provide measures of the speed of adjustment in 13 countries.
The main empirical result is that observed earnings do not instantaneously adjust to human-capital productivity (net potential earnings) since no one country has a speed of adjustment either equal or closed to one. Hence, assumption (10) in the standard Mincerian model is rejected by the ECHP data.
As one would reasonably expect, due to different labor-market institutions, the speed of adjustment of observed hourly wages to human-capital productivity is heterogeneous across European countries. Particularly, Finland is the country with the highest speed of adjustment, while Luxemburg is the country with the lowest speed.
Since the dynamic Mincer equation seems robust on the empirical ground, the next step consists of discussing its possible theoretical foundations. Specifically, the next section shows that a dynamic Mincer equation (14) can be obtained as the solution of a simple employer-employee wage bargaining model.

3. Theory: bargaining model

From a theoretical point of view, assumption (10) fits within the perfect-competition framework where the nominal wage equals the monetary value of the marginal labor productivity. However, if one believes that the imperfect-competition framework is a more realistic view of the labor market[2], then *several* arguments can support the

[2] A general reference is the New Keynesian view of the labor market.

statement that assumption (10) is unlikely to hold. This manuscript focuses on *one* of the possible arguments: the existence of wage bargaining at employer-employee level. Additional arguments (asymmetric information, role of unions and efficiency wages) are briefly discussed in the last section of this paper.

The standard Mincerian model puts too much emphasis on the supply side: the more an individual invests in his/her human-capital development, the higher his/her wage is. The model that is presented in this section aims at enhancing the role played by demand factors in determining wages, without diminishing the one played by supply factors. More explicitly, the argument is that schooling and post-schooling investments provide individuals with *net potential* earnings, meaning skills required to earn a given amount of money. However, *observed* earnings are likely to be the result of both employee's skills (supply) and employer's willingness to pay (demand). Since real-life labor markets are characterized by wage bargaining, the possibility of a margin-formation between observed earnings and net potential earnings should not be ruled out a-priori. This implies that observed earnings may not coincide with net potential earnings, although the former generally depend on the latter.

As additional feature, the model keeps into account the stylized fact that observed earnings exhibit path-dependence. To the best of our knowledge, this feature is novel because the existing (micro and macro) evidence on the autoregressive nature of observed earnings[3] has not received attention in Mincerian studies so far.

To anticipate the model's conclusion, current observed earnings are shown to be dependent on both past observed earnings and current net potential earnings.

Let us assume that the logarithm of the observed earnings of an employee arises from a simple, decentralized Nash bargaining between an employee and an employer and that:

- Employee objective function: the employee maximizes his/her observed earnings at time t[4], namely the employee maximizes $U_t^{\text{employee}} = \ln w_t$;

- Employer objective function: the employer maximizes the difference between the monetary value of the employee's net productivity at time t and the salary that he/she has to pay to the employee, namely the employer maximizes $U_t^{\text{employer}} = \ln npe_t - \ln w_t$;

- Employee outside option: if bargaining fails, the outside option for the employee is the unemployment benefit at time t, i.e. $\tilde{U}_t^{\text{employee}} = \ln b_t$;

- Employer outside option: if bargaining fails, the outside option for the employer is $\tilde{U}_t^{\text{employer}} = 0$ because the employer neither gets the monetary value of the employee's net productivity nor pays a salary;

- Nash bargaining function: the Nash bargaining function has a Cobb-Douglas specification, i.e. $U_t = (U_t^{\text{employee}} - \tilde{U}_t^{\text{employee}})^{\rho}(U_t^{\text{employer}} - \tilde{U}_t^{\text{employer}})^{1-\rho}$.

As usual in the literature, the coefficient $\rho \in [0,1]$ in the Nash bargaining function is interpreted as the bargaining power of the employee, while $1-\rho$ is the bargaining

[3] See Taylor (1999) for a good survey.

[4] Note that both observed and net potential earnings must be measured in logarithms to be consistent with the Mincerian assumption (10).

power of the employer. The reason why the bargaining power of the employee is labeled in the same way as the speed of adjustment is clarified at the end of this section.

Following common practice, let us further assume that the unemployment benefit at time t is calculated as a share of the salary of the employee at time $t-1$, i.e. $b_t = \lambda w_{t-1}$ where $\lambda \in (0,1)$ is the so-called replacement rate. Note that this assumption is important because it introduces the lagged observed wage into the model.

The solution of the employer-employee bargaining problem provides the following first-order condition:

$$(15) \qquad \frac{\rho}{\ln w_t - \ln\lambda - \ln w_{t-1}} = \frac{1-\rho}{\ln npe_t - \ln w_t}$$

which, in turn, yields:

$$(16) \qquad \ln w_t = (1-\rho)\ln\lambda + (1-\rho)\ln w_{t-1} + \rho \ln npe_t$$

Hence, if the employee has full bargaining power ($\rho = 1$), then expression (16) becomes expression (10) and the standard Mincerian model holds. Intuitively, only when the employee has full bargaining power, he/she is actually able to earn all his/her net potential earnings. In this case, the employer is indifferent between employing and not employing because $U_t^{employer} = \tilde{U}_t^{employer} = 0$.

On the other hand, if the employee has zero bargaining power ($\rho = 0$), then expression (16) implies $\ln w_t = \ln\lambda + \ln w_{t-1}$ which, in turn, implies $\ln w_t = \ln \lambda w_{t-1} = \ln ub_t$. In this case, the employee is indifferent between working and being unemployed because $U_t^{employee} = \tilde{U}_t^{employee}$.

In general, when the bargaining power of the employee is neither null nor full ($0 < \rho < 1$), replacing expression (9) into (16) yields:

$$(17) \qquad \ln w_t \approx (1-\rho)\ln\lambda + (1-\rho)\ln w_{t-1} + \rho\left(\alpha + \beta s + \delta z + \phi z^2\right)$$

or alternatively:

$$(18) \qquad \ln w_t \approx \tau + \upsilon_0 + \upsilon_1 \ln w_{t-1} + \upsilon_2 s + \upsilon_3 z + \upsilon_4 z^2$$

where $\tau = (1-\rho)\ln\lambda$ and the υ coefficients are defined as in section 2.

Note that, when the replacement rate λ equals to one, model (18) and model (14) perfectly match. Therefore, the bargaining power of the employee can be interpreted as a proxy of the speed of adjustment and vice-versa. Specifically, the fact that the speed is far from being one indicates that the bargaining power of the employee is far from being full and vice-versa.

4. Implications for the schooling return

This section shows that a dynamic version of the Mincer equation implies that the return to schooling in terms of observed earnings is not independent of labor-market experience. This result is consistent with recent empirical evidence provided by Heckman et. al. (2005). In addition, it is shown that the return to schooling in terms of net potential earnings, provided by the standard Mincer equation, can also be computed using its dynamic version.

4.1 Static return to schooling in terms of net potential earnings

To begin, we find of interest stressing that the total return to schooling in the static model (11) is given by the following expression:

$$(19) \qquad \frac{\partial \ln w_t}{\partial s} = \frac{\partial \ln w_{s+z}}{\partial s} \approx \beta$$

and is constant over the working life, meaning independent of labor-market experience z. Further, because of assumption (10), the return to schooling in terms of observed earnings and the one in terms of net potential earnings coincide[5].

We label β as static return to schooling in terms of net potential earnings and show, in subsection 4.3, that our interpretation of β in terms of *net potential* rather than *observed* earnings is the most appropriate.

4.2 Returns to schooling in terms of observed earnings

The dynamic model (14) allows obtaining the evolution of the schooling return over the entire working life. For instance, at time s, expression (14) can be written as follows:

$$(20) \qquad \ln w_s \approx \rho\alpha + (1-\rho)\ln \overline{w}_{s-1} + \rho\beta s + \rho\delta 0 + \rho\phi 0^2$$

where $\overline{w}_{s-1}$ is the minimum wage at time $s-1$, assumed to be independent of schooling years. Therefore, the return to schooling, at time s (i.e. when an individual enters the labor market), is given by:

$$(21) \qquad \beta(0) = \frac{\partial \ln w_s}{\partial s} \approx \rho\beta .$$

Analogously, at time $s+1$, expression (14) can be written as follows:

$$(22) \qquad \ln w_{s+1} \approx \rho\alpha + (1-\rho)\ln w_s + \rho\beta s + \rho\delta 1 + \rho\phi 1^2$$

and the total return to schooling is given by:

$$(23) \qquad \beta(1) = \frac{\partial \ln w_{s+1}}{\partial s} \approx \rho\beta + \rho\beta(1-\rho) .$$

At time $s+2$, expression (14) is as follows:

$$(24) \qquad \ln w_{s+2} \approx \rho\alpha + (1-\rho)\ln w_{s+1} + \rho\beta s + \rho\delta 2 + \rho\phi 2^2$$

and the total return to schooling is given by:

$$(25) \qquad \beta(2) = \frac{\partial \ln w_{s+2}}{\partial s} \approx \rho\beta + \rho\beta(1-\rho) + \rho\beta(1-\rho)^2 .$$

[5] See expression (9).

Therefore, at time $s+z$, the return to schooling in terms of observed earnings is given by the following expression:

$$(26) \qquad \beta(z) = \frac{\partial \ln w_{s+z}}{\partial s} \approx \rho\beta\left[1+(1-\rho)+(1-\rho)^2+(1-\rho)^3+....+(1-\rho)^Z\right],$$

and is, in general, dependent of labor-market experience z.
Clearly, at the end of the working life, the total return in terms of observed earnings is as follows:

$$(27) \qquad \beta(T) = \frac{\partial \ln w_{s+T}}{\partial s} \approx \rho\beta\left[1+(1-\rho)+(1-\rho)^2+(1-\rho)^3+....+(1-\rho)^T\right].$$

4.3 Dynamic return to schooling in terms of net potential earnings

The return in expression (26) is, in general, lower than the return in expression (19), although the first converges to the latter as labor-market experience z increases. Indeed, for a value of $\rho \in (0,1)$, the following expression holds:

$$(28) \qquad \beta(\infty) = \lim_{z\to\infty} \beta(z) \approx \rho\beta\left[\frac{1}{1-(1-\rho)}\right].$$

Therefore, the dynamic model (14) is able to provide a measure of β comparable[6] with expression (19). We label $\beta(\infty)$ as dynamic return to schooling in terms of net potential earnings.
Expression (28) helps to show that our interpretation of β in terms of *net potential* rather than *observed* earnings is the most appropriate because nobody can live and work forever. To the extent of T being a finite number, the return to schooling in terms of observed earnings $\beta(z)$ can never be equal to β, but in the very special case of $\rho = 1$.

4.4 Final remarks

It is easy to prove that the following inequalities hold:

$$(29) \qquad \beta(0) < \beta(z) < \beta(T) < \beta$$

for every z and T such that $0 < z < T < \infty$ and $\beta > 0$, if $\rho \in (0,1)$.
In addition, one can verify that:

$$(30) \qquad \beta(0) = \beta(z) = \beta(T) = 0 < \beta$$

for every z and T such that $0 < z < T < \infty$ and $\beta > 0$, if $\rho = 0$.
Finally, it is easy to show that:

$$(31) \qquad \beta(0) = \beta(z) = \beta(T) = \beta$$

[6] Notice that $\rho\beta\left[\frac{1}{1-(1-\rho)}\right] = \beta$.

for every z and T such that $0 < z < T < \infty$ and $\beta > 0$, if $\rho = 1$.

4.5 Example

As a matter of example, we use expression (26) to compute returns to schooling in terms of observed earnings using Appendix estimates. Particularly, we consider two extreme cases: the country with the highest estimated adjustment speed, Finland, and the country with the lowest speed, Luxemburg. As shown in Figure 2 (the horizontal axis measures potential labor-market experience), at the beginning of the working life, for individuals with the same observed characteristics, the return to schooling is higher in Finland than in Luxemburg, while the converse happens at the end of the working life. Note that a standard Mincerian model cannot capture these dynamics and *overestimates* the observed-wage return to schooling, particularly at the beginning of the working life.

5. Conclusions

A seminal work by Mincer (1974) has been the starting point of a large body of literature dealing with the estimation of a wage equation where the hourly-wage logarithm is explained by schooling years, potential labor-market experience, and experience squared. Within this framework, the coefficient of schooling years is usually interpreted as being the return to an additional year of schooling in terms of *observed* earnings.

An excellent synthesis of the research papers adopting the Mincer equation as underlying framework has been provided by Card (1999). The reviewed works generally focused on the estimation of the *average* impact of schooling on earnings, by means of both ordinary least squares and instrumental-variable techniques.

Today, 'the state of the art' described by Card looks outdated. This is partly because the last decade was characterized by a special interest in adopting the Mincer equation for identifying the effect of schooling not only on the mean but also on the *shape* of the conditional wage distribution, using the quantile-regression techniques due to Koenker and Bassett (1978). Starting from a seminal work by Buchinsky (1994), the last few years saw the publication of numerous estimates of the schooling-coefficient along the conditional wage distribution, with the frequent finding that education has a positive impact on within-groups wage inequality, as suggested by Martins and Pereira (2004) among others. Additional results using instrumental-variable-quantile-regression techniques have been provided by Arias et al. (2001), Chernozhukov and Hansen (2006), Lee (2007) and Andini (2008).

In spite of its wide acceptance within the profession, the spread of the framework developed by Mincer over the last forty years has not been uncontroversial. Some authors criticized the Mincerian framework by arguing that the equation is not able to provide a good fit of empirical data; some stressed that the average effect of schooling on earnings is likely to be non-linear in schooling; some suggested that education levels should replace schooling years in the wage equation. For instance, Murphy and Welch (1990) maintained that the standard Mincer equation provides a very poor approximation of the true empirical relationship between earnings and experience, while Trostel (2005) argued that the average impact of an additional year of schooling on earnings varies with the number of completed schooling-years.

In summary, despite some critical voices, the history of human-capital regressions seems characterized by a generalized attempt of *consistently* estimating the coefficient of schooling (both on average and along the conditional wage distribution), under an implicit acceptance of the theoretical interpretation of the schooling-coefficient itself. Nevertheless, the important issue of the theoretical interpretation of the schooling-coefficient has been recently rediscovered and discussed by Heckman et al. (2005), who empirically tested several implications of the classical Mincerian framework, using Census data for the United States. Among other implications of the Mincerian approach, the authors tested and often rejected the implication that the return to schooling in terms of observed earnings is *independent* of labor-market experience.

On the lines of Heckman *et al.* (2005), our paper has provided additional theoretical and empirical arguments against the usual interpretation of the coefficient of schooling in the standard Mincer equation. Indeed, we have argued that the return to schooling in terms of observed earnings is, in general, *dependent* of labor-market experience. As shown, the latter result can be easily derived from a dynamic specification of the Mincer equation where past observed earnings contribute to explain current observed earnings.

To conclude, it is worth stressing that this paper does not claim for generality. Clearly, the theoretical model in section 3 holds under a set of specific assumptions. The main issue, at this point, is whether these assumptions bring us closer to reality (enhanced role of demand factors in determining wages) or not. In any case, there seems to be substantial empirical evidence supporting the argument that past observed earnings, *together with* accumulated human capital (schooling and post-schooling investments), play an important role in explaining current observed earnings. This finding should open the door to new research effort looking for alternative, and perhaps more general, micro-foundations of a dynamic Mincer equation. Issues related to asymmetric information (for instance, the case where the employer does not observe the net potential earnings of the employee), role of unions (wage bargaining at collective level and insider-outsider considerations) and efficiency wages (the employer cannot observe the employee's effort) are interesting topics for future investigation.

References

Andini C. (2008) The Total Impact of Schooling on Within-Groups Wage Inequality in Portugal, *Applied Economics Letters*, 15(2), 85-90.

Arias O., Hallock K.F., Sosa-Escudero W. (2001) Individual Heterogeneity in the Returns to Schooling: Instrumental Variables Quantile Regression Using Twins Data, *Empirical Economics*, 26(1), 7-40.

Buchinsky M. (1994) Changes in the U.S. Wage Structure 1963-1987: Application of Quantile Regression, *Econometrica*, 62(2), 405-458.

Card D. (1999) The Causal Effect of Education on Earnings, in: Ashenfelter O., Card D. (Eds.) *Handbook of Labor Economics*, New York, North-Holland.

Chernozhukov V., Hansen C. (2006) Instrumental Quantile Regression Inference for Structural and Treatment Effect Models, *Journal of Econometrics*, 132(2), 491-525.

Flannery M.J., Rangan K.P. (2006) Partial Adjustment toward Target Capital Structures, *Journal of Financial Economics*, 79(3), 469-506.

Heckman J.J, Lochner L.J., Todd P.E. (2003) Fifty Years of Mincer Earnings Regressions, *NBER Working Papers*, nº 9732, National Bureau of Economic Research, May.

Heckman J.J., Lochner L.J., Todd P.E. (2005) Earnings Functions, Rates of Return, and Treatment Effects: the Mincer Equation and Beyond, *NBER Working Papers*, nº 11544, National Bureau of Economic Research, August.

Koenker R., Bassett G. (1978) Regression Quantiles, *Econometrica*, 46(1), 33-50.

Lee S. (2007) Endogeneity in Quantile Regresssion Models: A Control Function Approach, *Journal of Econometrics*, 141(2), 1131-1158.

Martins P.S., Pereira P.T. (2004) Does Education Reduce Wage Inequality? Quantile Regression Evidence from 16 Countries, *Labour Economics*, 11(3), 355-371.

Mincer J. (1974) *Schooling, Experience and Earnings*, Cambridge MA, National Bureau of Economic Research.

Murphy K.M., Welch F. (1990) Empirical Age-Earnings Profiles, *Journal of Labor Economics*, 8(2), 202-229.

Taylor J.B. (1999) Staggered Price and Wage Setting in Macroeconomics, in: Taylor J.B, Woodford M. (Eds.) *Handbook of Macroeconomics*, New York, North-Holland.

Trostel P.A. (2005) Nonlinearity in the Return to Education, *Journal of Applied Economics*, 8(1), 191-202.

Figure 1. Speed of adjustment in 13 countries

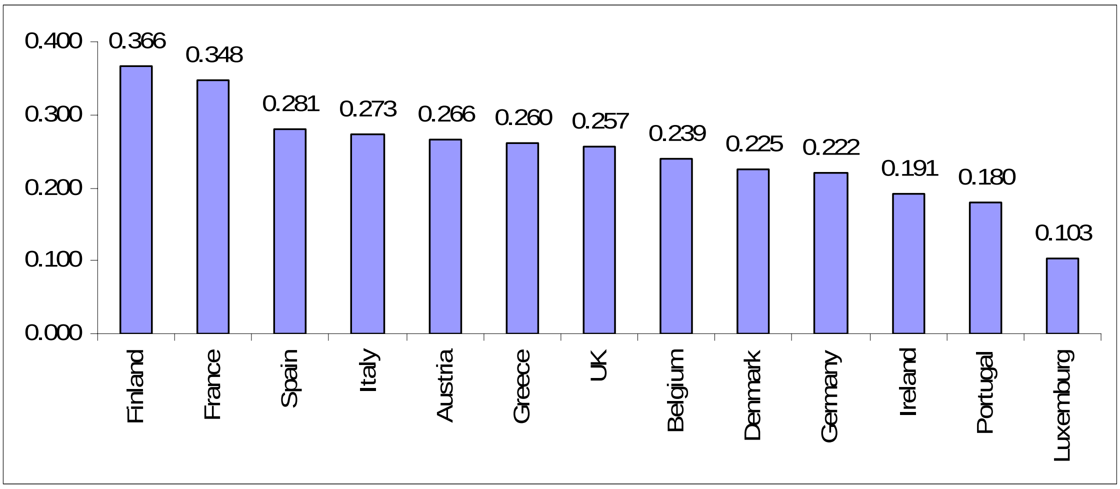
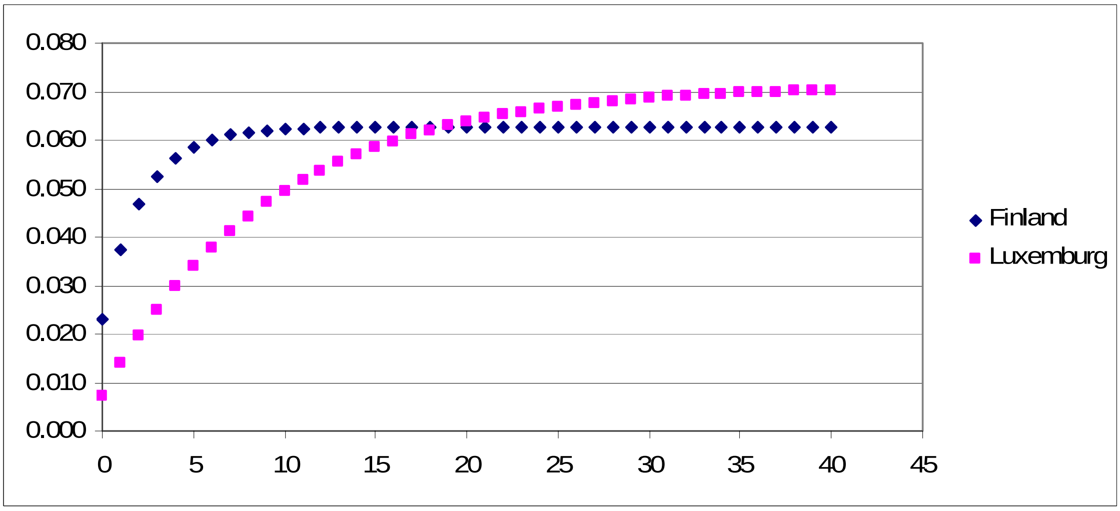


Figure 2. Returns to schooling in terms of observed earnings



APPENDIX

United Kingdom

Linear regression

Number of obs	=	1673
F(4, 1668)	=	619.07
Prob > F	=	0.0000
R-squared	=	0.7595
Root MSE	=	.25787

lnw	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnw(-1)	.7426604	.0355119	20.91	0.000	.6730078	.8123129
s	.0219434	.0040531	5.41	0.000	.0139937	.0298931
z	.0072357	.0033551	2.16	0.031	.0006551	.0138163
z2	-.0001402	.0000618	-2.27	0.023	-.0002615	-.000019
_cons	.2285857	.0434871	5.26	0.000	.1432905	.3138808

Germany

Linear regression

Number of obs	=	1433
F(4, 1428)	=	861.16
Prob > F	=	0.0000
R-squared	=	0.8216
Root MSE	=	.26761

lnw	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnw(-1)	.7785949	.0228916	34.01	0.000	.7336901	.8234998
s	.0122567	.0017606	6.96	0.000	.0088031	.0157103
z	.0130776	.0030054	4.35	0.000	.0071822	.018973
z2	-.0002529	.0000609	-4.16	0.000	-.0003723	-.0001335
_cons	.4648309	.0511591	9.09	0.000	.3644759	.5651859

Denmark

Linear regression

Number of obs	=	1234
F(4, 1229)	=	275.83
Prob > F	=	0.0000
R-squared	=	0.7499
Root MSE	=	.24092

lnw	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnw(-1)	.775379	.0541923	14.31	0.000	.6690593	.8816986
s	.0089663	.0023441	3.83	0.000	.0043674	.0135651
z	.0012549	.0030144	0.42	0.677	-.0046591	.0071689
z2	-4.95e-06	.0000569	-0.09	0.931	-.0001166	.0001067
_cons	.991846	.2197059	4.51	0.000	.5608058	1.422886

Belgium

Linear regression

Number of obs	=	4788
F(4, 4783)	=	1305.35
Prob > F	=	0.0000
R-squared	=	0.7329
Root MSE	=	.21003

lnw	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnw(-1)	.7610172	.0222499	34.20	0.000	.7173971	.8046373
s	.0153309	.0016627	9.22	0.000	.0120713	.0185905
z	.0055855	.001611	3.47	0.001	.0024271	.0087439
z2	-.0000521	.0000335	-1.55	0.121	-.0001178	.0000137
_cons	1.223899	.1104141	11.08	0.000	1.007437	1.440361

France

Linear regression

Number of obs	= 4657
F(4, 4652)	= 1057.52
Prob > F	= 0.0000
R-squared	= 0.6111
Root MSE	= .2867

lnw	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnw(-1)	.6525568	.0211769	30.81	0.000	.6110399	.6940736
s	.0319533	.002397	13.33	0.000	.027254	.0366526
z	.0098967	.0018987	5.21	0.000	.0061745	.013619
z2	-.0001061	.0000401	-2.65	0.008	-.0001847	-.0000276
_cons	.8963042	.0614445	14.59	0.000	.7758438	1.016765

Ireland

Linear regression

Number of obs	= 4847
F(4, 4842)	= 2426.24
Prob > F	= 0.0000
R-squared	= 0.7549
Root MSE	= .28876

lnw	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnw(-1)	.8087401	.0121514	66.56	0.000	.7849177	.8325624
s	.0166225	.0021214	7.84	0.000	.0124635	.0207814
z	-.0002701	.0014011	-0.19	0.847	-.0030168	.0024767
z2	.0000276	.0000287	0.96	0.336	-.0000286	.0000838
_cons	.2397471	.0243078	9.86	0.000	.1920927	.2874015

Italy

Linear regression

Number of obs	= 12535
F(4, 12530)	= 3730.64
Prob > F	= 0.0000
R-squared	= 0.7001
Root MSE	= .20755

lnw	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnw(-1)	.7269337	.0096548	75.29	0.000	.7080087	.7458586
s	.0132013	.000689	19.16	0.000	.0118508	.0145518
z	.0070246	.0006799	10.33	0.000	.0056919	.0083573
z2	-.0001082	.0000151	-7.15	0.000	-.0001378	-.0000785
_cons	.5389731	.0201063	26.81	0.000	.4995616	.5783847

Greece

Linear regression

Number of obs	= 6836
F(4, 6831)	= 2709.31
Prob > F	= 0.0000
R-squared	= 0.7076
Root MSE	= .26512

lnw	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnw(-1)	.7398625	.0107062	69.11	0.000	.7188751	.7608499
s	.0168643	.0010021	16.83	0.000	.0149	.0188287
z	.0107335	.0012147	8.84	0.000	.0083522	.0131147
z2	-.0001779	.0000275	-6.47	0.000	-.0002318	-.000124
_cons	1.669132	.0679651	24.56	0.000	1.535899	1.802365

Spain

Linear regression

Number of obs	8848
F(4, 8843)	3799.60
Prob > F	0.0000
R-squared	0.7094
Root MSE	.27661

lnw	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnw(-1)	.7187288	.0101682	70.68	0.000	.6987967	.7386609
s	.0216141	.0011892	18.17	0.000	.0192829	.0239453
z	.0066541	.0010584	6.29	0.000	.0045795	.0087287
z2	-.0000685	.0000219	-3.13	0.002	-.0001114	-.0000256
_cons	1.678863	.0577148	29.09	0.000	1.565728	1.791997

Portugal

Linear regression

Number of obs	10186
F(4, 10181)	4101.48
Prob > F	0.0000
R-squared	0.7881
Root MSE	.22868

lnw	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnw(-1)	.8198847	.0144355	56.80	0.000	.7915882	.8481812
s	.0139634	.0014443	9.67	0.000	.0111322	.0167945
z	.0035807	.0009037	3.96	0.000	.0018093	.0053522
z2	-.0000447	.0000169	-2.64	0.008	-.0000779	-.0000115
_cons	1.056252	.0758707	13.92	0.000	.907531	1.204974

Austria

Linear regression

Number of obs	2764
F(4, 2759)	1754.93
Prob > F	0.0000
R-squared	0.8050
Root MSE	.25821

lnw	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnw(-1)	.734045	.0240946	30.47	0.000	.6867997	.7812902
s	.0145235	.0024542	5.92	0.000	.0097113	.0193358
z	.0070732	.0025197	2.81	0.005	.0021326	.0120139
z2	-.000121	.0000504	-2.40	0.016	-.0002199	-.0000221
_cons	1.106555	.0776585	14.25	0.000	.9542803	1.258829

Finland

Linear regression

Number of obs	1191
F(4, 1186)	200.81
Prob > F	0.0000
R-squared	0.6599
Root MSE	.26255

lnw	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnw(-1)	.6341611	.0655839	9.67	0.000	.5054877	.7628345
s	.0229301	.0040109	5.72	0.000	.0150608	.0307995
z	.006066	.0031192	1.94	0.052	-.0000537	.0121858
z2	-.0000409	.000074	-0.55	0.581	-.0001862	.0001043
_cons	1.198021	.2193737	5.46	0.000	.7676173	1.628425

Luxemburg

Linear regression

Number of obs	= 763
F(4, 758)	= 1153.27
Prob > F	= 0.0000
R-squared	= 0.8896
Root MSE	= .16551

lnw	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnw(-1)	.8974548	.0256433	35.00	0.000	.8471145	.9477951
s	.0072912	.0027012	2.70	0.007	.0019885	.012594
z	.0017657	.0028041	0.63	0.529	-.0037389	.0072704
z2	-.0000438	.0000609	-0.72	0.473	-.0001634	.0000758
_cons	.5931718	.126598	4.69	0.000	.3446474	.8416962