

Human capital and innovation: a model of endogenous growth with a “skill-loss effect”

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Abstract

The present paper argues that, in line with Nelson-Phelps (1966), there exist important complementarities among educational attainment, R and D activities (and their derived innovations) and economic growth, although subject to a “skill-loss effect” (-effect), due to the presence of workers who have to perform jobs that require other capacities than the ones they have. Taking Redding’s (1996) formal framework, the main result of our model suggests that the more distorted the labour market is, the stronger must be the investment in R and D necessary to attain a positive economic growth rate.

Citation: London, Silvia, Juan Gabriel Brida, and Wiston Adrian Risso, (2008) "Human capital and innovation: a model of endogenous growth with a “skill-loss effect”." *Economics Bulletin*, Vol. 15, No. 7 pp. 1-10

Submitted: January 22, 2008. **Accepted:** March 12, 2008.

URL: <http://economicsbulletin.vanderbilt.edu/2008/volume15/EB-08O10001A.pdf>

1. Introduction

There exist two basic frameworks in which the relationship between education and growth can be modelled and analyzed. The first one was introduced by Lucas (1988), who emphasized on human capital **accumulation** as an alternative source of sustained growth, instead of only technological change. The second approach goes back to the seminal work of Nelson and Phelps (1966), in which growth is described as being driven by the **stock** of human capital (HK), which in turn affects the ability to innovate. Both approaches yield insights on the growth effects of educational policies.

Further theoretical and empirical studies showed that the divergence in growth rates across countries could be due not so much to differences in the rates of accumulation of HK, as suggested by Lucas, but to differences in the corresponding levels (see for example Benhabib and Spiegel, 1994).

The present paper argues that, in line with the Nelson-Phelps approach, (N&P from now) there exist important complementarities among educational attainment, R&D activities (and their derived innovations) and economic growth, although subject to a “skill-loss effect” (which we call δ -effect), due to the presence of workers who have to perform jobs that require other (or lower) capacities than the ones they have.

Section II describes the δ -effect, that can be identified with the loss of acquired knowledge, as a result of disequilibrium in the labour market. Section III presents a formal model along the lines of Redding (1996), in which we introduce the parameter δ . Section VI introduces an empirical analysis for Argentina, in which we show that a distorted labor market can negatively affect the investment in human capital. Section V examines some policy implications and presents the conclusions.

2. The δ -effect

N&P presented the idea that one of the major roles of education is to increase the individual capacities to innovate and to adapt new technologies. Then, the rate of innovations would increase with the **level** of education attainment. Thus, the enrolment in secondary and higher education would best reflect the number of potential researchers/developers in an economy. This is consistent with the model of Romer (1990, in Aghion and Howitt 1999), in which the steady-state growth rate is an increasing function of the number of skilled workers. Therefore, the N&P approach shows that the marginal productivity of education attainment is an increasing function of the rate of technological progress. This implies that education should allow those countries with less advanced technologies to learn faster from the more advanced ones and thereby to achieve a higher productivity improvement in the adoption of innovations.

A large empirical literature supports the N&P conclusions (for instance Benhabib and Spiegel 2005). Nevertheless, there exists an important group of empirical analyses that demonstrates that the educational level attained is a necessary but not sufficient condition for growth (Azariadis and Drazen 1990, Ros 2003, Mariscal and Sokoloff 2000, Krueger and Lindahl 2001, among others).

While the empirical evidence shows that a high development of the human capital is not sufficient for reaching high levels of growth it also suggests something like a necessary condition: no country may follow a path of high economic growth without a continuous investment in human capital. Azariadis and Drazen (1990) observed, for the period 1960-1980, that no country with low initial educational level could grow quickly. Later, in Ros (2003), Latin American countries are shown to be paradigmatic cases of the need for further conditions for a sustained growth process. Most of them, even with very high

initial levels of formal education, did not grow as fast as other countries that started with similar initial levels of human capital. This is particularly the case of Argentina, Uruguay and Panama, countries in which the average worker had more than four years of formal studies in 1960 but grew only at a 1.5% rate since then. An analogous conclusion is reached in the more historical study of Mariscal and Sokoloff (2000).

Those studies pose the question of why investment in HK does, in some cases, fail to constitute a source of growth, while it succeeds at it in others. One of the possible answers emphasizes on some particular situations that may arise in the labour market. Notice that heterogeneity in technologies of production must be accompanied by heterogeneity in the formation of HK. But, as it is usual in developing countries, it may be the case that there exists a significant mismatch between the demand and supply of skills, which ends up with individuals employed to perform tasks unrelated to their training. Even worse, they may even remain unemployed. In these cases there is a “loss” of HK stock: workers have abilities that are not demanded (over-qualification), or they have to spend time at work to get the skills that are actually demanded, or worse yet, they remain unemployed. This situation can be called a “skill-loss effect”. We represent this by means of a parameter δ , $0 \leq \delta \leq 1$, **an index that summarizes all the possible causes of HK depreciation, either because of unemployment, under or over employment**. It takes value 1 when skills are not lost, and 0 when the loss is maximum.

3. The model

We investigate the relationship between HK and R&D when the δ -effect is introduced, and the consequences for economic growth. We follow the lead of Redding (1996).

Let us consider a continuum of overlapping generations of individual workers, each of whom lives for 2 periods. The lifetime utility a worker of generation t is given by:

$$Ut(c_1, c_2) = c_1 + \rho c_2 \quad (1)$$

Where c is consumption, and ρ is the discount factor. Therefore, individuals are risk neutral. They inherit or are born with one unit of human capital $h_{1,t}$ (from investment in HK of the preceding generation), and invest a fraction u of their working time in their youth to increase it^I. Then:

$$h_{2,t} = h_{1,t} + \gamma u^\theta \quad (2)$$

γ is a parameter of efficiency of the educational system and $0 < \theta < 1$. Both γ and θ represent the social and institutional conditions of the system. The individual decision of how much time to devote to work or to study will be critical, depending if workers internalize or not δ -effect.

We assume that each worker is randomly matched one-to-one with an entrepreneur, who also belongs to a continuum of overlapping generations. The joint effort, given by a linear technology, yields:

$$y_{j,t+1}^i = A_{t+1}^i \cdot \delta \cdot h_{j,t+1} \quad (3)$$

A_{t+1}^i is the i th entrepreneur’s productivity, while $\delta \cdot h_{j,t+1}$ denotes period j ’s HK of the worker employed by i , adjusted by a δ -effect, $0 \leq \delta \leq 1$ ^{II}. We do not consider unskilled work, assuming that all employees have a certain degree of education. Without taking into account this effect, i.e. before being employed, the actual value of human capital of

^I We only consider high school and college education, where there exists an opportunity cost of studying, due to the potential wage at the market labour.

^{II} If $\delta = 1$ there is no δ -effect, since there are no distortions in the labour market, and all the accumulated human capital is productive.

an individual, depends on u, γ and θ . To avoid the interaction with other effects that may enhance the amount or the quality of HK, we do not assume that it can be obtained through learning-by-doing nor admit spillover effects among firms.

Technology A^i will depend on the particular situation of each firm i , according to A^{MAX} , the leading-edge technology available in the economy.^{III} Entrepreneurs can invest a non-monetary amount equal to a fraction α of period 1's output, inducing a jump in productivity from A^i to λA , closer to A^{MAX} , where $\lambda \geq 1$. Additionally, there are two kinds of investment: on R&D (with a probability of success μ , $0 < \mu < 1$ that represents the probability of developing a new technology^{IV}) or the purchase of new technologies. In the last case the increasing productivity will depend on the labour employed.

According to the differences in their investment policies, there are two basic kinds of firms. On one hand those that produce innovations (and benefit from its temporary monopolistic rents^V). On the other those that work with past technologies. For the first class of firms, the general production function is:

$$y_{j,t+1}^{in} = \lambda A_{t+1} \cdot h_{j,t+1} \quad (4)$$

The δ -effect does not appear (or $\delta = 1$) because we assume that in the innovating firms workers and technologies are perfectly matched, because the workers produce, using their skills and knowledge, these technologies. This is the case of Redding's argument^{VI}.

It is quite different for firms that produce with the old technology. First, it can be possible that the δ -effect operates due to disequilibria in the labour market. Second, the old technology has a lower productivity, represented the difference between A and λA . Then, the non-innovative firms have the following production function:

$$y_{j,t+1}^{non-in} = A_{t+1} \cdot \delta \cdot h_{j,t+1} \quad (5)$$

From (4) and (5) we can obtain a global production function, considering that there are a innovative firms and $(1-a)$ no-innovative ones:

$$y_{j,t+1} = a y_{j,t+1}^{in} + (1-a) y_{j,t+1}^{non-in} = (a\lambda + (1-a)\delta) A_{t+1} h_{j,t+1} \quad (6)$$

where the optimal amount obtains by producing $\lambda A_{t+1} h_{j,t+1}$, i.e. in the absence of δ -effect ($\delta = 1$), or equivalently, when there are no non-innovative firms.

Now assume that individual workers can obtain an income:

$$w_{j,t} = \beta(1-u)A_t \quad (7)$$

at period I, that represents the opportunity cost of studying, β is the fraction of current product they earn. At period II, they can be matched with either an innovative or a no-innovative firm. Then the expected wage will be:

$$w_{j,t+1} = \rho(1+\gamma u^\theta) \left[p(\beta\delta A) + (1-p)(\mu\lambda A + (1-\mu)A) \right] \quad (8)$$

Where p is the probability to be employee at the innovative or non-innovative sector. Considering the intertemporal budget constraint:

$$c_1 + \rho c_2 \leq w_{j,t}(1-u)h_{j,t} + \rho w_{j,t+1}h_{j,t+1} \quad (9)$$

^{III} We assume that A^{MAX} is idiosyncratic, and does not represent the international leading-edge.

^{IV} We assume a stochastic production of technology.

^V Monopolistic rents remain until a new technology is invented. At this time, the old technology is commonly known.

^{VI} This perfect match disappears if we consider that firms may have a R&D sector, separated from the productive sector.

The optimal allocation of time between current production and education when individuals internalize the possibility that δ -effect affects their futures salaries will solve the following maximization program:

$$\underset{u}{Max} \beta A \left[(1-u) + \rho(1+\gamma u^\theta) \left[p\delta + (1-p)(\mu\lambda + (1-\mu)) \right] \right] \quad (10)$$

The first order condition for (10) yields the equilibrium fraction of time of period one devoting to accumulate human capital:

$$u = \left[\left(p\delta + (1-p)(\lambda\mu + (1-\mu)) \right) \rho\gamma\theta \right]^{\frac{1}{1-\theta}}$$

$$\text{if } 0 \leq \left[\left(p\delta + (1-p)(\lambda\mu + (1-\mu)) \right) \rho\gamma\theta \right]^{\frac{1}{1-\theta}} < u^* \quad (11)$$

If (11) becomes $\geq u^*$, we consider that $u = u^*$ where u^* is the highest fraction of time that, from a technical and practical point of view, people can assign to study (In other words, $(1-u^*)$ is the lowest fraction of time that individuals devote work).

Equation (11) shows that u is an increasing function of μ , the probability of innovating successfully; λ , the degree of technological progress; $(1-p)$, the probability of being employed in an innovative firm; and γ , the efficiency of educational system. In turn u decreases on δ .

The entrepreneurs will choose a R&D effort (α) that maximizes benefits. We concentrate only on the innovative firm's case, because their investment decisions will constitute the real source of growth of the economy, besides HK accumulation. We do not consider in this case the accumulation of capital as an endogenous source of growth, although is relatively easy to incorporate it. Then, innovators will choose their effort to maximize benefits:

$$\underset{\alpha}{MAX} B(\mu) = \left\{ -\mu\alpha\alpha A + \rho(1-\beta)(\mu\lambda + 1-u)(1+\gamma u^\theta)A \right\} \quad (12)$$

From the first order condition:

$$-\alpha\alpha + \rho\lambda(1-\beta)(1+\gamma u^\theta) = 0$$

$$\alpha = \frac{\rho\lambda(1-\beta)(1+\gamma u^\theta)}{a} \quad (13)$$

When $\alpha \leq (\rho\lambda(1-\beta)(1+\gamma u^\theta))/a$, innovators will invest. Note that α is an increasing function of u, γ and θ , all capital human formation parameters, and a represents the proportion of innovative firms in the economy. If $a = 1$, is similar to Redding's case.

Comparative Static: from low-development trap to sustained-growth

Given the previous analysis, there are many possible paths for this economy. We will analyse first the more pessimistic case: no growth.

As remarked by Aghion and Howitt (1999), the strategic complementary between the workers' choice of education and the firms' R&D decisions may lead to a low-development trap in which $\mu = 0$. Consider two main cases: without δ -effect (where all firms are innovative), case "R", and our model. In the first case, the low-development trap implies that the time spent in studying is:

$$u_R = \left[\rho\gamma\theta \right]^{\frac{1}{1-\theta}} \quad (14)$$

In our model,

$$u = \left[\left(p\delta + (1-p) \right) \rho\gamma\theta \right]^{\frac{1}{1-\theta}} \quad (15)$$

The difference between (14) and (15) is $(p\delta + (1-p))^{1-\theta}$. That is, the time spent in studying is lower than in the first case. Without innovations, individuals that recognize the existence of δ -effect will invest less time in studying, reinforcing the low-development trap if we consider equation (13), in which the effort to innovate α is a positive function of time spent in studying. An interesting empirical literature shows that for Latin American countries there is an important desertion in secondary schools, given by the high opportunity costs and the low probabilities of getting an employment in the more dynamics industries (Carlson 2002).

When $\mu > 0$, a positive growth rate requires that $\alpha \leq (\rho\lambda(1-\beta)(1+\gamma u^\theta))/a$, and

$$u'_R = [(\mu\lambda + (1-\mu)\rho\gamma\theta)]^{1-\theta} \quad (14')$$

$$u = [(p\delta + (1-p)(\mu\lambda + (1-\mu)\rho\gamma\theta)]^{1-\theta} \quad (15')$$

If people do not internalize δ -effect, the time spent to HK formation (in hours) is greater, being the u'_R case. With the presence of no-innovative firms ($p > 0$) the HK

accumulation will be greater than optimal, given by the difference $(p\delta + (1-p))^{1-\theta}$.

An interesting result arises: in an economic system with marked differences among firms (innovative and no-innovative), the time devoted to study is greater if people hope to work in an innovative firm, with higher salaries, ignoring the δ -effect. If innovations are successful, the distance from A to λA increases, and the δ -effect is stronger, weighted up by p . But probably not all individuals will continue with the same expected salary function: some of them will consider u and others u_R . As a dynamic problem, is this the first step towards a dual economy?

From the analysis for the entrepreneurs, the main difference between our and Redding's work is the proportion of innovative firms a in the economy: $\alpha_R = \rho\lambda(1-\beta)(1+\gamma u^\theta)$, while our α comes from equation (14). Being $0 \leq a \leq 1$, it is possible that the effort in a mixed economy must be greater than in one in which all firms perfectly match workers and technology, considering both with the same parameters.

4. A simple empirical assessment

In this section we want to put to test some of the conclusions of the previous model. In particular, we check whether a distorted labor market can negatively affect the investment in HK. We do this by examining annual data for Argentina from 1990 to 2005, provided by SITEAL^{VII}. Even with such a small data set we can detect that the conclusions of our model hold.

We take the enrollment rate in elementary and high school as proxies of HK investment. On the other hand we use over-occupation^{VIII} as a proxy of a distorted labor market.

The general empirical model is given by equation (1).

$$ER_t = \beta_0 + \beta_1 OO_t + \varepsilon_t \quad (1)$$

Where ER is for enrolment rate, OO is over-occupation, and ε_t is a stationary process. It is expected that the sign of ε_t will be negative, showing that a distorted labor market produces a reduction of the investment in HK.

^{VII} <http://www.siteal.iipe-oei.org/>

^{VIII} Under-occupation was not considered because the time series started in 1998.

As it is well known in econometrics, most of the economic series present a trend. But spurious regressions^{IX} are likely to be obtained by using traditional techniques (i.e.: ordinary least squares). Instead, it is common in time series analysis to use cointegration techniques. Finding a cointegration relationship is equivalent to obtain an economic long-run relationship.

Johansen (1988) and Johansen and Juselius (1990) proposed a method for testing the existence of cointegration vectors. As the first step in this analysis we have to analyze the existence of trends in the time series. Augmented Dickey Fuller (ADF) test is usually applied in cases like this one, under the null-hypothesis that the process is non-stationary.

Table I and II show ADF test for the variables used in this study:

Table I: ADF, Unit Root Test results. LEVELS						
<i>Variable</i>	<i>ERP</i>	<i>ERS</i>	<i>OO</i>	<i>ERPM</i>	<i>ERSM</i>	<i>OOM</i>
Trend and constant	-4.180*	-0.566	-2.512	-0.457	-0.623	-2.921
Constant	-3.995*	-0.903	-1.336	0.161	-0.937	-2.289
without trend and constant	-1.968	-0.646	0.007	1.116	-0.676	0.382
* Rejection of the null hypothesis at 5%						
Table II: ADF, Unit Root Test results. FIRST DIFFERENCE						
<i>Variable</i>	<i>D(ERP)</i>	<i>D(ERS)</i>	<i>D(OO)</i>	<i>D(ERPM)</i>	<i>D(ERSM)</i>	<i>D(OOM)</i>
Trend and constant	-7.027*	-3.864*	-2.836	-3.868*	-3.833*	-3.341
Constant	-6.745*	-3.371*	-3.164*	-3.192*	-3.393*	-3.719*
without trend and constant	-6.850*	-3.422*	-3.245*	-3.073*	-3.440*	-3.870*
* Rejection of the null hypothesis at 5%						

Note, from Table I and II that enrollment rate in elementary school (ERP), enrollment in high school (ERS), over-occupation (OO), and the respective proportion for the masculine population ERPM, ERSM, and OOM have all of them unit roots. Therefore, cointegration techniques are appropriate for these variables. However, given how small the sample is, we have to consider the results carefully.

The second step in the study is to detect the existence of cointegrating vectors by using the Johansen test. We estimate four long-run relationships between ER and OO according to the trace and maximum eigenvalue tests.

Once the cointegration relationship is obtained is important to study the existence of weak exogeneity. The importance of studying exogeneity is discussed in McCallum (1984). Weak exogeneity allows using the estimated equation without modeling the variable that we do not consider endogenous to the model. In the present case the variable is the distortion in the labor market approximated by OO. This variable is shown to be weakly exogenous.

Table III shows the cointegrating relationship once controlled for weak exogeneity.

^{IX} See Phillips (1986) for an analysis of spurious regressions

Table III: Cointegrating Relationship

1)	(ERP) =	6.06	-0.377 (OO)
		[3.69531]	[-16.1062]
2)	(ERS) =	58.35	-14.64 (OO)
		[-5.18217]	[4.76857]
3)	(ERPM) =	6.84	-0.56 (OOM)
		[-16.7269]	[5.28760]
4)	(ERSM) =	56.85	-83.48 (OOM)
		[-5.78285]	[5.69390]

Source: Own elaboration

All the equations present the correct signs. In particular, that an increment of distortion in the labor market generates a lower investment in human capital. Note from the first two equations that the effect is larger in the case of more “skilled” human capital. Enrollment in secondary education is more affected than in primary schooling by a distortion in the labor market. We note also, in 3) and 4), that the model using the investment in human capital for men is more affected than the general one by distortions in the labor market.

Next we proceed to test for Granger causality for the different variables, Table IV shows the results.

Table IV: Pairwise Granger Causality Tests

Sample: 1990 2005			
Lags: 2			
Null Hypothesis:	Obs	F-Statistic	Probability
OO does not Granger Cause ERP	14	3.140	0.092
ERP does not Granger Cause OO		1.096	0.375
OO does not Granger Cause ERS	14	5.224	0.031*
ERS does not Granger Cause OO		3.488	0.076
OOM does not Granger Cause ERPM	14	2.499	0.137
ERPM does not Granger Cause OOM		0.874	0.450
ERSM does not Granger Cause OOM	14	3.175	0.091
OOM does not Granger Cause ERSM		3.971	0.058

* Rejection of the null hypothesis at 5%

Table IV suggests that unidirectional Granger-causality exists only from OO to ERS. These results reinforce the conclusions pointed out in the previous sections, in particular that individuals who recognize the existence of a δ -effect will invest less time in studying, reinforcing the low-development trap. The aforementioned empirical analysis shows, in fact, that the investment on human capital is reduced when the distortion in the labor market increases. This result is stronger for men than for women and for high school than for primary school.

5. Preliminary Conclusions

This is a model that presents a variation of Redding’s argument. First, there is a δ -effect according to which the human capital accumulated is partially lost due to imperfections in matching technologies and worker’s skills. The other difference,

complementary to the first, is to consider the possibility of a variety of firms, represented by two main groups: innovative and no-innovative firms. To illustrate the differences in efficiency, we assumed that the first ones match perfectly its workers with their technology, but the latter don't.

Under this new setting, the possibility to reach a higher growth is more difficult and it requires a greater effort in R&D' investment, which is in turn discouraged by lower amount of time devoted to accumulate human capital when individuals recognize the δ -effect. The general policy recommendation in the literature, namely to increase the HK formation, does not ensure a sustained growth process when the probability to find work in an innovative firm is low, and the distance between A and λA is growing, in fact, in presence of a high δ -effect and a high proportion of non-innovative firms, it can engender a vicious circle, making δ endogenous^x.

Perhaps it is necessary to include in this analysis differences in the HK formation, with the possibility to have a perfect match in both innovative and no-innovative firms. The current discussion about the role of the formal educational system in Argentina is focusing on the necessity of a careful design of study programmes, in order to satisfy the labour demand (local and international), technological progress, and the inner dynamic of the firms. Assuming that not all firms are innovative, the first step to reach higher growth rates is to diminish the weight of the δ -effect.

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^x In this direction further investigations are oriented.

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