ICT, Signaling and Economic Growth

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ABSTRACT

This paper examines the influence of the expansion in higher education systems in the past decade, as a result of highly developed ICT and Government policy, on economic growth. The paper presents a theoretical model, using the *signaling* theory, and showing the conditions under which an improvement in human capital leads to higher economic growth. In addition, empirical evidence that reinforces the results of the model is developed. We conduct regressions for 60 countries on tuition fees in the institutions of higher education (private and public institutions) as a percentage of the GNP per capita, on the growth in the past decade. For testing the influence of ICT level, we use restricted samples for OECD and developing countries. The results of the empirical tests were robust to a variety of different specifications, and support the main assumptions of the theoretical model.

Keywords: ICT, Signaling, Economic growth.

1. INTRODUCTION

In this paper we examine the influences of wider access to higher education on economic growth. The main question we focus on is whether the expansion in higher education systems and the greater accessibility to higher education improve the contribution of the human capital to the economic growth of the economy.

In the past decades, there was a huge increase in higher education in all western countries. For instance, in the USA, almost 42% of the average cohort began their studies in higher education institutions in 2002. In United Kingdom it was about 45% and in Australia and New Zealand it was almost 70% of the average cohort [7]. In Israel, almost 49% of the average cohort began their studies in higher education institutions in 2002 and about 21% from the relevant population (ages 22-34) are students in the higher education system [20].

These changes were generally an outcome of government policy, but there was also a great change in the general accessibility to knowledge: the improvement in Information and Communication Technologies (ICT's), especially its applications in higher education systems. Thanks to the Internet, "distance learning" systems and computer support systems, the process of studying becomes much easier and cheaper [36].

The mainstream literature today (see for instance Mincer [18], Becker [5]-[6], Taubman and Wales [30]-[31], Barro and Sala-Martin [4]) is that an increase in human capital leads to higher productivity, and therefore to higher growth. These theories imply that the higher the level of education for all, the better for the economy. However, when abilities of students are different and there exists two main sectors, the production sector and the R&D sector, we can show that an equilibrium in which everybody acquires higher education is not optimal. Incorporating the signaling paradigm [25] [14], in a model of growth a la Romer [23] permits us to show under which condition higher education for all is (or is not) optimal.

The signaling paradigm assumes that the principal contribution of education is the selection of candidates for the labor market and that education is used as a signal to the employers about the real ability and primary talents of the workers (see in [3] [14] [25] [26])[1]. It leads to the creation of two types of equilibria, either pooling or separating.

From the reciprocal connections between the concepts which result from the signaling theory, such as the costs of education, the distribution of acquisition of education by various individuals in the population, the level of ability in various sectors of the labor market and the level of wages, it is possible to infer the scope of the growth in the economy.

The main exogenous parameter, which leads the dynamics of the equilibrium, is the cost of higher education. Indeed, acquiring higher education is accompanied by high costs - direct and indirect costs. The tuition fees and the loss of income during the study period are the main costs (in recent years one should also add the costs of a preparatory program before entering the university), but highly developed ICT actually reduces these costs [16]. Therefore, the more the ICT is developed and reduces the direct and indirect costs of higher education, the more important is the existence of tuition fees in higher education, to obtain a good influence on economic growth in the economy.

The model describes a system in which the total costs of higher education determine the type of the signaling equilibrium and influence the level of economic growth in the economy.

The paper is divided into four parts. Section II presents the theoretical model, Section III presents the empirical research and Section IV is the conclusion.

2. THE MODEL

2.1 General Description

In the economy, there are two main sectors: the production sector in which one final good is produced, and the R&D sector in which newer and more productive machines are being developed. The principal input in the model is effective units of labor, i.e., human capital. Capital is embedded in the machines, i.e., intermediate goods with which one starts the production.

Our description of the production size is based on Romer model [23] in which the increase in the number of intermediate goods that are produced with capital, permits the growth in the economy. The emergence of new machines is actually the determinant of the rate of growth in the economy, and the higher the productivity of human capital in the R&D sector is, the higher the rate of growth [10] [11].

However, in our model, workers are not homogenous; they are different in their ability. Workers can have either a low or high ability. The labor sector cannot a priori distinguish between them. However if by investing in education, workers can signal their type, then the labor market will know to distinguish between them.

[1] It is important to stress that signaling theory does not necessarily contradict the human capital theory. Theoretically, one's ability can be improved by the acquisition of education. However, the acquisition of education will still signal to the employer about the real level of the workers' talents.

In the model we show that an equilibrium in which ability can be revealed leads to higher growth than an equilibrium in which ability is not known. The intuition of this result is that growth in this economy is due to the discoveries of new technologies in the R&D sector. The higher the ability of workers in the R&D sector, the higher the rate of growth of technology and of economic growth [10] [11].

A simple design in order to signal the types of workers is their level of education. It is enough that there is a difference in the total costs of acquisition of education among individuals to get a separating equilibrium, i.e., one in which we can distinguish between the types of individuals. The total costs include the time and the effort as well as the price of education. We assume that individuals whose ability is low need more time for the acquisition of education. Furthermore, we assume that highly developed ICT reduces the total costs of acquisition of education for all kinds of individuals. Though, the level of ICT might be different among countries.

In consequence in countries where the total costs are low, we will get a pooling equilibrium, in which ability are not revealed. However, in countries where the total costs are high, the equilibrium will be of a separating type, in which only high ability people learn.

We will first present the three sectors of the production; we then analyze the rate of growth of the economy, and the elements that affect it in steady state. We then turn to analyze the labor market, and the effects of signaling.

2.2 The Production Sector

The economy produces one final good, which is consumed. This good is produced with labor and intermediate goods. The production function takes the form:

(1) $Y = H_Y^{1-\alpha} \cdot \sum_{j=1}^{A} x_j^{\alpha}$ or $Y = H_Y^{1-\alpha} \cdot \int_0^A x_j^{\alpha} dj$

Where: Y - the output at each period; H_Y - effective units of labor. Actually, $H_Y = a_y L_y$, where a_y - the ability of the labor force working in sector y. The workers in the economy differ by the levels of their ability: there are two levels of ability in the population – high (h) and low (l). Let us assume that the distribution of workers in the population is σ for high ability and (1-σ) for low ability in the population. L_y - the number of workers who work in the production sector; A - the level of the technology, which is represented by the total number of machines (x_j). It can be understood as improving the productivity of the labor using the capital at each period.

The firms involved in the production sector are maximizing profits:

(2) $\max_{L_y, x_j} (a_y L_y)^{1-\alpha} \cdot \int_0^A x_j^{\alpha} dj - w_y L_y - \int_0^A p_j x_j dj$

Where: p_j – the rental price for capital good j; w_y - the wage rate paid for labor in sector y.

The first-order conditions characterizing the solution to this problem are:

(3) $w_y = (1\text{-}\alpha)\dfrac{Y}{L_y}$ and

(4) $p_j = \alpha (a_y L_y)^{1-\alpha} x_j^{\alpha - 1}$.

2.3 The Intermediate-Goods Sector

The profit maximization problem for an intermediate goods firm is:

(5) $\max_{x_j} \pi_j = p_j(x_j) x_j - r x_j$

It should be noted that each intermediate-goods firm owns a patent and is therefore a monopoly that sees the price as negatively related to the demand. The first-order condition for this problem, for each j is:

(6) $p'(x)x + p(x) - r = 0$,

From equation (4), we note that the demand elasticity is equal to α-1. Substituting into equation (6), we get that:

(7) $p = \dfrac{1}{\alpha} r$.

So the intermediate-goods firm charges a price over its marginal cost, r: This is the solution for all the monopolist firms.

Therefore, from equations (7) and (4) we get that the profit for each capital goods firms is given by:

(8) $\pi = \alpha(1-\alpha)\dfrac{Y}{A}$

The total demand for capital by intermediate-goods firms is actually equal the total capital stock in the economy: $\int_0^A x_j dj = K$. Since the price of all intermediate goods are equal, then the actual quantity of each intermediate is also equal and will be denoted x, which means that:

(9) $x = \dfrac{K}{A}$,

so we can rewrite the production function to:

(10) $Y = A(a_y L_y)^{1-\alpha} x^{\alpha}$, or:

$$Y = A(a_y L_y)^{1-\alpha} A^{-\alpha} K^{\alpha} = K^{\alpha} (A a_y L_y)^{1-\alpha}$$

2.4 The Rate of Growth of the Economy

In this model, we assume that the factors of production are constant, i.e. there is no growth of population, and capital is constant. The only factor that leads to growth is the increase in the number of new technologies existing, which are embedded in new intermediate goods available on the market. Based on Romer [23] and on Galor and Tsiddon [10] , we assume that the intensity of technological progress, i.e., the number of new inventions is a function of the ability; the size of the labor force in the R&D sector, and of the size of the technological already in existence (this is the usual externality of spillover effects). Therefore:

(11) $\dot{A} = \delta a_r \cdot L_r \cdot A$

where: a_r is the ability of the labor force in the R&D sector, L_r the size of the labor force in the R&D sector, A the amount of machines existing, and δ is a positive parameter. Assuming that δ is greater than one, is to assume that the ability which enters the production function directly, has a higher impact in the R&D sector. It is in fact assuming that "intelligence" affects more the productivity in the R&D sector than in the production sector.

In consequence we get that the rate of growth of the inventions, which is also (from equation 10) the rate of growth of the economy- g is in steady state constant and is:

(12) $g = \dfrac{\dot{A}}{A} = \delta a_r \cdot L_r$

2.5 The Research Sector

In the research sector, the inventor can patent his invention and sell the exclusive rights to produce a new capital good. The inventor sells the patent to an intermediate-goods firm, which uses it as a set of instruction to transform a unit of raw capital into a unit of a new capital good. From the asset pricing arbitrage equation we get that

(13) $r P_r = \pi + \dot{P}_r$,

We have noted in the previous section that since there is no increase in population, output Y, and inventions, A grow at the same rate, g. Since profits, π, are proportional to Y/A (see equation 8), π in steady stays is constant, and from equation (13) patent price P_r is also constant. So we get:

(14) $P_r = \frac{\pi}{r}$.

2.6 Size of the labor force in the R&D sector

In section 2.5, we have shown that the rate of growth of the economy is a function of the size of the labor force in the R&D sector, L_r. It is therefore of utmost importance to analyze the size of this labor force. The equilibrium which permits to find this size is that if workers ability cannot be revealed (what we denote as a pooling equilibrium), then all workers hired either in the R&D sector or in the production sector get the same wage rate. In case ability can be revealed (a separating equilibrium), then workers will get a wage relative to their ability. We start by finding the pooling equilibrium.

2.6.1 Pooling

The wage rate in the production function is given by equation (3):

(3) $w_y = (1\text{-}\alpha)\frac{Y}{L_y}$

While the salary earned from employment in the R&D sector is:

(15) $w_r = \delta a_r \cdot A \cdot P_r$

Substituting the price P_r from equation (14), and profits π from equation (8), and equating salaries in both sectors, we get that the size of the labor force working in the production sector in the case of a pooling equilibrium, denoted L_y^p is:

(16) $L_y^p = \frac{r}{\alpha \cdot \delta a_r}$

Assuming that the labor force is constant and denoted by $\overline{L}$, then we get that the ratio of the population working in the R&D sector as a percent of the total labor force, s^p is:

(17) $s^p = 1 - \frac{r}{\alpha \cdot \delta a_r \cdot \overline{L}}$

The rate of growth of the economy given by equation (11) becomes:

(18) $g = \frac{\dot{A}}{A} = \delta a_r \cdot \overline{L} - \frac{r}{\alpha}$

Note that in equations (15) to (18) the ability factor a_r, is a weighted sum of the ability of both population, since the distribution of the population working in the R&D sector is equal to the one in the whole population. So:

(19) $a_r = \sigma a^h + (1-\sigma)a^l$

2.6.2 Separating equilibrium

When there is total knowledge on the type of each individual, there are three possibilities of equilibrium: (1) an equilibrium in which the size of the population working in the R&D sector (s) is exactly equal to the population with high ability (σ). (2) An equilibrium in which the size of the population working in the R&D sector (s) is greater than the population with high ability (σ). (3) And an equilibrium in which the size of the population working in the R&D sector (s) is smaller than the population with high ability (σ). The type of equilibrium which will prevail in the economy is of course function of the demand function for the final goods (which is function of the price).

In these three cases, we get a different size of the R&D sector and a different growth rate. They are presented in equations (20)-(28):

1. $s = \sigma$

In this type of equilibrium, we denote the optimal size of the R&D sector as s^{r1}:

(20) $s^{r1} = \sigma$

(21) $L_y^{r1} = (1-\sigma)\overline{L}$

(22) $g = \frac{\dot{A}}{A} = \delta a^h \cdot \sigma \overline{L}$

2. $s > \sigma$

In this type of equilibrium, we denote the optimal size of the R&D sector as s^{r2}:

(23) $s^{r2} = 1 - \frac{r}{\alpha \cdot \delta a^l \cdot \overline{L}}$

(24) $L_y^{r2} = \frac{r}{\alpha \cdot \delta a^l}$

(25) $g = \frac{\dot{A}}{A} = \delta \overline{L}\left(\sigma a^h + (1-\sigma)a^l\right) - \frac{r}{\alpha}$

3. $s < \sigma$

In this type of equilibrium, we denote the optimal size of the R&D sector as s^{r3}:

(26) $s^{r3} = 1 - \frac{r}{\alpha \cdot \delta a^h \cdot \overline{L}}$

(27) $L_y^{r3} = \frac{r}{\alpha \cdot \delta a^h}$

(28) $g = \frac{\dot{A}}{A} = \delta a^h \overline{L} - \frac{r}{\alpha}$

Since equations (18, 22, 25, 28) display the rate of growth in all the different equilibria, we can now compare the case of separating versus pooling. We will show that in an economy where there is the possibility of knowing the types of workers, i.e., separating, there is a higher growth rate than in the case of pooling.

Proposition 1

The rate of growth in a pooling equilibrium is always lower or equal to the rate of growth in a separating equilibrium.

Proof

•1 When comparing the rate of growth under separating s^{r3} and pooling s^p, since a^h is greater than a^l, then we get that:

(29) $g_{|s^{r3}} > g_{|s^p}$

•2 When comparing the rate of growth under separating s^{r2} and pooling s^p, it is easy to show that they are equal.

•3 When comparing the rate of growth under separating s^{r1} and pooling s^p, indeed equation (30) holds in case that $\sigma > s^{r3}$.

(30) $g_{|s^{r1}} > g_{|s^p}$

We will show that this will always be the relevant case in the next section.

2.7 The labor sector

2.7.1 Education

Each worker, whatever his level of ability, selects either to acquire education or not. The costs of acquisition of education comprise three elements: The first is the time and effort needed for the acquisition of education. Individuals whose ability is low need plenty of time for the acquisition of education, whereas individuals whose ability is high need a shorter period [14] [25]. In consequence, the total costs for acquisition of education is negatively related to the ability of workers. Therefore, the level of education the worker will acquire may function as a signal for the employer about the real ability of each worker.

The second element is the price paid for education which principally includes the tuition costs. We will differentiate two types of economies by the level of their tuition costs. In economy 1, the price for education is low (P_1), and in economy 2 the price for education (P_2) is high.

The third element is the level of ICT in the economy. As stated above, highly developed ICT reduces the costs for all individuals. This means there is a negative influence on the total costs for acquisition of education, whatever their level of ability. For the sake of simplicity, let us assume in developing this model that the level of ICT is constant for all economies.

The total costs of acquisition of education among individuals is therefore:

$$(31)\ C_i^l = e^l \cdot P_i = \frac{m}{a^l} \cdot P_i\ ;\ C_i^h = e^h \cdot P_i = \frac{m}{a^h} P_i,\quad i=1,\ 2$$

where e^l and e^h are the level of efforts produced by individuals with low and high ability respectively, and we assume that it is inversely related to their ability. m is a positive parameter which represents the general level of ICT in the economy. We, of course, get that C_i^l is higher than C_i^h.

2.7.2 Wages

Workers either work in the final good sector or in the R&D sector. Individuals working in the final good sector get their marginal product which is displayed in equation (3). Workers in the R&D sector get the patent fees of selling their new technology. Therefore they receive the amount of new patents they sell multiply by the price, that is:

$$(15)\ w_r = \delta a_r \cdot A \cdot P_r$$

In order to compare the results between separating and pooling equilibria, we present the wages in the different possible equilibria. There is a need to some notations. We denote w^l and w^h the wages of low ability workers and high ability workers respectively, in a situation we can distinguish the ability of workers, i.e., separating equilibrium. We denote $\tilde{w}$, the wages of all workers when the ability of workers cannot be distinguished, i.e. in a case of pooling equilibrium.

Corollary 1

In order to get a pooling equilibrium, a necessary and sufficient condition is that condition (A1) holds.

A1: $0 < w^l < \tilde{w} - c^l$

Proof

Let us show that if condition A1 holds, then pooling is an equilibrium. The right hand side of condition A1 represents the net wages in case all individuals learn and there is no way to distinguish between them. The left hand side of A1 represents the wage received by low ability people in case one can distinguish between abilities.

Condition A1 means that the net wages of the low ability people under pooling is higher than if they do not learn (and then there is a separating equilibrium); so it means that pooling is an equilibrium.

Let us show that a separating equilibrium is not possible when condition A1 holds. For having a separating equilibrium, condition A2 has to hold, when:

A2: $w^l > w^h - c^l$

But from A1, we have that

$$(32)\ w^l < \tilde{w} - c^l < w^h - c^l$$

So, it contradicts condition A2, and therefore a separating equilibrium is not possible.

Corollary 2

In order to get a separating equilibrium, a necessary and sufficient condition is that conditions (A2) and (A3) hold.

A2: $w^l > w^h - c^l$

A3: $w^h - c^l > w^l$

Proof

Condition A2 states that workers with low ability get a higher wages when they do not learn and are therefore known to be of low ability, than if they will go and learn.

Condition A3 states that workers with high ability are better-off learning. Therefore these two conditions together are necessary to get a separating equilibrium. Since A2 contradicts A1, then pooling is not possible.

These two corollaries permit us to come to the main proposition of this model, which states that depending on the tuition level, given the level of ICT, countries will have either a separating or pooling equilibrium.

Proposition 2

When tuition costs are low, the only equilibrium is of a pooling form; and when tuition costs are sufficiently high, the only equilibrium is of a separating form. The rate of growth in countries with low tuition is lower than the rate of growth in countries with high tuition.

Proof

Let us denote the country with a low tuition cost, P_1 as country 1, and the country with high tuition cost, P_2 as country 2. We will show under which conditions on P_1 and P_2, country 1 has indeed a pooling equilibrium, and country 2 has a separating one.

We start by analyzing wages. The wage in a pooling equilibrium, $\tilde{w}$ is:

$$(33)\ \tilde{w} = (1-\alpha)\frac{Y}{L_y},$$

When: $Y = \left(A^p \cdot \tilde{a} \cdot L_y^p\right)^{1-\alpha} K^\alpha$; $\tilde{a} = \sigma a^h + (1-\sigma) a^l$; $L_y^p = \dfrac{r}{\alpha \cdot \delta \tilde{a}}$

The gap between the wages of high and low ability workers in a separating equilibrium depends on the size of σ, i.e., whether we are in the case s^{r1}, s^{r2} or s^{r3}. These three gaps are:

s^{r1}

$$(34)\ w^h - w^l = (1-\alpha)Y\left[\frac{\alpha\delta a^h}{r} - \frac{1}{(1-\sigma)\bar{L}}\right]$$

When: $Y = \left(A^{r1} \cdot a^l \cdot L_y^{r1}\right)^{1-\alpha} K^\alpha$

s^{r2} and s^{r3}

$$(35)\ w^h - w^l = \delta\alpha\frac{(1-\alpha)Y}{r}\left[a^h - a^l\right]$$

Country 2

Let us show that country 2 with tuition P_2 has a separating equilibrium, i.e. that A2 and A3 hold. It is easy to show that for these conditions to hold, it is sufficient that:

$$(36)\ \frac{P_2 m}{\beta a^l} < w^h - w^l < \frac{P_2 m}{a^l}$$

Defining

$$(37)\ \psi_1 = \frac{\delta a^l \cdot A \cdot P_r}{m}$$

then, in the case of s^{r2} and s^{r3}, when P_2 is greater than $\psi_1\left[a^h - a^l\right]$ and smaller than $\beta\psi_1\left[a^h - a^l\right]$, we are in the case of inequality (36); that is, conditions A2 and A3, and we get a separating equilibrium.

For the case of s^{r1} , in order to get (36), it is enough that

(38) $$\beta\psi_1\left[a^h - \frac{r}{\alpha\cdot\delta(1-\sigma)\cdot\bar{L}}\right] \geq P_2 \geq \psi_1\left[a^h - \frac{r}{\alpha\cdot\delta(1-\sigma)\cdot\bar{L}}\right]$$

Including both cases together (which we refer as condition A4), we get that in country 2, low ability individuals will not learn, high ability individuals will learn and will be working in the R&D sector.

<u>*Country 1*</u>

Let us show that country 1 with tuition P_1 has a pooling equilibrium, i.e. that A1 holds. It is easy to show that for this conditions to hold, it is sufficient that:

(39) $$P_1 < \frac{a^l}{m}\left(\tilde{w} - w^l\right)$$

Defining

(40) $$\psi_2 = \frac{a^l}{m}(1-\alpha)K^\alpha$$

In the case of s^{r2} and s^{r3}, when P_1 is smaller than $\psi_2 \cdot \frac{\alpha\delta}{rK^\alpha}\left[\tilde{a}\,Y_p - a^l Y_{s2}\right]$, equation (39) holds, that is we get a pooling equilibrium.

For the case of s^{r1}, in order to get (39), it is enough that

(41) $$P_1 < \psi_2\left[A_p^{1-\alpha}\cdot\tilde{a}\left(\frac{\alpha\delta}{r}\right)^\alpha - \frac{(A_{s1}a^l)^{1-\alpha}}{\left[(1-\sigma)\bar{L}\right]^\alpha}\right]$$

Including both cases together (which we refer as condition A5), we get that in country 1, all individuals learn, so that there is no way to distinguish the ability of workers. Therefore, the people hired in the R&D sector are from both abilities, and as a consequence, the number of new discoveries is lower and growth is lower than in country 2, as we have shown in Proposition 1.

In order to close the model, one has to find the type of separating equilibrium which takes place. The conditions for each of the equilibria, especially in case of s^{r1}, are influenced by the size of σ , since it has implications on the sign of (w^h-w^l).

In conclusion, in a *Romer* framework, in which there are two main sectors, we have introduced differences in ability which can be revealed through education. We have shown that the possibility of revealing the types of individuals is of utmost importance for economic growth and this can be done by tuition fees, given the level of ICT. In the next section, we will check if the rate of growth of countries which are involved in R&D and develop ICT, is indeed related to costs of acquisition of education.

3. THE EMPIRICAL PART

Most of the empirical research related to the effects of education and human capital focuses on the examination of the *signaling* theory versus the *human capital* theory. Since it is difficult to measure directly ability and productivity, the empirical tests on signaling concentrate on comparing situations in which it is due to occur (see for instance Psacharopoulos [21], Wolpin [37], Tucker [34]-[35], Albrecht [1]-[2], Riley[22], Taubman and Wales [30]-[31], Grubb [12], Kroch and Sjoblom [15]). However, previous researches do not relate to the two options of equilibria which are given by the signaling theory (*separating* or *pooling*). Neither did they inquire the different conditions for the validity of these equilibria.

Hence, we suggest to develop empirical tests for the signaling theory by combining it with *growth* empirical tests. Thus, it will be possible to get some empirical evidence for signaling theory, as well as some confirmation of the model presented above.

3.1 General Description

In our model, tuition fees for higher education as well as the level of ICT in the economy, are the main determinants of economic growth. The assumption is that countries with high tuition fee, will be in separation equilibrium, and therefore their growth level will be higher than the countries in which the tuition fee is low (or zero), i.e., countries in pooling equilibrium. In countries with a high level of ICT, the importance of the existence of tuition fees and its level, are even higher. We generally refer to the OECD countries as economies with highly developed ICT (it can be measured, for example, by the percentage of Internet users in the population or the number of personal computers per households).

Moreover, we assume that if the level of higher education exceeds a particular threshold, the probability that the economy will be in a pooling equilibrium is higher, and the economic growth will be lower. So when the percentage of individuals who acquire higher education (i.e., students) from an age group is higher, the economy tends to be in equilibrium of the *pooling* type and vice versa[2].

The period chosen in the empirical test is adjusted to the model (the years 1989-1999), since radical changes and developments in higher education systems throughout the world and in ICT level, took place especially in the last decade (as is described in PBC Report [29] and in Locksley [16]).

Our empirical part will be based on Mankiw, Romer and Weil [17], which examined the empirical application of the Solow Model [24], and then added some tests on human capital, as well as other known variables which affect economic growth.

3.2 Variables and Data

The dependent variable is *gln89-ln99* - the growth rate of GNP during the last decade, calculated as the change between the logarithm of output per capita between 1989 and 1999**.**

The explanatory variables are:

1. *s* – changes in the stock of capital, calculated as the average part of the real investment (including governmental investment) in the real product (real GDP);
2. *n* – rate of population increase between the years 1989-1999;
3. *school* – the percentage of the population of working age, who have studied in high school (the percent of the 12–17 years cohort from the 15-65 years cohort registered for high-school studies). This variable represents the basic level of human capital stock in the economy;
4. *cost/gnp99* - The level of (direct) tuition fee which is paid for the acquisition of higher education at the B.A. level (in dollars), as a percent of the GNP per capita in 1999. Since there is a wide range of tuition fees, two options were inserted to the tests – a maximal tuition fee (*costmax/gnp99*), which is usually paid in private institutions of higher education and a minimal tuition fee (*costmin/gnp99*), which is usually paid in public institutions;
5. s*tudents* - The percentage of the population of the appropriate age group (25-34) that applied for B.A. studies.
6. *gnp89* – The output per capita in the basic year- 1989. It is common to insert this variable to test for convergence.

[2] In case this assumption is true, there will be some kind of rejection of the null hypothesis, which results from the human capital theory. According to this theory, the rise in the number of students will improve growth rate in the economy.

7. *OECD*- dummy variable for testing the difference between developed and undeveloped countries. It get the value 0 for OECD countries and 1 for the others.

The source of the data for all variables appears in the references.

We use cross section data (as in Barro and Sala-I-Martin [4]) The data were collected for 60 countries: 30 OECD countries and 30 developing countries.

3.3 Estimation

Since we assume that the explanatory variables are not connected to the random factor (ε), it is possible to apply the estimation of the equations with the method of the Ordinary Least Squares – OLS. Though, we made some tests and corrections for heteroskedasticity in the estimation[3].

The main equation for estimation is:

$$(42)\ gln89\text{-}ln99_i = \alpha + \beta_1 \cdot s_i + \beta_2 \cdot n_i + \beta_3 \cdot school_i + \beta_4 \cdot cost/gnp99_i + \beta_5 \cdot students_i + \beta_6 \cdot gnp89_i + \varepsilon_i$$

When: i - state i; *gln89-ln99* - the growth rate in state i in the decade 1989-1999; ε_i - an unexplained residual; the other variables were previously defined.

The variables are gradually inserted to the estimation. In each version another explanatory variable is inserted, in order to check its influence on the tests. Furthermore, various combinations of variables are concluded in the estimation, in order to find the best explanatory combination for economic growth, and to avoid molticolinearity between variables as *students* and *school*.

Moreover, we examine the difference between developed and undeveloped countries introducing the binary indicator of *OECD*. One way of testing the robustness of our results is to pool all countries together, and include the dummy variable in the estimation. However, a more efficient option for our model is to use restricted samples. In this way we run regressions separately for OECD countries and other countries in order to test whether the coefficients for *cost/gnp99* variables are positive and significantly different from zero.

3.4 Results

The main results of the estimation are presented in Tables 1a and 1b. We present the results for two groups: OECD countries and all countries (full sample), since the results for the developing countries were generally insignificant.

OECD countries

Our results for the OECD countries support the assumptions of the model (see table 1a). The positive correlation between tuition fees and growth is robust to a variety of different specifications. First, R^2 rose significantly (up to 0.88) as a result of the insertion of the variables *students* and *costmax/gnp99*. Secondly, the coefficient of main explanatory variable in the model- *costmax/gnp99*- is positive and highly significant in most of the versions of the estimation[4]. However, this variable itself can explain only 8% of the growth rate (see column 6). There is significant evidence for convergence in the model (see columns 1, 3 and 4). The coefficients for the variables *school* and *students* are negative and in some versions- indistinguishable from zero (see columns 1-3).

All countries

Our results for the full sample (see table 1b), are more complicated. The R^2 is much lower than for the OECD countries, and the variable *costmax/gnp99* can explain only 2% of the growth rate. However, the coefficient of the variable *costmax/gnp99* is positive and significant when the variables *n*, *s* and *students* are included (but not with the variables *school* and *gnp89* -see columns 2 and 5). So actually, in the full samples regressions there is no robust evidence for relationship between tuition fees and growth, when we include variables for the low level of human capital stock (high school) or for convergence.

Table 1a – The Results for OECD countries

Regression Number:	**1**	**2**	**3**	**4**	**5**	**6**
			Y= *gln89-ln99*			
*Cons_*	1.289 (0.024)	0.9517 (0.088)	1.023 (0.036)	1.377 (0.000)	1.016 (0.000)	-0.015 (0.651)
students	-0.002 (0.617)	-0.009 (0.129)		-0.014 (0.029)	-0.024 (0.004)	
school	-0.065 (0.039)		-0.023 (0.638)			
costmax/gnp99	0.008 (0.000)	0.008 (0.001)	0.0017 (0.025)	0.0067 (0.046)	0.0106 (0.004)	0.082 (0.040)
s	0.0296 (0.063)	0.027 (0.170)	0.0461 (0.017)			
n	-1.551 (0.134)	-1.832 (0.136)	-0.365 (0.678)			
gnp89	-0.000 (0.000)		-0.000 (0.000)	-0.003 (0.006)		
R^2	0.88	0.85	0.56	0.74	0.58	0.08
N	26	26	29	26	26	29
Robust P-Values in parentheses.						

Table 1b – The Results for Full Sample

Regression Number:	**1**	**2**	**3**	**4**	**5**	**6**
			Y= *gln89-ln99*			
*Cons_*	-0.111 (0.040)	-0.037 (0.773)	-0.199 (0.061)	0.803 (0.000)	0.077 (0.032)	0.004 (0.908)
students	-0.007 (0.001)			-0.015 (0.014)	-0.008 (0.147)	
school		-0.016 (0.411)				
costmax/gnp99	0.1645 (0.001)	0.0762 (0.163)	0.1465 (0.001)	0.006 (0.001)	0.0381 (0.273)	0.0565 (0.232)
s	0.0019 (0.149)	0.021 (0.479)	0.0442 (0.122)		0.0003 (0.755)	
n	-0.104 (0.209)	-0.024 (0.789)	-0.063 (0.499)		-0.062 (0.370)	
gnp89					-0.000 (0.012)	
R^2	0.37	0.18	0.26	0.30	0.25	0.02
N	41	38	41	41	41	47
Robust P-Values in parentheses.						

In conclusion, the empirical tests confirm the implications of our model. The various regressions performed on economic growth are implying that higher tuition fees, especially in highly developed ICT countries, lead to higher growth.

4. CONCLUSION

This paper focuses on the effects of higher costs of education on human capital and growth. We present a model with a Romer [23] framework, in which there are two main sectors: the production of final goods and a R&D sector producing new ideas of machines. Moreover, workers are not homogenous; they have different abilities. In our model, we have shown that the possibility of revealing the types of individuals is of utmost

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[3] If tuition fees (*cost/gnp)* in the equation for estimation are endogenous and influenced by the growth rate, estimation of the equations using OLS method is potentially inconsistent. In this case we have to find an instrumental variant (IV) which is partially correlates with *cost/gnp* and uncorrelated with ε. In our follow up research we control for endogeneity, and propose some options for IV. We also use some interactions between the variables, to check the potential combined influence. We show that the main results are not significantly different from those presented as follows.

[4] It is important to indicate that when the variable *costmin/gnp99* is inserted to the regressions, the results are insignificant.

importance for economic growth and this can be done by high costs of education. Indeed, our paper has shown that higher costs for acquisition of higher education leads to a separating equilibrium and therefore to higher growth. Therefore, the existence of tuition fees or other admission barriers to higher education are important to obtain higher economic growth. This is important especially where ICT is developed and reduces the total costs for acquisition of higher education.

The empirical part tends to confirm the results of the model, i.e., that the rate of growth of countries, which are undertaking R&D and developing their ICT, is indeed related to the costs of acquisition of education.

These results are intriguing since they are counterintuitive. The conventional view on education is that higher tuition fees will lead to less investment in human capital and therefore to lower growth. In this model, higher tuition fees leads to higher growth because it permits to reveal the ability of individuals, and the high-ability workers will work efficiently in the sector that leads to growth – the R&D sector. In follow up research, we develop the next level of the model, actually creating a loop: the more rapid the economic growth, the more ICT is developed, which in turn influences the costs of higher education. In this way, the process of the model is repeated at a higher level of all its components

This paper has policy implication as well, and it permits to analyze the welfare effects of governmental policies in higher education. For instance, in some countries, and especially in Israel, as a part of the widespread trend towards the expansion of higher education and access to higher education to all, there were some propositions to cancel the entry exams to university and to reduce the tuition fees in universities. However in some other countries as the UK, there is a tendency to increase tuition. Our paper shows that the second type of policy leads to higher economic growth.

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