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Could Education Increase the Economic Growth of Mexico?

¿Podría la Educación Aumentar el Crecimiento Económico de México?

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ABSTRACT

This paper studies the role of education on the economic growth of Mexico. The Uzawa-Lucas Model is used to study the contribution of human capital on growth, while the specific role of education is accounted with a Vector Error Correction (VEC) Model. The main finding of this paper is that an increase of one percent in human capital implies an increase of 1.59 percent on Mexican Gross Domestic Product (GDP). And given the role of education on human capital, an increase of one percent in years of schooling causes an increase in the long run GDP growth rate of 2.19 percent.
Keywords: Economic Growth; Uzawa-Lucas Model; Human Capital; Education.
JEL Classification: C68; D58; I26; O41

RESUMEN

Este trabajo de investigación estudia el papel de la educación en el crecimiento económico de México. Se utiliza el modelo Uzawa-Lucas para estudiar la contribución del capital humano al crecimiento, mientras que el papel específico de la educación se estima con un Vector de Corrección de Errores (VEC). El principal hallazgo de este trabajo es que un aumento de uno por ciento en el capital humano implica un aumento de 1.59 por ciento en el Producto Interno Bruto (PIB) mexicano. Y dado el papel de la educación en el capital humano, un aumento del uno por ciento en los años de escolaridad provoca un aumento en la tasa de crecimiento del PIB a largo plazo del 2.19 por ciento.

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Palabras clave: Crecimiento Económico; modelo Uzawa-Lucas; Capital Humano; Educación.
Clasificación JEL: C68; D58; I26; O41.

INTRODUCTION

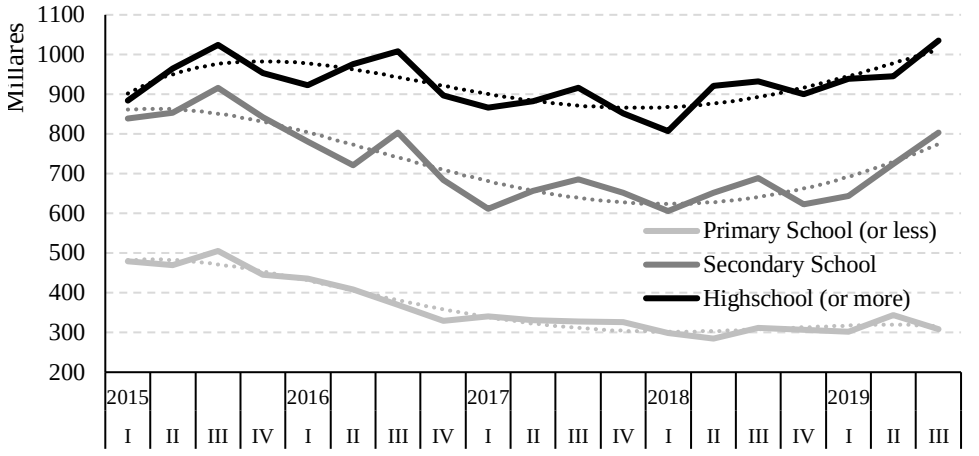
The economic growth of Mexico has been poor in the past four decades. And, although the economy has been stabilized in terms of inflation and debt, we have not seen again the high growth rates that Mexico had during the 60's and 70's. Likewise, despite the many structural reforms implemented at the end of the twentieth century, and more recently in 2013, the Mexican GDP has not grown as it was expected, in part due to the unfavorable external conditions. In this context a natural question is, how a developing economy, such as Mexico, could increase its growth rates?

In this paper, I propose to look at the education as a factor that promotes the economic growth in the long run and, which I consider a main component of human capital. Indeed, recently Manuelli et al. (2014) showed that human capital could be a more important factor of economic growth than what other authors have thought (Klenow et al. [1997]; Hall et al. [1999]; Parente et al. [2000]; and Bils et al. [2000]), and whom, in fact, downplayed the role of human capital in explaining economic growth. Specifically, the model proposed by Manuelli et al. (2014), implies that a large fraction of the cross-country differences in output are due to differences in the quality of human capital.

Likewise, other authors (Pelinescu [2015] and Teixeira et al. [2016]) have found empirical results that are consistent with the economic theory. Human capital improves the quality of labor, increasing its productivity and, hence, the economic growth. Hence, they have found a significant relationship between GDP per capita and human capital.

Nonetheless, we could say that the debate about the importance of human capital on the economic growth is still open. Indeed, some authors have suggested that human capital could be negatively related to employment rates (Ramos et al. [2009] and Čadil et al. [2014]). This negative relationship between employment and human capital (measured as educational attainment) can be observed in Mexican data (see Figure 1).

Figure 1
Number of unemployed Mexican workers



Source: Own elaboration with data of ENOE survey, INEGI.

We observe that, for Mexican data, the unemployment rate has an inverted U shape with respect to school attainment. This means that unemployment increases with schooling until college education, but those agents with graduate education levels have a lower unemployment rate (see Table 1, Figure 2). However, this negative correlation does not necessarily imply that human capital induces less growth. It could be the case that the positive effect of schooling can only be realized after an economy crosses a threshold level of development (Ahsan et al., 2017), which have not been reached yet by the Mexican economy.

Table 1
Unemployment for years of schooling

Schooling	Unemployment rate
Primary School (<6 years)	2.06
Secondary School (6-9 years)	3.75
Highschool (9-12 years)	4.54
College (12-16 years)	5.55
Master (16-18 years)	4.31
PhD (>18 years)	1.49

Source: ENOE 2019-III, INEGI.

On the other hand, with respect to the role of education, Hanushek et al. (2008) find that there is strong evidence that cognitive skills of population are powerfully related to individual earnings and economic growth. This is because education increases human capital of labor force, which increases labor productivity and transitional growth toward a higher equilibrium output level. But also, because education increases the innovative capacity of the economy, knowledge of new technologies, products and processes, and thus promotes growth (Benos et al., 2014).

Figure 2
Mexican unemployment rate by schooling

Note: Fitted values from a quadratic regression of unemployment on schooling.
Source: Own elaboration.

It is important to mention that there are two issues that are not addressed in this paper, but which are interesting for future research on the role of human capital in developing economies, for Mexico. The first one is the quality of education. Despite the gap between developed and developing economies has been partially reduced in terms of school attainment, there is still a serious gap in terms of the quality of education, which could play an important role for explaining the effect of education on economic growth (Hanushek, 2013).

The second issue is the labor market segmentation. Recently, it has been noticed the importance of considering a duality of forces in the labor market of

developing countries (Alcaraz et al. [2015], Valdivia et al. [2011] and Maloney [2004]). Indeed, in Mexico, two types of workers coexist in the labor market; those who belong to the formal sector and those who work in the informal sector. The crucial aspect of this duality is that a reduction of the fraction of workers in the informal sector could potentially increase productivity and, hence, increase economic growth.

Although the quality of education and the labor market segmentation are determinant factors, in this research I only focus on the education (measured as years of schooling) of a representative agent, as a variable that drives the economic growth of Mexico. I draw on the Uzawa-Lucas model (ULM), by using time series of the last thirteen years (on a quarterly basis). The reason why I use the ULM among the other endogenous growth models, which represent the household behavior, is because the former has a simpler and realistic representation of an economy, considering human capital as a core element. Thus, the ULM let me measure the role of human capital in the economy of a two-sector dynamic model. Since the sector that produces human capital is well defined in the model, I just had to introduce the role of education in the human capital accumulation. That is why I propose a VEC model of human capital, where schooling is one of the elements of it.

The estimation and interpretation of the model coefficients let me conclude that a one-percent increase in the human capital growth rate, in the long run, produces an increase of 1.59 percent in the Mexican GDP growth. Likewise, an increase of one percent in schooling causes an increase in long run GDP growth rate of 2.19 percent.

The remaining of the paper is organized as follows: In the first section I discuss the state of the art. In the second section I describe the theoretical economic growth model of Uzawa-Lucas. I present the empirics in the third section and explain the data and the Generalized Method of Moments (GMM). The results are presented in the fourth section and finally, the conclusions are presented.

I. Literature Review

One of the first papers that studied the effect of education on the economic growth of Mexico was conducted by Fuller et al. (1986), who find that improvements in the quality of education are more important than the expansion of education itself. Since then, the quality of education in Mexico has reached a minimum required level, so we expect to find a positive effect of education on economic growth even though the quality of education remains the same.

After the seminal contributions of Fuller et al. (1986), Díaz-Bautista (2000) highlights the role of human capital on the regional convergence among the states of Mexico and on the economic growth. Similar results are exposed by García-Verdú (2007), who finds that increases in educational attainment account for nearly one third of real GDP per worker.

The most related paper with my research is the one conducted by Gong et al. (2004), who modify the effects of education and human capital on growth in their variant of Uzawa-Lucas growth model, and test it using time series data from United States (U.S.) and Germany for the period 1962-I to 1996-IV. Gong et al. (2004) consider two versions of the model. The first version assumes that the time spent on education is exogenous and given and does not consider the external effect of human capital. In the second version, the time spent on education is an endogenous variable and the external effect of human capital is considered. Their results show that the model is consistent with the time series of U.S. and Germany, and that there is a nonlinear relationship between human capital and economic growth in both economies.

However, Gong et al. (2004) obtained a negative rate of accumulation of human capital in the original version of the ULM, which makes no sense. That is why they propose a modified version of the model.

From my knowledge, there are no other studies that examine the role of education in the economic growth of Mexico using endogenous growth models, however, there are some studies that get results pointing out to the positive effects of education on economic growth. For example, Ocegueda et al. (2004) analyze the process of regional growth in the border states of Mexico and the U.S. during the period 1975-2000. Their results suggest that human capital and economic specialization have played an important role in economic growth.

Additionally, related literature yields results that are consistent with theoretical predictions, despite its arguably rigurosity, for instance, Ocegueda et al. (2013) use panel data with human capital as the proportion of the population with some level of training obtained in different grades. The authors find that education played an important role in stimulating Mexican economic growth in the period 1990-2008. In another study, Meza et al. (2012) analyze whether the curse of natural resources is present in Mexico. For that purpose, they examine education and human capital during the period 1993-2003 and show that indeed natural resources affect economic growth negatively, while a greater level of education contributes positively. Nevertheless, caution should be taken with their results since they do not correct for endogeneity problems in their models.

On the other hand, Caselli et al. (2013) seek to answer the question of how GDP per worker would increase if workers had more schooling. To do this, they use an approximation to the problem by means of a nonparametric upper bound on output growth generated by more schooling. Their results suggest that, in 2000, if Mexican schooling increased at U.S. level (from 9 to 13 years of schooling), the Mexican GDP would increase by up to 88.6 percent. For the whole sample of 90 countries GDP growth would increase 61 percent, on average.

Interestingly, Hanushek et al. (2012) studied a puzzle among Latin American economies about the fact that the school attainment has increased but not the economic growth, in that region. The authors suggest that we should study the educational achievement, which fully accounts for the poor growth performance of Latin American countries. Nonetheless, for the case of Mexico, Levy and López-Calva (2016) explain the puzzle using the school attainment, they claim that highly educated workers are misallocated in firms that are intense in low educated workers.

In this research paper, I include the education measured as years of schooling (educational attainment), which means that the estimated effect of education on economic growth could be greater if we also increase the quality of education. I base my estimations on the ULM, and I estimate the parameters of technology and preferences with Mexico's time series data using the GMM. I also propose a VEC model in order to consider the role of education on human capital. This helps me to answer whether education has a positive effect on economic growth rates of Mexico.

II. The Uzawa-Lucas Model

The Uzawa-Lucas Model (ULM) is an endogenous growth model since the savings rate is endogenously determined by the parameters of preferences and technology. It contains scale effects in the sense that the increase in human capital formation increases the rate of balanced growth. The model has two sectors, one that produces the physical good using labor, physical capital and human capital, while the other produces the human capital using only human capital. The physical good can be consumed or invested in the creation of physical capital goods. The agent's preferences over consumption streams are defined as:

$$U(c) = \int_0^{\infty} L(t) \frac{c(t)^{1-\sigma} - 1}{1-\sigma} e^{-\rho t} dt \qquad (1)$$

where L is labor, ρ is the discount factor, $\frac{1}{\sigma} > 0$ is the intertemporal elasticity of substitution of consumption, and $c = \frac{C}{L}$ is consumption per worker.

I assume that in the economy there is a representative skilled worker with ability level h, who spend a fraction $u(t)$ of her no-leisure time to the current production, while she spends a fraction $(1 - u(t))$ of her no-leisure time to the accumulation of human capital.

The resources constraint is given by:

$$L(t)c(t) + \dot{K}(t) = AK(t)^{\alpha}[u(t)h(t)L(t)]^{1-\alpha} h_a^{\zeta}(t) \qquad (2)$$

where $Y(t) = AK(t)^{\alpha}[u(t)h(t)L(t)]^{1-\alpha} h_a^{\zeta}(t)$ is the production function, A is the constant level of technology, $\alpha \in (0,1)$ is the share of capital (K) in production,

h is the human capital and $\zeta \geq 1$ is the parameter of externality, hence, the term h_a^{ζ} captures the external effects of human capital.

The equation (2) implies that human capital is a non-excludable public good but is a rival one.[1] Lucas (1988) uses the following linear formulation of Uzawa-Rosen:

$$\dot{h}(t) = h(t)\kappa(1 - u(t)) \qquad (3)$$

where κ is the maximum growth rate of human capital.

The intuition of equation (3) is as follows: if no effort is devoted to human capital accumulation, $u(t) = 1 \Longrightarrow \dot{h}(t) = 0$. If all the effort is devoted to the accumulation of human capital, $u(t) = 0$ then $h(t)$ grows at the rate κ. Also, notice that I assume that human capital does not depreciate; the intuition is that knowledge and skills do not deteriorate over time as physical capital do.

In summary, the solution of the model is given by the following maximization problem over consumption and the proportion of no-leisure time spent in the production sector:

$$\max_{c,u} \int_0^{\infty} L(t) \frac{c(t)^{1-\sigma} - 1}{1 - \sigma} e^{-\rho t} dt$$

subject to the resource constraint and the Uzawa-Rosen condition for human capital accumulation:

$$\dot{K}(t) = AK(t)^{\alpha}[u(t)h(t)L(t)]^{1-\alpha} h_a^{\zeta}(t) - L(t)c(t)$$
$$\dot{h}(t) = h(t)\kappa(1 - u(t))$$
$$K(0) \geq 0, \quad h(0) \geq 0$$

According to Lucas (1988), in the presence of an external effect h_a^{ζ}, the optimal path of growth and competitive growth path should not necessarily have to match with each other. Hence, it is not possible to construct the equilibrium analogous to that in Solow (1957). However, it is possible to do so in the way that Romer (1990) suggests, by obtaining the optimal paths and equilibrium separately and comparing them.

An optimal path is defined as the choice of *K(t)*, *h(t)*, $h_a(t)$, *c(t)* and *u(t)* that maximizes utility, subject to (2) and (3), and to the constraint $h(t) = h_a(t)$ for all t.

Hence, for an equilibrium path, first take a path $h_a(t)$, $t \geq 0$ as given. With $h_a(t)$ given, consider the problem of the private sector (households and firms) that

[1] In this case human capital is a public good that is subject to congestion because the overall level of human capital per worker, $\frac{Lh}{L}$, increases the efficiency of input labor, *L*.

would be solved if each agent had the average level of human capital that follows the path $h_a(t)$. That is, to solve the problem of choosing *h(t)*, *k(t)*, *c(t)* and *u(t)* that maximize utility, subject to (2) and (3), taking $h_a(t)$ as exogenously determined. When the path of solution *h(t)* match the path given $h_a(t)$ the system is in equilibrium (Lucas, 1988).

The Hamiltonian of the problem is:

$$\mathcal{H}(K,h,\theta_1,\theta_2,c,u) = L\frac{c^{1-\sigma}-1}{1-\sigma} + \theta_1\left[AK^{\alpha}(uhL)^{1-\alpha}h_a^{\zeta} - Lc\right] + \theta_2[h\kappa(1-u)]$$

In this model there are two control variables: consumption, *c(t)*, and the time devoted to production, *u(t)*, which are selected to maximize the Hamiltonian, $\mathcal{H}$.

First Order Conditions:

$$c^{-\sigma} = \theta_1$$
$$\theta_1(1-\beta)AK^{\alpha}[uhL]^{-\alpha}Lh^{1+\zeta} = \theta_2 h\kappa$$

The rates of change in prices θ_1 and θ_2 of the two types of capital are given by:

$$\dot{\theta}_1 = \rho\theta_1 - \theta_1 AK^{\alpha-1}[uhL]^{1-\alpha}h^{\zeta}$$
$$\dot{\theta}_2 = \rho\theta_2 - \theta_1(1-\alpha+\zeta)AK^{\alpha}[uL]^{1-\alpha}h^{-\alpha+\zeta} - \theta_2\kappa(1-u)$$

and the transversality conditions are:

$$\lim_{t\to\infty} e^{-\rho t}\,\theta_1(t)\mathrm{K(t)} = 0$$
$$\lim_{t\to\infty} e^{-\rho t}\,\theta_2(t)\mathrm{h(t)} = 0$$

Let γ be the growth rate of per capita consumption $\frac{\dot{c}(t)}{c(t)}$,

$$\alpha AK(t)^{\alpha-1}[u(t)h(t)L(t)]^{1-\alpha}h(t)^{\zeta} = \rho - \sigma\gamma \qquad (4)$$

where ρ is the discount factor and $\frac{1}{\sigma} > 0$ is the intertemporal elasticity of substitution of consumption.

K(t) must grow at the rate $\gamma + n$ (where *n* is the rate of population growth rate) and the savings rate *s* is constant on a balanced growth path, with a value given by:

$$s = \frac{\alpha(\gamma+n)}{\rho+\sigma\gamma} \qquad (5)$$

Let $\psi = \frac{\dot{h}(t)}{h(t)}$ be now in a balanced path; it is clear from (2) that:

$$\psi = \kappa(1-u)$$

Differentiating (4) and solving for γ, the growth rate of per capita consumption and capital is:

$$\gamma = \left(\frac{1-\alpha+\zeta}{1-\alpha}\right)\psi$$

Thus, with *h(t)* growing to a fixed rate ψ, the term $(1-\alpha+\zeta)\psi$ plays the role of an exogenous rate of technological change, which decreases with β and increases with ζ and ψ.

Using the above, the growth rate of human capital efficiency is:

$$\psi^* = \sigma^{-1}\left[\kappa - \left(\frac{1-\alpha+\zeta}{1-\alpha}\right)(\rho - n)\right] \qquad (6)$$

By the same procedure used to derive the effective growth rate ψ^*, we can obtain the equilibrium growth rate ψ:

$$\psi = \frac{(1-\alpha)[\kappa - (\rho - n)]}{\sigma(1-\alpha+\zeta)-\zeta} \qquad (7)$$

From equations (6) and (7) the efficient and competitive growth rates of human capital are obtained, in a balanced path. In both cases, growth increases with effective investment in human capital κ, and decreases when the discount rate ρ increases. Notice that theory predicts sustained growth with or without externalities ζ. If $\zeta = 0$, $\gamma = \psi$, while if $\zeta > 0$, $\gamma > \psi$, the externalities induce to a faster human capital than physical capital growth (Lucas, 1988).

III. EMPIRICS

According to Gong et al. (2004) even though the scale effects may occur in the early stages of growth, they appear not to be observed for the time series from the U.S. and Germany. In both countries, the time spent in education increases, however the rate of growth of human capital decreases slightly over time. For this reason, the estimation of equation (2) produces a negative κ, which does not make sense to economic theory.

I expect to get the correct sign of the parameter κ for the case of Mexico, since its accumulation of human capital is lower than in Germany and the U.S. I use the GMM in order to estimate the parameters of the ULM.

Parameter estimation procedure

The reverse causality of growth and human capital accumulation implies an endogeneity problem. Hence, the estimation of the parameters in the ULM using Ordinary Least Squares (OLS) produces biased and inconsistent estimators. In

addition, equations are not linear, so it is inappropriate to apply OLS. Given these problems, I use the GMM to work with nonlinear equations and to deal with the endogeneity concern for the reverse causality of human capital and economic growth.

Solving the first order conditions of the ULM, yields the following system of four differential equations:[2]

$$\frac{\dot{k}}{k} = Ak^{\alpha-1}u^{1-\alpha}h^{1-\alpha+\zeta} - \frac{c}{k} \tag{8}$$

$$\frac{\dot{c}}{c} = \frac{\alpha}{\sigma}Ak^{\alpha-1}u^{1-\alpha}h^{1-\alpha+\zeta} - \frac{\rho}{\sigma} \tag{9}$$

$$\frac{\dot{h}}{h} = \kappa(1-u) \tag{10}$$

$$\frac{\dot{u}}{u} = \frac{(\alpha-\zeta)}{\alpha}\kappa u + \frac{(1-\alpha+\zeta)}{\alpha}\kappa - \frac{c}{k} \tag{11}$$

In order to estimate the parameters of the model, I express the above equations as:

$$\frac{k_{t+1}-k_t}{k_t} = Ak_t{}^{\alpha-1}u_t{}^{1-\alpha}h_t{}^{1-\alpha+\zeta} - \frac{c_t}{k_t}$$

$$\frac{c_{t+1}-c_t}{c_t} = \frac{\alpha}{\sigma}Ak_t{}^{\alpha-1}u_t{}^{1-\alpha}h_t^{1-\alpha+\zeta} - \frac{\rho}{\sigma}$$

$$\frac{h_{t+1}-h_t}{h_t} = \kappa(1-u_t)$$

$$\frac{u_{t+1}-u_t}{u_t} = \frac{(\alpha-\zeta)}{\alpha}\kappa u_t + \frac{(1-\alpha+\zeta)}{\alpha}\kappa - \frac{c_t}{k_t}$$

We are interested in the following vector of parameters:

$$b \equiv \begin{pmatrix} A \\ \alpha \\ \kappa \\ \rho \\ \sigma \\ \zeta \end{pmatrix}$$

Which is estimated using the following system of equations:

$$k = Ak_t{}^{\alpha-1}u_t{}^{1-\alpha}h_t{}^{1-\alpha+\zeta} - \frac{c_t}{k_t} + \varepsilon_1$$

$$c = \frac{\alpha}{\sigma}Ak_t{}^{\alpha-1}u_t{}^{1-\alpha}h_t^{1-\alpha+\zeta} - \frac{\rho}{\sigma} + \varepsilon_2$$

$$h = \kappa(1-u_t) + \varepsilon_3$$

[2] The entire development is in the Annex A.1.

$$u = \frac{(\alpha - \zeta)}{\alpha}\kappa u_t + \frac{(1 - \alpha + \zeta)}{\alpha}\kappa - \frac{c_t}{k_t} + \varepsilon_4$$

Where the errors ε_i, for *i=1,…,4*, are assumed white noise; $k = \frac{k_{t+1} - k_t}{k_t}$ is a vector of $n \times 1$ dimensions; $c = \frac{c_{t+1} - c_t}{c_t}$ is a vector of $n \times 1$ dimensions; $h = \frac{h_{t+1} - h_t}{h_t}$ is a vector of $n \times 1$ dimensions and; $u = \frac{u_{t+1} - u_t}{u_t}$ is a vector of $n \times 1$.

Rewriting as a matrix and taking the expectation:

$$E\begin{pmatrix} k + \frac{c_t}{k_t} - A{k_t}^{\alpha-1}{u_t}^{1-\alpha}{h_t}^{1-\alpha+\zeta} \\ c + \frac{\rho}{\sigma} - \frac{\alpha}{\sigma}A{k_t}^{\alpha-1}{u_t}^{1-\alpha}h_t^{1-\alpha+\zeta} \\ h - \kappa(1 - u_t) \\ u + \frac{c_t}{k_t} - \frac{(\alpha - \zeta)}{\alpha}\kappa u_t + \frac{(1 - \alpha + \zeta)}{\alpha}\kappa \end{pmatrix} = E\begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \end{pmatrix}$$

Given that the errors ε_i are white noise:

$$E\begin{pmatrix} k + \frac{c_t}{k_t} - A{k_t}^{\alpha-1}{u_t}^{1-\alpha}{h_t}^{1-\alpha+\zeta} \\ c + \frac{\rho}{\sigma} - \frac{\alpha}{\sigma}A{k_t}^{\alpha-1}{u_t}^{1-\alpha}h_t^{1-\alpha+\zeta} \\ h - \kappa(1 - u_t) \\ u + \frac{c_t}{k_t} - \frac{(\alpha - \zeta)}{\alpha}\kappa u_t + \frac{(1 - \alpha + \zeta)}{\alpha}\kappa \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \qquad (12)$$

Where (12) is known as the *moment conditions*. Define $g_T(b)$ as the sample mean of the errors ε_i, for the vector of parameters b in a sample of size T.

$$g_T(b) = \frac{1}{T}\sum_{t=1}^{T}\varepsilon_t(b) = E_T[\varepsilon_t(b)] = E_T\begin{pmatrix} k + \frac{c_t}{k_t} - A{k_t}^{\alpha-1}{u_t}^{1-\alpha}{h_t}^{1-\alpha+\zeta} \\ c + \frac{\rho}{\sigma} - \frac{\alpha}{\sigma}A{k_t}^{\alpha-1}{u_t}^{1-\alpha}h_t^{1-\alpha+\zeta} \\ h - \kappa(1 - u_t) \\ u + \frac{c_t}{k_t} - \frac{(\alpha - \zeta)}{\alpha}\kappa u_t + \frac{(1 - \alpha + \zeta)}{\alpha}\kappa \end{pmatrix}$$

The first step of estimating b consists of minimizing the quadratic form of the sample mean of the errors.

$$\hat{b}_1 = \underset{\hat{b}}{argmin}\, g_T(\hat{b})' W g_T(\hat{b})$$

From where we started taking the weighting matrix W as the identity matrix $W = \mathbb{I}$. The estimator obtained is consistent and asymptotically normal. Then, $\hat{b}_1$ is used to construct an estimate $\hat{S}$ of the covariance matrix of the errors:

$$S \equiv \sum_{j=-\infty}^{\infty} E\left[\varepsilon_t(b)\varepsilon_{t-j}(b)'\right]$$

Accordingly, in a second stage $\hat{b}_2$ is estimated using the inverse of the covariance matrix $\hat{S}^{-1}$ as the weighting matrix in the quadratic form of the errors:

$$\hat{b}_2 = \underset{b}{argmin}\, g_T(b)'\hat{S}^{-1}g_T(b)$$

Now, $\hat{b}_2$ is an asymptotically normal, asymptotically efficient and consistent estimator of the vector of parameters b.

Data

To carry out the implementation of the model, I need data of human capital in Mexico. Generally, human capital includes the unobserved stock of knowledge and skills of a person, which increases her productivity. This stock may be acquired through school but could also be acquired outside the formal education system.

Figure 3
Mexican Human Capital

Source: Own elaboration based on Mulligan and Sala-i-Martin (1997) methodology, using data from INEGI.

Hence, in a broad definition, the measurement of human capital should cover formal and informal education, physical and mental skills, nutrition and social services that affect the quality of work.

Mulligan et al. (1997) propose to measure human capital as the average labor income in state *i* divided by the wage of workers with zero schooling in the same state:

$$h_i(t) = \frac{\int_0^\infty w_i(t,s)\eta_i(t,s)ds}{w_i(t,0)}$$

This means that the quality of a person would be related to the wage rate received in the market. If the type of education that a person received was helpful, markets reward you with a high salary. Similarly, if a person is devoted to study a field that is not useful from the point of view of production, the productive human capital of that person would be low.

In order to capture all the components of human capital, in this study I use the methodology proposed by Mulligan et al. (1997). I use the average wage and the number of workers in order to obtain the average labor income, both variables are available at the National Survey of Occupation and Employment (ENOE, by its acronym in Spanish). I also assume that the salary of an unskilled person is equivalent to the minimum wage per day, which is available at the National Minimum Wage Commission. Notice that the estimated human capital that I obtained is consistent with the official estimation of labor productivity published by INEGI (see Figure 3). The relation between both variables seems to lose after the 2008-2009 financial crisis.

On the other hand, I used the System of National Accounts (SNA) in order to obtain data of GDP, consumption and capital. Additionally, I got data of GDP produced in the health sector, which is also available in the SNA, and data of schooling come from the ENOE. All data have a quarterly frequency, except the minimum wage, which have an annual frequency.[3] Furthermore, all variables are seasonally adjusted with the official models of INEGI, meanwhile I adjusted the series from ENOE with the X13-ARIMA program.

Moreover, the model requires an approximation of the no-leisure time devoted to current production, u. To do this, I follow a similar methodology as Gong et al. (2004), that is; although it is recognized that the time devoted to human capital accumulation involves many years of schooling, work experience, etc.; the number of students across the country in a given school year is estimated as a fraction of total employment. The intuition is that, by using this ratio of the number of Mexicans who are studying, I capture the effect of those agents who spend time in education rather than going to work.

$$(1-u) = \frac{number\_of\_students}{L}$$

[3] This is not a concern, since the minimum wage changes annually at the beginning of each year.

VEC Model for Human Capital

In response to the fact that the variable "human capital" constructed in this study does not distinguish between the contribution of education, experience or abilities, I propose a VEC model for human capital to identify solely the effect of education on economic growth.

Table 2
VEC Model of Human Capital

Dependent Variable: DLOG(Human-Capital) Method: Least Squares Sample: 2006QII - 2016QIV		
Variable	Coefficient	t-Statistic
LOG(Human-Capital(-1))	-0.084*** (0.024)	-3.30
LOG(Schooling(-1))	0.342*** (0.119)	2.09
LOG(Health(-1))	-0.257** (0.110)	-3.54
DUMMY1304	0.028** (0.011)	7.03
DUMMY1401	-0.027** (0.011)	-2.52
DLOG(Human-Capital(-3))	0.189* (0.099)	1.91
DLOG(Schooling)	1.623* (1.231)	1.83
DLOG(Schooling(-3))	0.888* (0.689)	1.79
DLOG(Health(-2))	0.163*** (0.059)	2.77
R-squared	0.730	
Adjusted R-squared	0.622	
S.E. of regression	0.010	
Durbin-Watson statistic	1.867	

Standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1
Source: Author´s calculations.

In order to control for other variables that could influence human capital, I include in the model the GDP produced for the health sector, meanwhile I measure the education as years of schooling. On the other hand, notice that the GDP produced in health sector does not mean the accumulation of heath, on the contrary, it means the accumulation of sickness. Hence, I expect a positive sign for years of schooling but a negative sign for the variable "health".

In my VEC model,[4] the cointegration vector is represented by the (three) first variables in logarithms. Thus, I find that, in the long run, one percent increase in years of schooling produce a 0.342 percent increase in human capital (for quarterly growth rates). On the other hand, I find that a bad health abates the formation of human capital in a rate of 0.257 percent (see Table 2).

IV. RESULTS

I find that solving the ULM with data from Mexico does not yield, in general, the conventional parameters, which means that this model does not represents adequately this developing economy. However, I imposed some restrictions to get results consistent with the theory, i.e. I constrained: $0 \leq \alpha \leq 1$, and $A, \rho, \sigma \geq 0$.

Table 3
Uzawa-Lucas Model Estimation

Parameters	Mexico/1	USA/2	Germany/2
A	1.01***	0.06***	0.05***
	(0.32)	(0.01)	(0.00)
α	0.38***	0.54***	0.48
	(0.08)	(0.13)	(0.36)
ρ	0.38**	0.03***	0.01***
	(0.18)	(0.00)	(0.00)
σ	4.47***	1.55	0.40***
	(1.01)	(1.17)	(0.10)
κ	0.48***	0.07***	0.06***
	(0.18)	(0.00)	(0.01)
ζ	0.97***	-0.01	0.01
	(0.31)	(0.07)	(0.39)

[4] All variables in the VEC model are integrated of order one, according to the conventional unit root tests (ADF, PP and KPSS tests), and are also cointegrated according to the Johansen cointegration test (see Annex).

Equations		*DW Test*	
(8)	1.8	1.9	1.9
(9)	1.8	1.8	2.0
(10)	1.7	1.3	0.9
(11)	2.3	0.2	0.3

/1 Results obtained using the Generalized Method of Moments (GMM) with Mexican data.
/2 Results from Gong et al. (2004) for their modified ULM.
Standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1
Source: Own calculations

Table 3 shows the results of the coefficients estimated from the ULM. Once I impose the afore mentioned restrictions, the coefficients' magnitudes and signs are consistent with theoretical predictions. For example, the share of physical capital is roughly one third, just as the convention in literature. The elasticity of substitution, $1/\sigma = 0.22$, is also consistent with the convention in macroeconomic models (Campbell and Mankiw [1989], and Lucas [2003]). The coefficient of the rate at which human capital accumulates, is positive and greater than the one estimated by Gong et al. (2004), $\kappa = 0.48$, which means that if individuals dedicated all their no-leisure time to the accumulation of human capital, this would increase in 0.48 percent. Additionally, the coefficient of human capital externality is also statistically significant, $\zeta = 0.97$, unlike the one obtained by Gong et al. (2004).

The hypothesis that an increase in human capital increases production, is confirmed; indeed, I find that the increment in production is about 1.59 percent,[5] once human capital increases in one percent. Thus, an increase of one percent in years of schooling causes an increase of the long run GDP growth rate of 2.19 percent.[6] Notice that data of human capital has a quarterly basis, hence, the contribution of schooling in human capital (0.34) of Table 2 has an annualized rate of 1.38 percent.

Once I obtain the estimated coefficients, I proceed to analyze the model equilibrium at the steady state (Table 4). I find that, considering the positive externalities of human capital ($\zeta > 0$), the GDP per capita equilibrium growth rate is 0.65 percent. Human capital grows at an annual rate of 3.03 percent, and per capita consumption grows at 1.67 percent. All those growth rates are consistent with a savings rate of 3.51 percent (for all these results I considered an annual population growth rate of 1.5 percent, which is the average growth rate in the period studied).

[5] The increase of 1.59 percent comes from the sum of the exponent of human capital and the exponent of human capital externalities: $(1-\alpha)+\zeta = (1-0.38)+0.97$=1.59

[6] The increase of 2.19 percent comes from the product of the contribution of human capital on GDP and the annualized contribution of years of schooling on human capital (1.38): $(1.59)(1.38) = 2.19$

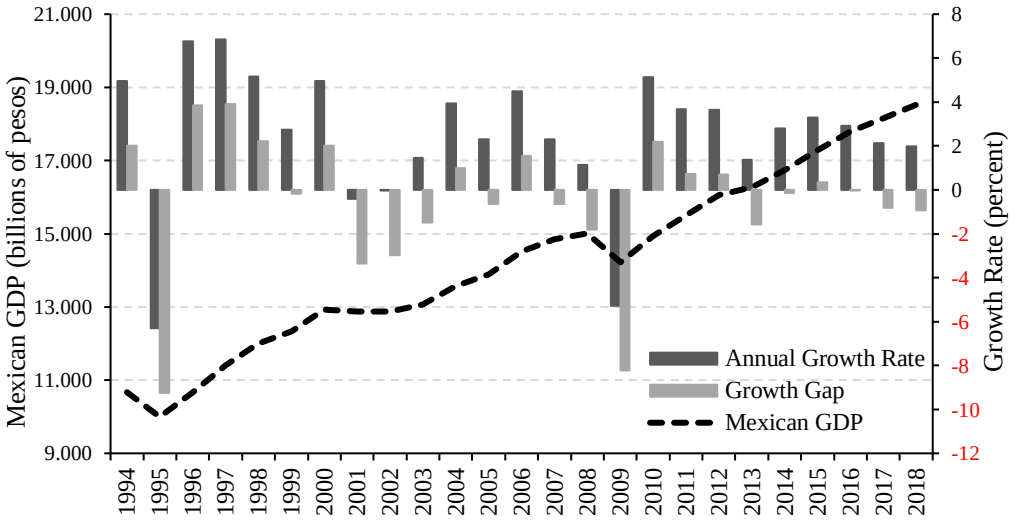
Table 4
Model equilibrium at the steady state

Equilibrium steady state		ζ>0		ζ=0	
		Quarterly growth	Annualized growth	Quarterly growth	Annualized growth
Growth rate of GDP per capita	ψ	0.16	0.65	0.36	1.44
Growth rate of human capital	ψ*	0.75	3.03	0.36	1.44
Growth rate of per capita consumption	γ	0.41	1.67	0.36	1.44
Savings rate	*s*	0.87	3.51	0.95	3.84

Note: The growth rates at the steady state were computed using the ULM parameters estimated using the GMM.
Source: Own calculations.

Notice that since theory predicts sustained growth with or without externalities, we can now analyze the equilibrium at the steady state without externalities, i.e. $\zeta = 0$; in that case, GDP per capita, human capital and consumption per capita grow at the same rate, i.e. an equilibrium annual growth rate of 1.44 percent, which is consistent with a savings rate of 3.84. These findings imply that the Mexican economy has a potential annual growth rate of 2.94 percent (1.44 of GDP growth + 1.5 of population growth). This means that, in 2016, the Mexican GDP growth was near its potential growth, but in 2017 the growth rate was 1.1 percentage points under its potential (Figure 4).

Figure 4
Mexican growth rate and growth gap



Source: Own elaboration with INEGI data and the potential growth rate estimated of 2.94 percent.

CONCLUSIONS

In this research I measure the effect of education on economic growth in a developing economy. For that purpose, I use Mexican time series to taste the Uzawa-Lucas Model (ULM) with the Generalized Method of Moments (GMM). Given that the ULM explains the influence of human capital on economic growth (but not the education on growth), I propose a VEC model of human capital in order to consider the indirect effect of education on the economic growth.

My results provide evidence that a rise of one percent in years of schooling increases human capital accumulation by 0.34 percent, on a quarterly basis, and at an annualized rate of 1.38 percent. Moreover, I find that an increase of one percent in human capital increases GDP by 1.59 percent. Thus, a rise of one percent in years of schooling causes an increase of the long run GDP growth rate of 2.19 percent. Additionally, based on the results of my VEC model, I conclude that a bad health abates the formation of human capital in a rate of 0.26 percent (on a quarterly basis).

Furthermore, omitting the effect of human capital externalities, I find that the Mexican economy has a potential annual growth rate of 2.94 percent. This result could be useful to policymakers (for example, as an additional estimation of the output gap,

which is of interest for the Central Bank when taking monetary policy decisions) and as a reference to further research on the estimation of Mexican potential growth rate. Likewise, the parameters estimation that I have done in this research can also be used as a referent for future research, especially for the calibration of Macroeconomic models.

Finally, future research should consider two important issues that were not included in this paper. First, although I found that an increase in the educational attainment will increase the economic growth of Mexico, it is also true that my findings assume no changes in the quality of education. Improving the quality of education and rising the educational attainment would produce an even better effect on growth. Second, the segmentation of the Mexican labor market implies that an important proportion of workers considered in this research have a low productivity. Hence, since my results are based on an average of productive and unproductive workers, an increase of the years of schooling in each of both sectors is uncertain. My hypothesis is that increments of educational attainment in the productive (formal) sector would improve, even more, the economic growth of Mexican GDP.

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REFERENCES

Ahsan, Humna, and M. Emranul Haque (2017). Threshold effects of human capital: Schooling and economic growth. *Economics Letters*, Vol. 156, July, pp. 48-52. https://doi.org/10.1016/j.econlet.2017.04.014

Alcaraz, Carlo, Daniel Chiquiar, and Alejandrina Salcedo (2015). Informality and segmentation in the Mexican labor market. Banco de México Working Paper series (No. 2015-25).

Benhabib, Jess and Roberto Perli (1994). Uniqueness and indeterminacy. *Journal of Economic Theory*, Vol. 63 (1), pp. 113-142. https://doi.org/10.1006/jeth.1994.1035

Benos, Nikos and Stefania Zotou (2014). Education and economic growth: A meta-regression analysis. *World Development*, Vol. 64, pp. 669-689. https://doi.org/10.1016/j.worlddev.2014.06.034

Bils, Mark and Peter J. Klenow (2000). Does schooling cause growth? *American Economic Review*, Vol. 90 No. 5, pp. 1160-83. DOI: 10.1257/aer.90.5.1160

Čadil, Jan, Ludmila Petkovová, and Dagmar Blatná (2014). Human capital, economic structure and growth. *Procedia Economics and Finance*, Vol. 12, pp. 85-92.
https://doi.org/10.1016/S2212-5671(14)00323-2

Campbell, John Y., and N. Gregory Mankiw (1989). Consumption, income, and interest rates: Reinterpreting the time series evidence. *NBER macroeconomics annual*, Vol 4, pp. 185-216. https://doi.org/10.1086/654107

Caselli, Francesco and Antonio Ciccone (2013). The contribution of schooling in development accounting: Results from a nonparametric upper bound. *Journal of Development Economics*, Vol. 104, pp. 199-211.
https://doi.org/10.1016/j.jdeveco.2013.02.006

Díaz Bautista, A. (2000). Convergence and economic growth in Mexico. *Frontera norte*, Vol. 12 No.24, pp. 85-110.

Fuller, Bruce, John H. Edwards, and Kathleen Gorman (1986). When does education boost economic growth? School expansion and school quality in Mexico. *Sociology of Education*, Vol. 59, No. 3, pp. 167-181. DOI: 10.2307/2112341

García-Verdú, Rodrigo (2007). Demographics, Human Capital and Economic Growth in Mexico: 1950-2005. Unpublished Manuscript.

Gong, Gang, Alfred Greiner and Willi Semmler (2004). The Uzawa-Lucas model without scale effects: Theory and empirical evidence. *Structural Change and Economic Dynamics*, Vol. 15 No. 4, pp. 401-420.
https://doi.org/10.1016/j.strueco.2003.10.002

Hall, Robert and Charles Jones. (1999). Why do some countries produce so much more output per worker than others? *The Quarterly Journal of Economics*, Vol. 114 No. 1, pp. 83-116. https://doi.org/10.1162/003355399555954

Hanushek, Eric A. (2013). Economic growth in developing countries: The role of human capital. *Economics of Education Review*, Vol. 37, 204-212.
https://doi.org/10.1016/j.econedurev.2013.04.005

Hanushek, Eric A. and Ludger Woessmann. (2008). The role of cognitive skills in economic development. *Journal of Economic Literature*, Vol. 46 No. 3, pp. 607-668. DOI: 10.1257/jel.46.3.607

Hanushek, Eric A., and Ludger Woessmann. (2012). Schooling, educational achievement, and the Latin American growth puzzle. *Journal of Development Economics*, Vol. 99 No. 2, pp. 497-512.
https://doi.org/10.1016/j.jdeveco.2012.06.004

Klenow, Peter and Andrés Rodríguez-Clare. (1997). The Neoclassical revival in growth economics: Has it gone too far? In *NBER Macroeconomics Annual 1997*. Vol. 12, pp. 73-103. https://doi.org/10.1086/654324

Levy, Santiago, and López-Calva, Luis (2016). Labor earnings, misallocation, and the returns to education in Mexico. IDB Working Paper Series Nº IDB-WP-671.
http://dx.doi.org/10.2139/ssrn.2956686

Lucas Jr., Robert E. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, Vol. 22, No. 1, pp. 3-42.
https://doi.org/10.1016/0304-3932(88)90168-7

Lucas Jr., Robert E. (2003). Macroeconomic priorities. *American economic review*, Vol. 93 No 1, pp. 1-14. DOI: 10.1257/000282803321455133

Maloney, William F. (2004). Informality revisited. *World development*, Vol. 32 No. 7, pp. 1159-1178. https://doi.org/10.1016/j.worlddev.2004.01.008

Manuelli, Rodolfo E. and Ananth Seshadri (2014). Human capital and the wealth of nations. *The American Economic Review*, Vol. 104, No 9, pp. 2736-2762.
DOI: 10.1257/aer.104.9.2736

Meza, Juan A., Karla Barrón and José Urciaga (2012). Recursos naturales y crecimiento económico, analizando el capital humano en México. *Revista Internacional Administración y Finanzas*, Vol. 5, No. 1, pp. 93-102.

Mulligan, Casey B. and Xavier Sala-i-Martin (1997). A labor income-based measure of the value of human capital: An application to the states of the United States. *Japan and the World Economy*, Vol. 9 No. 2, pp. 159-191. https://doi.org/10.1016/S0922-1425(96)00236-8

Ocegueda, Juan M. and Gladys Plascencia (2004). Crecimiento económico en la región fronteriza de México y Estados Unidos: Una contrastación empírica de la hipótesis de convergencia." *Frontera Norte*, Vol. 16 No. 31, pp. 7-26.

Ocegueda, Juan M., Juan Meza y Domingo Coronado (2013). Impacto de la educación en el crecimiento económico en México, 1990-2008. *Revista Internacional de Administración y Finanzas*, Vol. 6 No. 1, pp. 75-88.

Parente, Stephen and Edward Prescott. (2000). *Barriers to Riches*. Cambridge, MA: MIT Press.

Pelinescu, Elena (2015). The impact of human capital on economic growth. *Procedia Economics and Finance*, Vol. 22, pp. 184-190.
https://doi.org/10.1016/S2212-5671(15)00258-0

Ramos, Raul, Jordi Suriñach, and Manuel Artís (2012). Regional economic growth and human capital: the role of over-education. *Regional Studies*, Vol. 46, No. 10, pp. 1389-1400.
https://doi.org/10.1080/00343404.2012.675140

Romer, Paul. (1990). Endogenous technological change. *The Journal of Political Economy*, Vol. 98 No. 5, pp. 71-102. https://www.jstor.org/stable/2937632

Solow, Robert M. (1957). Technical change and the aggregate production function. *The Review of Economics and Statistics*, Vol. 39 No. 3, pp. 312-320. DOI: 10.2307/1926047

Teixeira, Aurora A., and Anabela S. Queirós (2016). Economic growth, human capital and structural change: A dynamic panel data analysis. *Research policy*, Vol. 45 No. 8, pp. 1636-1648. https://doi.org/10.1016/j.respol.2016.04.006

Uzawa, Hirofumi (1965). Optimum technical change in an aggregative model of economic growth. *International Economic Review*, Vol. 6 No. 1, pp. 18-31. DOI: 10.2307/2525621

Valdivia López, Marcos, and Mercedes Pedrero Nieto (2011). Segmentación laboral, educación y desigualdad salarial en México. *Revista mexicana de sociología*, Vol. 73 No. 1, pp. 139-175.

ANNEX

A.1. Differential equations to be estimated in the Uzawa-Lucas model with externalities

To keep the notation of the model without externalities, in order to estimate its parameters, we express the first order conditions as:

$$c^{-\sigma} = \theta_1$$
$$\theta_2 h\kappa = \alpha\theta_1 u^{-\alpha} AK^{\alpha}[hL]^{1-\alpha} {h_a}^{\zeta}$$
$$\dot{\theta}_1 = \rho\theta_1 - \theta_1 \alpha AK^{\alpha-1}[uhL]^{1-\alpha} {h_a}^{\zeta}$$
$$\dot{\theta}_2 = \rho\theta_2 - \theta_1(1-\alpha)h^{-\alpha}AK^{\alpha}[uL]^{1-\alpha}{h_a}^{\zeta} - \theta_2\kappa(1-u)$$
$$\lim_{t\to\infty} e^{-\rho t}\,\theta_1(t)\mathrm{K(t)} = 0$$
$$\lim_{t\to\infty} e^{-\rho t}\,\theta_2(t)\mathrm{h(t)} = 0$$

Following Benhabib and Perli (1994) we obtain the system of four equations *k*, *h*, *c* y *u*, where $k = \frac{K}{L}$ and $c = \frac{C}{L}$. From the resources constraint we have:

$$\dot{K} = AK^{\alpha}[uhL)]^{1-\alpha} h_a^{\zeta} - Lc$$

Assuming that in equilibrium $h_a = h$ and rearranging:

$$\dot{K} = AK^{\alpha}u^{1-\alpha}h^{1-\alpha+\zeta}L^{1-\alpha} - Lc$$

Dividing both sides by *L*:

$$\dot{k} = A\left(\frac{K}{L}\right)^{\alpha} u^{1-\alpha}h^{1-\alpha+\zeta} - c$$

Dividing both sides by *k*:

$$\frac{\dot{k}}{k} = Ak^{\alpha-1}u^{1-\alpha}h^{1-\alpha+\zeta} - \frac{c}{k}$$

From the F.O.C. we have:

$$-\sigma\frac{\dot{c}}{c}=\frac{\dot{\theta}_1}{\theta_1}$$

And that:

$$\dot{\theta}_1=\rho\theta_1-\theta_1\alpha AK^{\alpha-1}[uhL]^{1-\alpha}{h_a}^{\zeta}$$

$$\frac{\dot{\theta}_1}{\theta_1}=\rho-\alpha AK^{\alpha-1}u^{1-\alpha}h^{1-\alpha+\zeta}L^{1-\alpha}=\rho-\alpha Ak^{\alpha-1}u^{1-\alpha}h^{1-\alpha+\zeta}$$

Using the above two results:

$$\frac{\dot{c}}{c}=\frac{\alpha A}{\sigma}k^{\alpha-1}u^{1-\alpha}h^{1-\alpha+\zeta}-\frac{\rho}{\sigma}\qquad(\text{A. 1})$$

Furthermore, we know that:

$$\frac{\dot{h}}{h}=\kappa(1-u)$$

And substituting in the F.O.C.:

$$\theta_2=\frac{(1-\alpha)c^{-\sigma}u^{-\alpha}AK^{\alpha}h^{\zeta-\alpha}L^{1-\alpha}}{\kappa}\qquad(\text{A. 2})$$

Taking logarithms in (A.2):

$$\ln(\theta_2)=\ln(1-\alpha)-\sigma\ln(c)-\alpha\ln(u)+\ln(A)+\alpha\ln(K)+(\zeta-\alpha)\ln(h)+(1-\alpha)\ln(L)-\ln(\kappa)$$

Differentiating with respect to time and simplifying:

$$\frac{\dot{\theta}_2}{\theta_2}=\rho-\kappa$$

Furthermore, in (2):

$$\frac{\dot{K}}{K}=Ak^{\alpha-1}u^{1-\alpha}h^{1-\alpha+\zeta}-k^{-1}c$$

Substituting and simplifying:

$$\rho - \kappa = -\sigma\left[\frac{\alpha A}{\sigma}k^{\alpha-1}u^{1-\alpha}h^{1-\alpha+\zeta} - \frac{\rho}{\sigma}\right] - \alpha\frac{\dot{u}}{u} + \alpha\left[Ak^{\alpha-1}u^{1-\alpha}h^{1-\alpha+\zeta} - k^{-1}c\right] + (\zeta-\alpha)[\kappa(1-u)]$$

$$\alpha\frac{\dot{u}}{u} = -\alpha Ak^{\alpha-1}u^{1-\alpha}h^{1-\alpha+\zeta} + A\alpha k^{\alpha-1}u^{1-\alpha}h^{1-\alpha+\zeta} - \alpha k^{-1}c + (\zeta-\alpha)\kappa(1-u) + \kappa$$

$$\alpha\frac{\dot{u}}{u} = -\alpha k^{-1}c + (\zeta-\alpha)\kappa(1-u) + \kappa$$

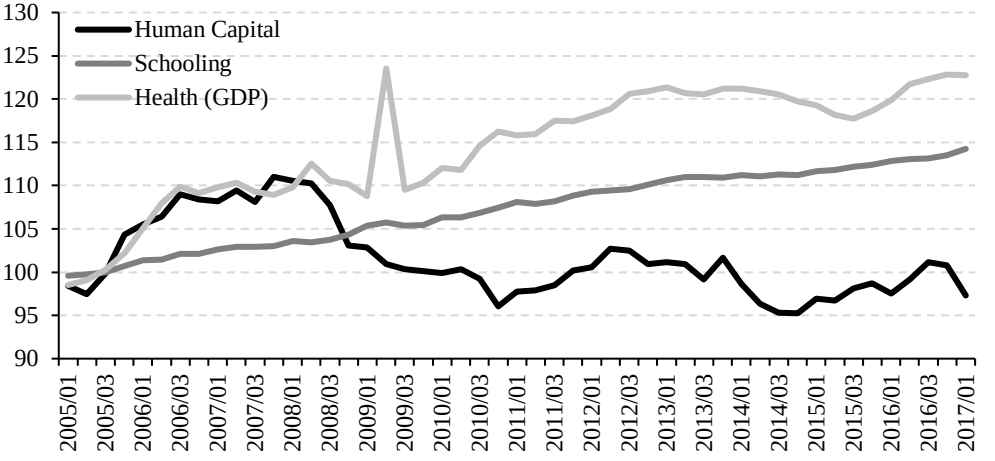
$$\frac{\dot{u}}{u} = -\frac{(\zeta-\alpha)}{\alpha}\kappa u + \frac{(\zeta-\alpha)}{\alpha}\kappa + \frac{\kappa}{\alpha} - \frac{c}{k}$$

$$\frac{\dot{u}}{u} = \frac{(\alpha-\zeta)}{\alpha}\kappa u + \frac{(1-\alpha+\zeta)}{\alpha}\kappa - \frac{c}{k}$$

A.2. Unit root and cointegration tests.

This annex complements the analysis developed in section 4.3. I am proposing a VEC model in order to measure the effect of education on human capital. A graphical inspection suggests that human capital is highly correlated with qualified workers and with the GDP generated in the health sector (see Figure 5).

Figure 5
Human capital and its components



Source: Data from ENOE, INEGI.

Furthermore, all variables seem to have a unit root, but I prove it formally. Indeed, before modelling the VEC model it is necessary to make sure that all variables are integrated of the same order. Table A.1 shows the unit root tests, which was conducted for the period 2005-I:2016-IV. I only show the p-values of those tests in which their coefficients are statistically significant. In summary, all tests show that the three series are not stationary. Furthermore, I show that the three variables are integrated of first order.

Table A.1
Unit Root Tests

Indicator Name	Ho: The series has a unit root						Ho: The series is stationary	
	Augmented Dickey-Fuller Test			Phillips-Perron Test			Kwiatkowski-Phillips-Schmidt-Shin Test	
	None	Intercept	Intercept and Trend	None	Intercept	Intercept and Trend	Intercept	Intercept and Trend
Human Capital	[0.000]		**0.297** [0.000]	[0.000]		**0.238** [0.000]	**0.05>p>0.01** [p>0.10]	p>0.01 [p>0.10]
Schooling	**1.000** [0.1391]	[0.000]	**0.579** [0.000]	**1.000** [0.000]	[0.000]	**0.653** [0.000]	**p<0.01** [p>0.10]	**0.05>p>0.01**
Health (GDP)	**0.986** [0.000]	**0.138** [0.000]	0.005 [0.000]	[0.000]	**0.175** [0.000]	[0.000]	**p<0.01** [p>0.10]	**0.05>p>0.01**

Note: Unit root tests were done for the period 2005-I:2016-IV. The p-values in blue indicate that the series has a unit root. The p-value in brackets refers to the unit root tests of series in first differences.
Source: Own calculations.

The next step is to show that there is at least one equation that relates the three variables in the long run. For that purpose, I use the Johansen Cointegration Test (JCT). I analyze the trace and the maximum eigenvalue tests, for which I assume a linear deterministic trend and only one lag for the series in first differences (the latter was determined according to a maximum length test, based on the conventional information criteria).

Table A.2
Johansen Cointegration Test

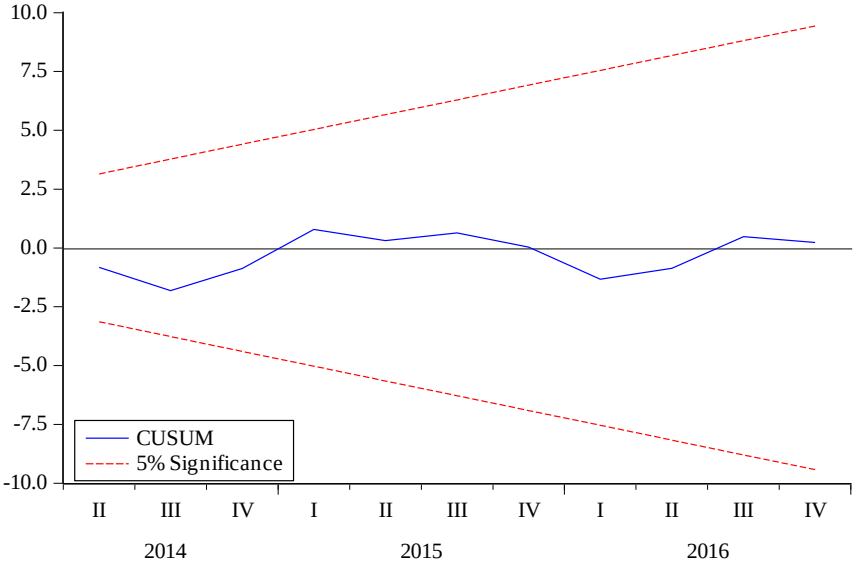
Hypothesis (number of equations)	Trace test		Maximum Eigenvalue test	
	Trace Statistic	Critical Value	Max-Eigen Statistic	Critical Value
None	31.35022*	29.79707	22.40121*	21.13162
At most 1	8.949005	15.49471	7.990743	14.2646
At most 2	0.958262	3.841466	0.958262	3.841466

Note: * denotes rejection of the hypothesis at the 0.05 level.
Source: Own calculations.

The results of the JCT suggest that there is one, or possibly two, equation(s) that relates human capital, education and health, in the long run. Furthermore, the JCT rejects the possibility that I could not find any long run relation among these variables.

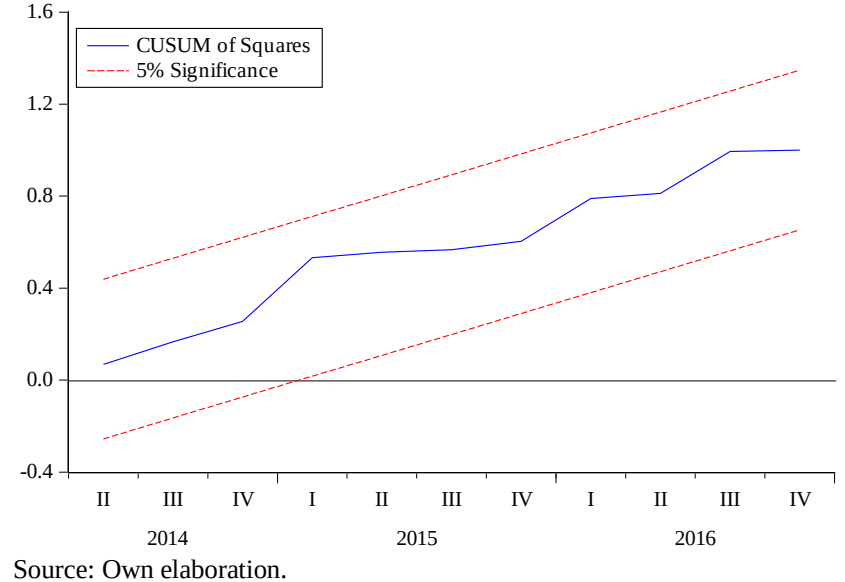
Finally, I show that the VEC model that I proposed is stable. Indeed, according to the CUSUM test, the coefficients estimated by my model are stable. Similarly, the CUSUM of squares test also concludes on favor of the stability of the coefficients estimated in the VEC model (see Figures 6 and 7, respectively).

Figure 6
CUSUM test



Source: Own elaboration.

Figure 7
CUSUM of squares test



Source: Own elaboration.