Economic growth in Colombia: an empirical approximation founded on the human capital perspective (1960 2009)

Crecimiento económico en Colombia: una aproximación empírica fundamentada en la perspectiva capital humano (1960 2009)

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Resarch article

Abstract

The aim of this paper is to determine an empirical model based on theoretical arguments, quantifying the influence of human capital, measured through a set of variables that reflect the bearing of health and education on the performance of economic growth observed for Colombia, between 1960 and 2009. The authors review the literature on economic growth and human capital, represented by health and education, so that, with the sources of information available in Colombia, they make a selection of data that allows the collection of variables that reflect and quantify the transmission channels suggested by the existing theory. Finally, they specify an empirical model that estimates the theoretical relationship between human capital and economic growth.

Keywords: economic growth, health, education, human capital.

JEL: E24, E25, I19, I29, O4, O49.

Resumen

El objetivo de este artículo es especificar un modelo empírico basado en los argumentos teóricos, que cuantifique la influencia del capital humano, medido a través de un conjunto de variables que reflejan el comportamiento de la salud y la educación, sobre el resultado del crecimiento económico observado para Colombia, entre los años 1960 y 2009. Realiza un recorrido por la literatura referente al crecimiento económico y el capital humano, representado por la salud y la educación, de tal manera que, con las fuentes de información disponibles en Colombia, realiza una selección de datos que permite la obtención de

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variables que reflejen y cuantifiquen los canales de trasmisión sugeridos por la teoría existente. Para terminar, especifica un modelo empírico que estima la relación teórica entre el capital humano y el crecimiento económico.

Palabras clave: crecimiento económico, salud, educación, capital humano.

INTRODUCTION

The concept and the importance of human capital are approached from multiple disciplines and with diverse criteria; in fact, it is not new in the field of studies that attempts to establish its influence on economic growth. After the mid-twentieth century, Theodore Schultz (1972) and Gary Becker (1983) posited the existence of the concept of human capital, which would be taken up by authors like Mincer (1984), in later studies. Human capital is not a recent discovery in the literature; its study began at the end of World War II, when it was necessary to rebuild the economies and generate the conditions that guarantee prosperity. Indeed, it was around 1950 that a whole stream of thought was generated that applied the research to economic growth and income distribution. The current study trends have been taken up in a number of ways, also linking it to the concept of economic growth, as in studies as important as Romer's (1994).

The objective of this article is to determine an empirical model based on the theoretical arguments in the literature that quantify the influence of human capital, measured through a set of variables that reflect the bearing of health and education on the economic growth observed for Colombia between the years 1960 and 2009, subject to the availability of data. This approach is carried out following the guidelines of Lucas (1988), in which an analysis of the determinants of growth is not sought, since it seeks to make an approximation of the account of the contributions that each of the factors related to human capital has on growth.

To begin with, a revision of the literature on economic growth and human capital, represented by health and education, is made, which allows us to deduce the appropriate channels and transmission mechanisms that relate to them. In addition, from data sources in Colombia, a selection of data is made so as to obtain variables that reflect the transmission channels suggested by the existing theory, using databases and official reports and, finally, specifying an empirical model for Colombia, in order to estimate the relationship between human capital and economic growth, controlling its effect through traditional variables such as growth in the stock of physical capital, among others.

The central hypothesis of this work is that human capital, which incorporates education and health, has a significant importance in Colombia's economic growth for the set study period. At the same time, between economic growth, education and health, there are two-way relationships, after controlling for their effects through other variables, which have traditionally been considered to affect the former. The paper seeks to contribute in the sense of highlighting the importance of incorporating health into the studies of human capital for Colombia, as a complement to education, which is present in most works.

BACKGROUND AND APPROACH OF THE INVESTIGATION

The first developments within the formal study of economic growth, within the neoclassical tradition, are related to the Harrod-Domar model (1939), who, based on a production function of fixed proportions, proposed a model in which the variations of the inputs provide the growth of the product. Three key elements within this model are highlighted: guaranteed growth, which is that experienced by the producers without the need for additional investment; natural growth, given by the expansion of the labor force by the population growth; and finally, current growth, which corresponds to the measurement of growth at each period of time

With regard to this, Solow (1988) shows the most relevant conclusion concerning this model and perhaps its greatest weakness

> (…) Harrod and Domar obtained their result under the assumption that the three fundamental ingredients-the rate of saving, the rate of growth of the labor force, and the ratio of capital to output-were given constants, facts of nature. The savings rate was a fact of preference; the growth rate of the labor supply was a demographic-sociological fact; the capital/output ratio was a technological fact.

One of the most important implications of this model is that if the economy changed regarding the equilibrium line of the model, it is possible that it no longer tends to it. That is why some authors call it the knife-edge model. From this model two great models emerge: that of Kaldor (1955), and that of Solow (1956), whose differences are basically in the assumptions and results obtained, as in the case of Solow some of the characterizations of the function of production correspond to the postulates of the neoclassical school.

The initial models of economic growth were characterized by the existence of two types of approaches, in terms of the way savings are treated: those of constant savings rates and those of the optimal savings path. The way in which savings are addressed - considering this as a relevant variable in the analysis - determines the type of model that results. The objective is to explain on what income variations depend over time. Almost contemporaneously, the need to understand human capital arose around 1950, based on empirical studies on economic growth and income distribution. It was born under two alternative schemes of study: on the one hand, the macroeconomic approach, in which it is related to aggregates and economic growth; the second possible approach is the microeconomic one, where individuals perform calculations to measure the incidence of education in their wages and in the distribution of income.

Within the evolution of ideas about growth, several fields of study have been opened up, following the basic principles of Arrow (1962), Romer (1994) and based on the evidence, the externalities that, on other companies and on the economy in general, have the discoveries of a firm. Later works by Romer (1986) and Lucas (1988) incorporate the idea of endogenous growth, which embodies a diverse body of empirical and theoretical works that emerged in the 1980s, which, differing from neoclassical growth, emphasize that

economic growth is an endogenous result of an economic system, not the result of forces that drive it from the outside.

Now, following Mincer (1993), there are two possible ways of understanding human capital; the first, from the macroeconomic point of view, understanding its relation to growth; or from the microeconomic perspective, when taking into account how greater investments in education modify the wage structure and the individual distribution of income.

One of the most important models for the macroeconomic approach is that of Lucas (1988). The implication of the external effect in the model is that, under a purely competitive balance, its presence leads to an underinvestment in human capital, since education generates an externality that is not taken into account by private agents. Thus, the balanced growth rate is lower than the optimum growth rate, because the balanced growth rate depends on the investment in human capital, therefore, it is concluded that government policies (subsidies) are required in order to increase the balanced growth rate to the optimum growth rate.

In general, the externalities that are most noticeable in studies are those generated by education, but in recent works the effect of health on economic growth has become important. Weil (2005) uses a micro-econometric model to estimate the effect of health on per capita GDP, controlled by an education variable in a sample of countries, which found that about 22.6% of the variance of the logarithm of GDP among countries is explained by their level of health, a participation similar to the variance explained by differences in the level of education.

For now, it will be said that human capital is not a recent discovery in the literature, although its development is. According to Jiménez and Simón (2004),

> "More than 200 years ago Adam Smith (1776) recognized the importance of personal skills in determining the wealth of individuals and nations. However, the formal concept of human capital was not developed until the 1960s and 1970s with the works of Schultz (1960, 1961), Becker (1962, 1964) and Blaug (1976). In them, human capital is related to productivity and is defined as the sum of the investments in education, work training, emigration or health that has as a consequence an increase in the productivity of workers."

According to Gaviria (2007), the "new" growth theory aims to break with the traditional version of the neoclassical models (Solow-Swan), according to which product and population growth rates are equalized at a steady state. In the same way, it seeks to endogenize the technical change, tying its evolution to physical capital. He further states that in the article that gave rise to the literature on endogenous growth, Paul Romer (1986) eliminated the tendency of diminishing returns of capital by assuming that knowledge was obtained as a by-product of investment in physical capital. This phenomenon is known as learning-by-doing and was initially proposed by authors such as Arrow (1962) who argued that technical progress had an endogenous behaviour.

There is also international evidence of the importance of human capital on growth: a high educational level allows a better adaptation to technologies, as well as greater access of the majority of the population to better standards of living. With respect to this capital, it can also be said, as Posada and Rubiano (2007) do, that economic growth, regardless of its cause, generates an increase in returns on human capital, which increases its accumulation, among other things, due to the fact that new technologies require new and advanced skills and knowledge from those who are immersed in the productive system.

This latter inclusion appears in several papers by Weil (2005) or in the more recent work by Aghion, Howitt and Murtin (2010), where the authors postulate that economic intuition, supported by particular empirical evidence, suggests that health affects growth through at least two channels. First, individuals with longer life expectancy are likely to save more, which favors capital accumulation and hence GDP growth. Second, individuals with a longer life expectancy are likely to invest more (or that their parents invest more) in education, which generates growth. However, in an environment marked by low infant mortality, parents seek a low level of fertility, which limits the growth of the total population and boosts GDP per capita growth. Finally, and more directly, healthy individuals tend to be more productive and more capable of creating and adapting to new technologies and, in general, are more able to cope with the rapid changes characteristic of a high growth environment.

The greatest difficulty in trying to make this analysis as completely as possible is that the relationships between growth, education and health are not unequivocal. The perception of education has changed in economic theory; in the neoclassical theory it was considered as an input of production; in the 1960s, it was incorporated into the growth models in the Solow residue. Individuals are born with an endowment of certain skills and abilities, but education can enhance them and improve work performance. However, Grooth and Massen (1993) have established that productivity depends on the education of individuals and their general state of health, and the level of education is known to affect health.

In this study, through the resulting econometric model, we seek to involve these interrelations and to show the contribution of human capital to Colombian economic growth. Similar works are, for example, Whalley and Zhao (2010), who carry out a study about the contribution of human capital to Chinese growth, in which they found that during the period 1978-2008 the stock of human capital grew annually by 7.6% and contributed 33.2% to growth

This work incorporates health and education as inputs to the production function, following Lucas (1988), through the results of improvement in one of these variables. That is, health, for example, is included through improvements in health that are reflected, among other things, in life expectancy, birth rate and mortality.

Approach to the problem and transmission channels

Starting from the theoretical analysis made by many authors such as Mincer (1993), health begins to influence the future performance of a worker from the moment of their gestation. Improvements in the health of pregnant mothers, child health care and the level of

education of the parents, among other socio-economic factors, along with the "initial endowment" of the new-born's abilities, influence the development of the child, and the health status and decisions about education that the adolescent will make.

Healthier individuals tend to have a greater life expectancy (Mincer, 1993), so the returns on education increase and make the option of choosing a greater number of years of it more attractive. On the other hand, healthier individuals in adolescence are healthier adults and are more productive in their jobs. In this way, health and education interrelated propitiate individuals capable of greater productivity, so that the wealth of a country is determined not only by its accumulation of physical capital, but also by access to education and the level of health of its population.

Some authors such as Bils and Klenow (2000) point out that, more educated individuals are more productive individuals and therefore through productivity the link between education and economic growth is established. On the other hand, studies of health and growth indicate that health measured through nutrition has a positive effect on productivity and therefore on economic growth. There are also other studies such as Cleuter and Lleras-Muney (2006), which try to verify the relationship between education and health; for example, more educated individuals are more aware of engaging in healthier behaviors so that, for these, mortality rates tend to be lower, but also inversely, a higher life expectancy makes it more profitable to access a higher level of education, so that the return on education increases and healthier individuals (who hope to live longer) are willing to accumulate a greater number of years of education. What is clear is that both health and education have effects on productivity and that health has effects on education and the latter on the former, as Groot and Maassen (2007) conclude.

However, empirical evidence has shown that not all countries have the same growth dynamics. In fact, according to P. Agénor and Montiel (2000), the traditional neoclassical approaches, which attribute growth to exogenous technological progress, cannot account for the large disparities in the pace of economic growth between countries. Considerable efforts have been made in recent years to understand the sources of economic growth and to explain the divergent patterns observed between countries. Within this theoretical tendency, and following Agénor and Montiel (2000), a particular source of externalities that has stood out in the literature of recent growth is the accumulation of human capital and its effect on the productivity of the economy. Lucas (1988) offers one of the best-known efforts to incorporate the filtering effects of human capital accumulation into a model based on the idea that individual workers are more productive, regardless of their skill level, if other workers have more human capital.

Figure 1 illustrates the network of interactions shown by the different studies cited. It should be noted that there is no single form of transmission between one variable and another. For example, the care of the pregnant mother affects the health of the new-born, but it will also affect the nutrition during their childhood and adolescence, the level and quality of education they receive and the decisions they make in adult life regarding risk prevention in health, so these transmission channels are not unique or contemporaneous, but they can be evidenced through a series of variables that show the result of this chain of actions.
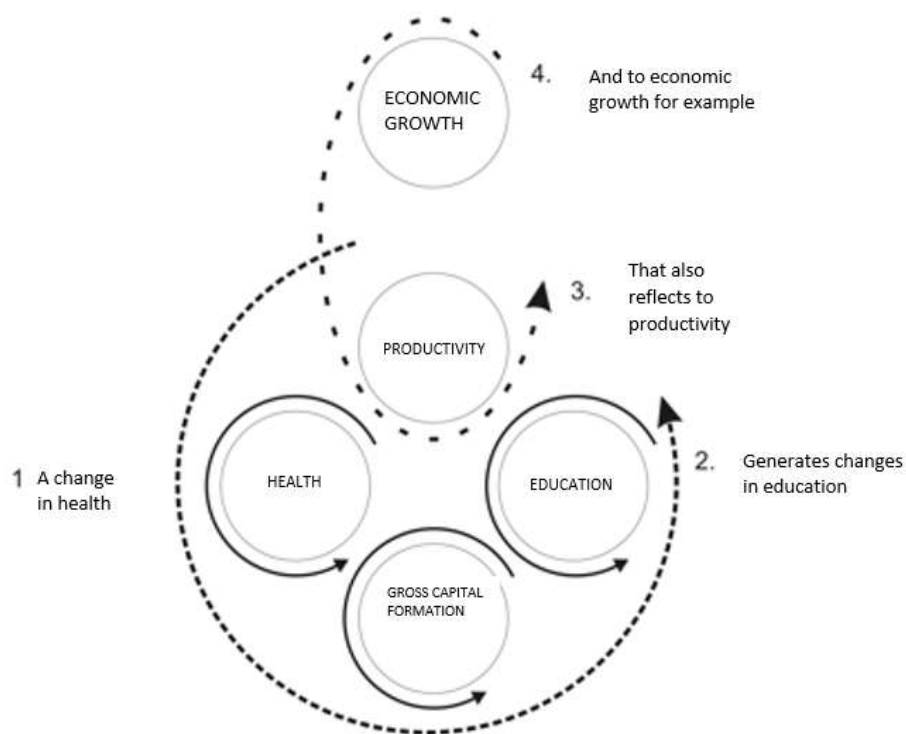
Figure 1. Scheme of the relation among the variables
Source: created by the authors.

Note how the interactions between the variables in question are conceived: a gear where a change in health can, in addition to improving the health of the individuals, boost education, and through productivity to economic growth and thence to the accumulation of capital, etc. And from there, the increase in economic activity can give impulse to health in a kind of multiplier effect; that is, as human capital is a factor of production, the product in turn is a factor in the generation of human capital, specifically of health and education.

The mortality rate could reflect this result, because, according to Weil (2005), all the influences that exist on the health of an individual throughout their life and, thus, in turn, an improvement in the mortality rate, can encourage people to change their preferences in such a way that they can change the factors that can influence health and so on.

Therefore, a key assumption to be made is the simultaneity and multiple interactions between the output of the economy, health and education, and other control variables. An example of this conception is to suppose that a set of variables exists that reflects the state or level of health. These variables can be the incidence of a certain disease in the infant population, the amount of calories consumed by the population, the weight and average size of the population, the mortality rate, etc. In turn, there are also variables that can influence the performance of the former, such as public spending on health, access to medical services, the number of hospital beds, etc.

On the other hand, the preferences of individuals are sensitive to changes in health, which are in interaction with educational changes, as previously stated, following Cleuter and Lleras-Muney (2006) and Groot and Maassen (2007). If there were an increase in public spending on health that generated a decrease in the incidence of certain diseases in the child population, this change should increase the level of health, which in turn may modify the preferences of individuals. These changes in preferences may encourage further changes in government policies and individual behaviors. In sum, there is an indeterminate number of interrelationships between "input[1]" and "output[2]" variables in health, in addition to the changes that are generated in the preferences of individuals, changes in education and changes in the output, which implies that both education and health assume complex dynamics, both autonomous (autocorrelated) and interrelated, contemporaneously as well as lagging in different time horizons.

Given the relationships between these variables, we propose a model of autoregressive vectors, since one of the advantages of this methodology is that it allows us to portray the fact of the multiple relationships and interactions between the different variables. The theoretical model that is proposed according to the previous discussion, portrayed in Figure 1, has the following structural form represented by the equation (1):

$$\begin{bmatrix} g_t \\ K_t \\ SAL_t \\ EDU_t \end{bmatrix} = \begin{bmatrix} \alpha_g \\ \alpha_k \\ \alpha_{SAL} \\ \alpha_{EDU} \end{bmatrix} + \begin{bmatrix} \alpha_{1,11} & \alpha_{1,12} & \alpha_{1,13} & \alpha_{1,14} \\ \alpha_{1,21} & \alpha_{1,22} & \alpha_{1,23} & \alpha_{1,24} \\ \alpha_{1,31} & \alpha_{1,32} & \alpha_{1,33} & \alpha_{1,34} \\ \alpha_{1,41} & \alpha_{1,42} & \alpha_{1,43} & \alpha_{1,44} \end{bmatrix} \begin{bmatrix} g_{t-1} \\ K_{t-1} \\ SAL_{t-1} \\ EDU_{t-1} \end{bmatrix} + ... + \begin{bmatrix} \varepsilon_{gt} \\ \varepsilon_{kt} \\ \varepsilon_{SALt} \\ \varepsilon_{EDUt} \end{bmatrix}$$

[1]

Where g_t is economic growth, K_t is the accumulation of capital EDU_t is the change in the level of education, and SAL_t is the change in the level of health for Colombia in a period of time. A dotted line is left indicating the existence of multiple lags for the four variables, which will be included in order to explain the non-contemporaneous effects, and their extension will depend on technical criteria combined with theoretical criteria.

HUMAN CAPITAL AND ECONOMIC GROWTH IN COLOMBIA (1960-2009)

Below are presented some important facts about economic growth in Colombia, in order to show the stylized facts that are intended to be interpreted in the econometric model. In the second part of this section there is a brief description of the methodology to be used and the results of the model

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[1] Following Weil (2005), these are those that in a linear conception are health inputs, such as the number of hospital beds or the number of doctors, etc.
[2] According to Weil (2005), these are those that show the results in health, like mortality rate, the incidence of certain diseases in a certain population etc.

To begin to describe human capital in Colombia, some variables related to health and education can be used. Colombia has been classified as a developing country. With respect to the Human Development Index calculated by the United Nations for 2007, the country is in 75th place with an indicator of 0.791, comparable with the Dominican Republic (0.798), Ecuador (0.772), Peru (0.773); but very far from Iceland (0.968) or Sierra Leone (0.336), (the extreme cases of that indicator). Its GDP was around US $234 billion in 2009, according to data from the World Bank, higher than the average of the countries considered. However, GDP per capita is below the world average. According to Urrutia and Posada (2007), when analyzing the economic growth of the last century (1900-2000), a relative stability of the growth rate can be evidenced, when comparing it with Latin America.

The dynamics of growth in Colombia have been positive for almost the entire period of the country's economic history. Between 1970 and 2005, Colombia grew by 4.3%, according to data from the National Administrative Department of Statistics (DANE, by its acronym in Spanish) and the authors' calculations, consistent with the interpretation made in some previous analyses carried out on the subject. According to GRECO (1999), "some countries advanced faster than Colombia, and according to the convergence literature, this influenced not only the initial per capita income but also the initial levels of education, infrastructure, institutional development, the degree of openness, etc. (Barro & Sala-i-Martin (1995) "The study made by Uribe (1994) also found that inflation had a negative impact on growth in Colombia, especially since 1970 when inflation reached double digits.
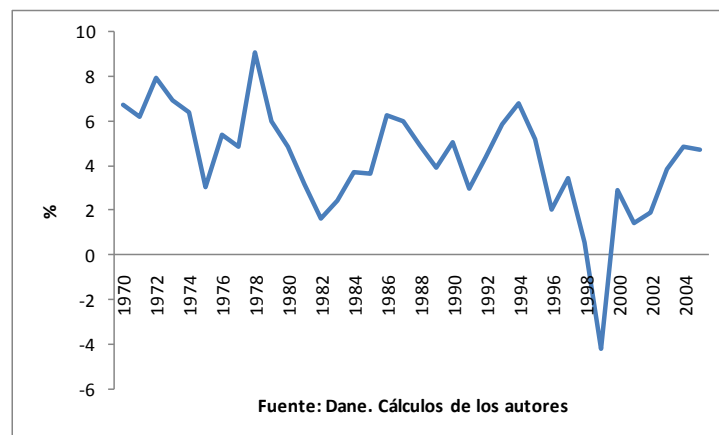

Figure 2. Economic growth in Colombia (percentage)
Source: Dane (2010). Calculations made by the authors.

This dynamic of growth can be explained from different perspectives. Below, and within the objectives of the present work, the behavior of the variables that will be included within the concept of human capital is shown. Colombia has about 45 million inhabitants, many of them still in the most uninhabited regions of the country. The conditions of health and education are limited by diverse realities; however there are general guidelines that will be taken into account within this work.

Education in Colombia

The Colombian Political Constitution indicates that education is a person's right, a public service that has a social function and that corresponds to the state to regulate and exercise a rigorous inspection and supervision regarding the educational service, in order to ensure its quality, for the fulfillment of its goals and for the best moral, intellectual and physical education of the students. It is also established that adequate coverage of the service must be guaranteed and that minors must be guaranteed the necessary conditions for their access to and permanence in the education system. The Colombian educational system consists of initial education, pre-school education, basic education (primary five grades and secondary four grades), secondary education (two grades and culminates with a certificate in secondary education), and higher education (Ministry of Education, 2009).

This structure, which also has a decentralized budget and functions, has improved education in Colombia as regards coverage. Thus, according to data from the Ministry of National Education (2009), the number of students enrolled in secondary education increased by more than 300,000 between 2000 and 2005. According to the Report on Educational Progress in Colombia 2006, however, 4 out every 10 young people of this school age do not study; and there are marked differences between departments: in Vichada, coverage is 21%, while in Bogota it reaches 73%. In addition, about one third of students have an age discrepancy that could exceed by three or more years the expected age for this level.

According to the National Report on Education in Colombia (2001) from the Ministry of Education, formal education is taught in approved educational establishments, according to a regular sequence of levels of education, subject to progressive curricular guidelines and leading to grades and certificates. Within the same report, it is mentioned that

> "The lowest coverage occurs in secondary education. Although between 2000 and 2005, enrollments increased by more than 33 thousand (sic) and covered almost one million students, 7 out of every 10 young people of the average age are not studying. A little more than a third of those attending 10th and 11th grade are (sic) at least three years older than the expected age for this level. Although coverage increased in all departments, there are gaps between them. In 2004, in Guainia, Guaviare, Vaupés and Vichada, only 1 in 10 young people attended this level at the age when they should do so; while in Bogotá it was 4 out of 10"

Thus, as can be seen in Figure 3, for each level of schooling the level of enrollment shows a growing trend; however, some regional inequities and disparities persist. In addition, while the trend of university students is increasing, they represent a relatively small proportion of the total population (on average 4.8% of the total enrolled for the period 1950-2005). In fact, its highest level is in 2005, when the proportion of students enrolled in university was 11.6% of the total population.
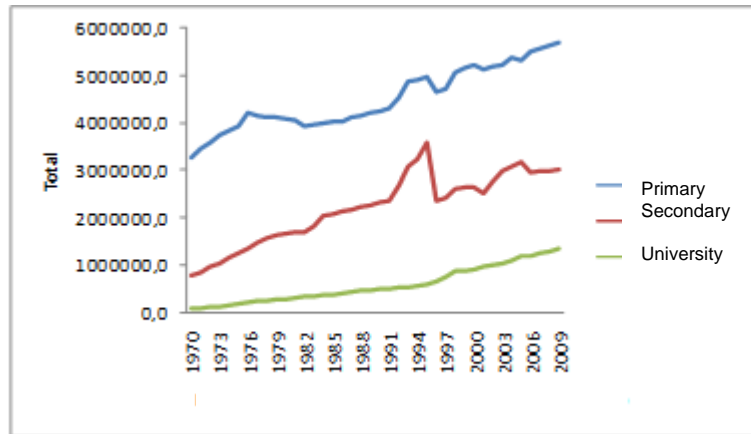
Figure 3. Number of enrolled students by school level
Source: Ministry of Education (2009)

Health in Colombia

Health in Colombia has been schematized in various ways throughout its history. According to Vivas (2006), although the constitutional reform of 1936 increased the responsibility of the state in the provision of health services, until the end of the thirties charity remained a legitimate form for the distribution of health resources from outside the state.

According to the National Department of Planning (2009), the management, regulation, modulation of funding, monitoring of insurance and harmonization of the provision of health services, are the responsibilities of the state. Within the framework of the General System of Social Security in Health, public health has among its objectives, the strengthening of the institutional capacity of planning and management, the development of the characteristics and conditions of human resources in health, and the elaboration of permanent processes of investigation aimed at improving the individual and collective conditions of health.

According to the report presented by the Colombian Institute for Family Welfare (ICBF, by its acronym in Spanish), the Food and Agriculture Organization of the United Nations FAO and others (2008), through the maps of the nutritional situation in Colombia, it can be said that, "In the analysis of the nutritional results of these studies, a problem of nutritional transition is identified. There is a problem of malnutrition of excess weight among adults but of undernutrition in the child population; a situation that makes it necessary to approach differentiated measures among population groups according to the nutritional problem to be addressed".

Other areas of great importance for the development of public health measures have to do with the monitoring, evaluation and analysis of the health situation (epidemiological surveillance), disease prevention and health promotion, the participation of citizens in the processes of public health, planning the development of policies and the institutional capacity of planning and management as regards public health, human resource development and training in public health, basic sanitation, research, reducing the impact of

emergencies and disasters on health, among others. The technical and technological conditions that have improved worldwide have reached Colombia and the regulatory conditions show their results in variables such as life expectancy which, as shown in Figure 4, shows an increasing trend.
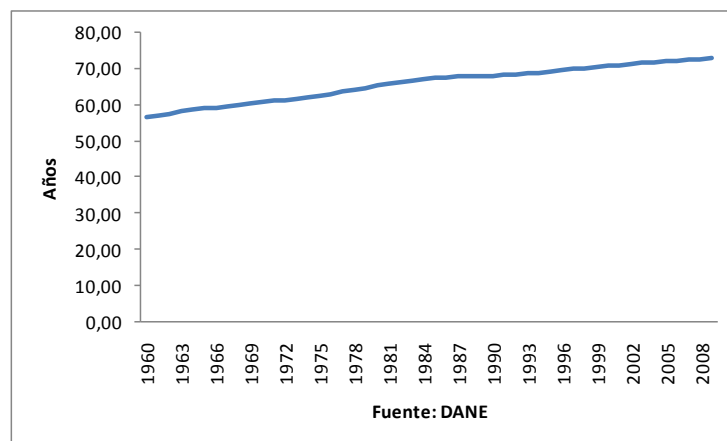

Figure 4. Life expectancy
Source: Dane (2009)

Variables used and first results

When consulting the existing databases, there are very few annual series of sufficient size to provide relevant information to the empirical model, when consulting the World Bank database, cited above, there is no data on education of the size or length required. In this case, the databases of the DANE (2009) were used, from which the series for schooling and enrollment could be obtained for primary, secondary and higher education.

Schooling is the total number of students enrolled, over the total population of school age[3]. This variable is stationary in first differences according to the applied tests[4] and it constitutes an intermediate output of education. Schooling is influenced by public policies and by the preferences of society, but an increase in schooling does not necessarily imply an increase in education. The reason is that this variable is measured by the number of students enrolled per level, so it includes those who drop out of classes during the school year. In addition, more schooling does not imply that students actually learn, that is, schooling does not reflect the quality of the education that is imparted.

Having no other indicators, a new variable is included as an alternative to schooling, which is called the potential loss in total education. This series is obtained from the number of students enrolled in primary, secondary and higher education, those enrolled in primary schools are subtracted from those enrolled in secondary schools; and, likewise, those

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[3] It includes the three levels (primary, secondary and higher).
[4] Augmented Dickey Fuller and Phillips Perron, Including intercept and trend, automatic in Eviews.

enrolled in secondary schools from those enrolled in higher education. Then both differences are averaged and with what is obtained, there is an average of the students who did not accede to the next level of education. This is called the loss, to the extent that these people will not continue to accumulate human capital through education. This variable would be interpreted inversely to schooling, the greater the loss and the lower the accumulation of human capital in terms of education, then we would expect an inverse relation of this series against per capita GDP. The word potential is added to the indicator, because ideally it would be expected that the students do not abandon the education system until completing higher education[5]. To include this indicator in per capita terms, it is transformed into changes and subtracted from the percentage change in the population. This variable is stationary in differences (I (1)) according to the three tests used.
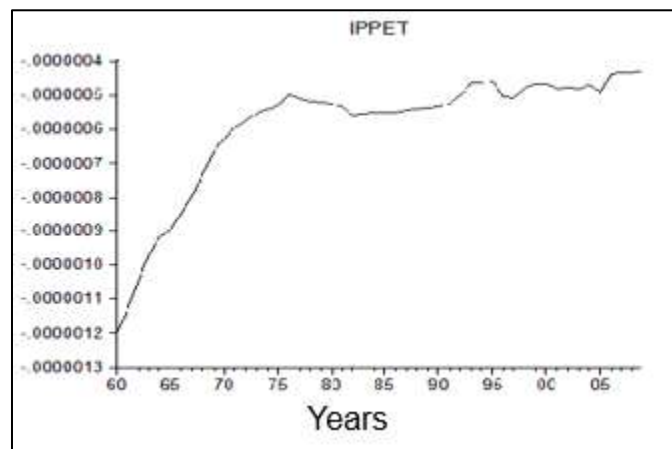

Figure 5. Potential loss in education index (IPPET, by its acronym in Spanish).
Source: elaborated by the authors

As in the case of education, when consulting the databases mentioned, there are very few data series that are of the size required. From the World Bank database were obtained: the birth rate per thousand (1000) inhabitants (TN*), life expectancy at birth (EVN*), mortality rate per thousand (1000) inhabitants (TM*), the total fertility rate consisting of the number of deliveries per woman (TF*).

Upon examining the data it was found that the birth rate has conflicting results regarding the existence of unit roots. The Augmented Dickey Fuller (ADF) test rejects the hypothesis of unit roots, even in levels and also in first and second differences. For its part, the Phillips-Perron (PP) test does not reject the hypothesis of unit roots either in levels or in first or second differences. As a third criterion the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) [6] test is used, which has, as a null hypothesis, that the series is stationary in tendency. When applied in levels, the statistic is greater than the critical values, so the null hypothesis is rejected; in differences, the test statistic is small, so it can be accepted that the

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[5] That is, when they obtain a technical, technological or professional title.
[6] Automatic KPSS test in the eviews package.
*TN: Some acronyms were kept in Spanish, in the same way they appear in the graphs in the appendix.

series of birth rates is stationary in tendency in first differences; therefore, the series is considered to be stationary in first differences.

Life expectancy at birth also has a contradictory behavior in the tests. According to the ADF, the hypothesis of unit roots can be rejected only in second differences, the PP in no case rejects this same hypothesis, whereas the KPSS does not reject the hypothesis of stationarity in first differences[7], if the unit root tests are specified only with intercept, the LEB maintains contradictory results; but in this case PP rejects unit root in levels, ADF rejects in second differences and KPSS rejects to 10% stationarity in first differences and up to 1% in second differences. The mortality rate also behaves similarly to life expectancy at birth. The ADF test only rejects the unit root in second differences, the PP, including intercept, rejects in levels, with intercept and trend does not reject the null hypothesis, and KPSS, including intercept, only accepts stationarity in second differences, when it also includes trend, it cannot reject stationarity in first differences.

The fertility rate shows varied results in the tests, the ADF always rejects the null hypothesis of a unit root, the PP rejects in first differences, as well as the KPSS that does not reject the hypothesis of stationarity in first differences. Therefore, it is considered that this series is stationary in first differences. The tests used with the different variables that approximate the behavior of health, in general, do not conclude, so they will be used at the discretion of the authors, taking into account that we will assume stationarity at a certain level[8] and that the results obtained using these variables could be questionable for this reason; however, these series are the only ones existing, the reason why the study is forced to use them. It will also be taken into account that the birth rate is the number of births relative to the total population; while fertility is the number of births per woman. In this case, the two indicators are quite close; therefore, the fertility rate will be used, which is based on other studies such as that of Lucas (1988).

The objective variable of this study is economic growth, which will be approximated with GDP per capita (PBIPC*), and following Lucas (1988), will be used in percentage changes. Gross capital formation (FBK*) is also included as an approximation to the physical capital factor (K) also in percentage changes, both variables were stationary in first differences (I (1)) according to the tests used. The frequency of all the data is annual.

Empirical verification: results of the analysis

During the course of this study, several models were estimated in which the fundamental ideas of the work were preserved. It seeks to introduce human capital, measured from education and health, and proposes an approach through the VAR methodology as a basic principle. The analysis begins with a review of the variables in the model, evaluating the series that reflect the human capital, then those that theoretically and technically have a better performance are selected and the Cholesky order is tested, in order to control the stability of the results, and, finally, the possibility of cointegration is explored. Following

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[7] Including intercept and trend in the test
[8] In general, in first differences.

Echavarría, López and Misas (2009), in this work it is understood that the VAR methodology is an ideal tool in this type of work, which allows the summarizing of the information contained in different economic series and simulating policy experiments, but it is clear that it is not without problems, some of them common to other methodologies.

Once the data series have been established, and having verified that these series have the same order of integration, and with several tests of the structure of the models [9] carried out, to evaluate them, several criteria are taken into account:

1. The technical specification requirements of the model must be met, that is, that the residuals are at least stationary, the variables have the same order of integration, and the number of lags is set on the basis of the Akaike Information Criterion AIC and Schwartz Criterion SC criteria, combined for the purpose of the study and theory.
2. The obtained results for the variance decompositions[10] and response impulses must be intuitive, that is, they must be consistent with the theory behind the study.
3. If more than one specification meets criteria 1 and 2, the best will be selected from among them according to those that most appropriately reflect the theory[11], where, in this order, the variance decompositions will be considered most important, the cointegration equations[12] and then the response impulses[13].

However, there is a concern related to the impact that the model of short-term shocks can have. To solve this, a simple concept of potential GDP is used, applying a Hodrick - Prescott filter on the GDP per capita series, in order to isolate these effects.

Stage I: Evaluating the different approaches to health and education

Initially, a Hodrick-Prescott filter is applied to the per capita GDP and its percentage change (G1) is calculated. Additionally, the stationarity tests are applied and it is concluded that this series was not stationary, so its use is ruled out; therefore, it should be noted that the results obtained will contain unquantified short-term shocks, which may introduce some bias into them.

Then, using the percentage change in the per capita GDP (G2), in this stage six different models are configured where different combinations of the series that have been obtained in the search for data are used. For health, the life expectancy at birth (SAL1), the mortality

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[9] For simplicity, the contemporary effects are not included, although they are clear (for example, to enroll a child in a school or pay for medical treatment, constitutes a contribution to GDP), the same would be counted on both sides of the equation.

[10] 10 periods are used both for variance decompositions and for response impulses, this is the configuration that comes automatically in e-views, varying the number of periods, the results of the decompositions do not vary significantly, so this configuration is selected.

[11] By this criterion, it can be understood that a specification that yields the least number of counterintuitive results will be better.

[12] For the models of error correction

[13] According to Montenegro (2007), the impulse response graphs have been left as the last selection criterion, because in case of correlation between the errors, the meaning of impulse response is not clear.

rate (SAL2) and the fertility rate (SAL3) are used. In theory, any of these three can explain a change in health, if life expectancy increases, if the mortality rate or the fertility rate is reduced[14]. To reflect changes in education, two indicators will be used, the percentage change in schooling (EDU1) and the percentage change in the potential loss in total education per capita (EDU2), capital accumulation will be represented by the percentage change in gross formation of capital (K).

Given the use of the VAR methodology, we will interpret the weight of each production factor within the per capita GDP (G2), through the decompositions of variance and its concordance with the theory based on the impulse response. In addition, in order to simplify the interpretation in the variables that have a theoretically inverse relation with the GDP, the multiplicative inverse of the same will be used. The models[15] estimated in general with two lags[16] show, from the response impulses and from the decompositions of variance, that the potential loss in total per capita education has a counterintuitive result, so its use is ruled out. Several models were made and it was found that the models 1, 2 and 3 were the most adjusted.

Selecting between these models, and according to the stated criteria, it is found that they have characteristic strengths and weaknesses; in model 1, the response impulses (Appendix 1) show mostly intuitive responses; however, the variance decompositions (Appendix 2) show that most of the forecast error is explained by the same variables. The opposite happens with model 2 (appendixes 3 and 4 respectively), we have some counterintuitive results in the impulse response, but the decomposition of variance gives more importance to other variables compared to the other estimated models. For these reasons, models 1 and 2 will be used for the next stages of the study.

II: Estimation of the participations of the factors and interrelations

Using models 1 and 2, their variance decompositions are again re-evaluated, altering the Cholesky order. These alterations are due to the fact that the true ordering of the variables is not known[17], but the change in GDP per capita (G2) is considered the first of this order, being the object of study variable and so as to avoid imposing an arbitrary ordering. The decompositions of variance are again estimated by alternating the order of the three factors of production considered. The results are shown below in Appendixes 5 and 6, as well as in

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[14] In this case, it is assumed that the fewer children they have, the more likely they are to be healthier, since they would have greater access to health services

[15] All the models estimated in the work have stationary residuals according to the tests ADF, PP and KPSS, and except for some particular cases, they are also noise according to their correlograms and statistics Q

[16] According to the Akaike Information Criterion and Schwartz Criterion tests by variable and of the model, the theory and maximizing degrees of freedom in order to improve the likelihood of estimates, except model 6 which required 3 lags to obtain stationary residuals.

[17] Two variables are fixed as first and second for a practical rather than theoretical reason. G2 is the variable with which these models measure economic growth. And K allows us to approach the effects of capital accumulation, a variable present in these models since Solow and which is simple to understand intuitively as a determinant of growth

Tables 1 and 2, which show the average, minimum and maximum results of the contribution of each of the variables in the determination of G2:

Table 1

	G2	K	SAL1	EDU1
Average	84.79	1.09	0.20	13.93
Minimum	83.73	0.29	0.12	11.74
Maximum	87.84	1.30	0.38	14.61

Table 2

	G2	K	SAL2	EDU1
Average	67.89	5.74	12.33	14.04
Minimum	62.03	0.87	8.00	9.00
Maximum	81.50	9.87	14.44	17.54

Table 1 shows the results of model 1, where, on average, education (EDU1), measured by the change in schooling, is the one that most "explains" economic growth, with about 14% physical capital which contributes about 1.1%, and health, as measured by life expectancy at birth (SAL1), which contributes only about 0.2%. In Table 2, which shows the results of model 2, education (EDU1) contributes the same 14% of the model 1, but unlike the latter, physical capital (K) contributes around 6% and health measured as the inverse of the mortality rate (SAL2), contributes approximately 12.3%.

Following Aghion and Howitt (2009), the share of economic growth that is not attributable to the factors of production is considered to be explained by total factor productivity (TFP). In the production functions, the TFP is denoted as the parameter of the state of technology, and, taking into account Whalley and Zhao (2010), in this case the TFP is approximated as the proportion of G2 that is explained by the same. If the production factors only explain between 15.21% and 32.11% according to models 1 and 2 respectively, the remaining contribution to economic growth must be explained by the total productivity of the factors, between 67.89% and 84.79% of model 2 and 1 respectively. According to the data and variables obtained, the human capital contribution measured with health and education is between 14.13% and 26.37%.

It should be borne in mind that these results include the biases attributable to the effects of short-term shocks, errors in the measurement of variables, the approximation of health and education through data series that do not reflect them fully. Also noteworthy is the low participation of physical capital (K) in determining economic growth, in contrast to the contributions of the TFP and human capital.

As for the interrelations between variables, models 1 and 2 show that in general this is low, according to the decompositions of variance of education and health, whose averages are shown in Tables 3, 4, 5 and 6:

Table 4. Education, model 1

	G2	K	SAL1	EDU1
Average	2.83	1.24	0.66	95.27
Minimum	0.30	0.01	0.52	93.47
Maximum	4.11	1.44	0.99	99.07

Table 3. Health, model 1

	G2	K	SAL1	EDU1
Average	22.44	4.85	69.18	3.53
Minimum	7.90	0.68	52.73	0.21
Maximum	31.59	6.23	91.13	10.07

Table 5. Health, model 2

	G2	K	SAL1	EDU1
Average	1.22	5.57	85.48	7.73
Minimum	0.08	1.65	58.98	0.71
Maximum	2.30	10.57	97.54	28.34

Table 6. Education, model 2

	G2	K	SAL1	EDU1
Average	2.68	2.09	6.28	88.95
Minimum	0.09	0.09	1.82	84.87
Maximum	3.29	3.28	8.58	98.00

Although this interrelation has been shown theoretically and in other studies, it is possible that due to the possible biases that have been stated, the results obtained do not clearly reflect the empirical existence of the same.

Stage III: Cointegration

Cointegration is explored from models 1 and 2, variables in levels and logarithms are used, changing the notation for GDP per capita (GDP), gross capital formation (LFBK), life

expectancy at birth (LEVN), Mortality rate (LTM) and schooling (LESC), when looking for the appropriate specification in the tests of Johannsen, it is found that adding variables increases the number of eigenvalues and by reducing them they are decreased, two lags are chosen to be consistent with the previously estimated models and no significant results are obtained.

Although there is evidence of a possible cointegration, the variance decompositions show results similar to the averages found in stage II, and the response impulses show generally counterintuitive results. The cointegration equations of model 1 are only intuitive in schooling with a positive coefficient, and in model two this same variable is the only one that has a negative coefficient that is not in accordance with the theory. The mortality rate has a negative coefficient and the gross capital formation coefficient is positive, as expected from the theory. The results are shown in appendix 7.

CONCLUSIONS

In accordance with the objective of this study, it has been possible to calculate the proportion of economic growth, measured by GDP per capita and explained by health and education, the estimates made reflect a contribution of between 14% and 25% of human capital and a contribution of the total productivity of the factors of between 68% and 85%. On the other hand, physical capital contributes between 1% and 6% approximately. These results are similar to those obtained by other authors cited above in terms of the contribution of human capital, but, on the other hand, they differ in the contributions of the TFP and physical capital. There are many possible biases such as the way these two factors are measured, the lack of data or the technical difficulties of the same, which do not allow us to affirm conclusively that the estimated coefficients reflect their true participations. In spite of this, it coincides, for example, with the results shown by Sala-i-Martin in the empirical evidence of his book. There, the regressions of Barro (1991) are shown, where the inclusion of the fraction of the population attending public schools in primary and secondary for 1960 in a cross-section of 114 countries, has a positive and significant coefficient for both variables. That is to say that education does have a positive relation with GDP growth, which leads us to think that our results, despite biases and possible criticisms of methodology, are not insignificant.

The variables used in this study are distant approaches, in the sense that there are other indicators that from the theory could better approximate the variations in health, such as indicators of malnutrition, incidence of diseases, among others. Likewise, it is difficult to imagine that schooling, the number of enrolled students or indicators such as potential loss in education, can reflect the true behavior of education; there should be variables that reflect the quality of the graduates, the improvements in citizen behavior, among others, that are not currently available. We also suggest a review of the methodology used to measure the variables used in this study, since the results of the tests performed and their mere observation seem to approximate mobile averages. It is possible that once these indicators are available for Colombia or their measurement is improved, the estimates can be retaken and the accounting for economic growth more appropriately approximated. On the other hand, the empirical existence of interrelations between the different factors and

the cointegration between the factors of production and the domestic product is not clear either, a fact that could be attributable to the aforementioned biases.

However, the review of the different models and estimates pursuing the conclusions that are made from the theory, has yielded the satisfactory result of having evidence that, despite not having the necessary force, does allow us to presume that at the moment of thinking about economic growth, it is not prudent to tackle this problem in an univocal way, ignoring the interrelationships between variables, but rather that is necessary to face it as a multidimensional problem, which includes human capital.

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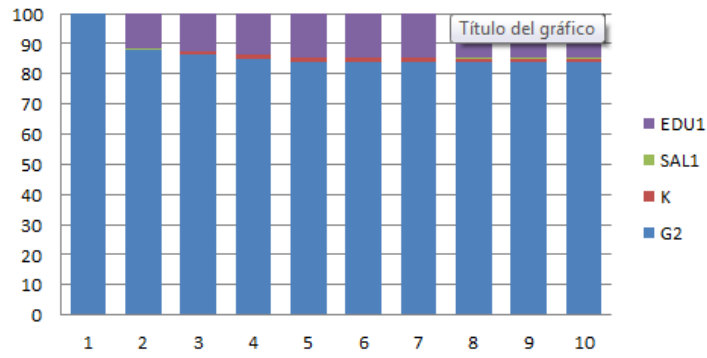
Appendix 1

Impulse response model I

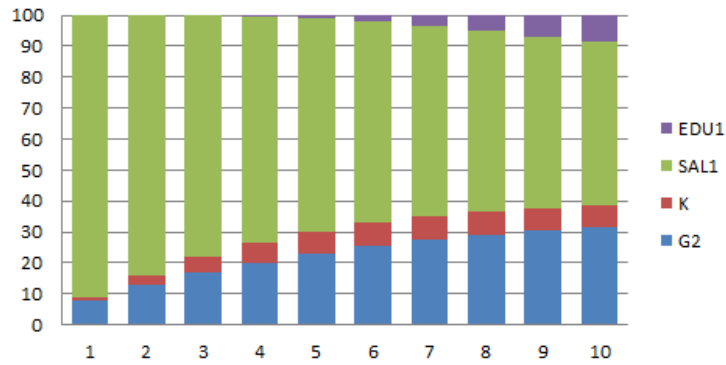Response to Cholesky One S.D. Innovations ± 2 S.E.
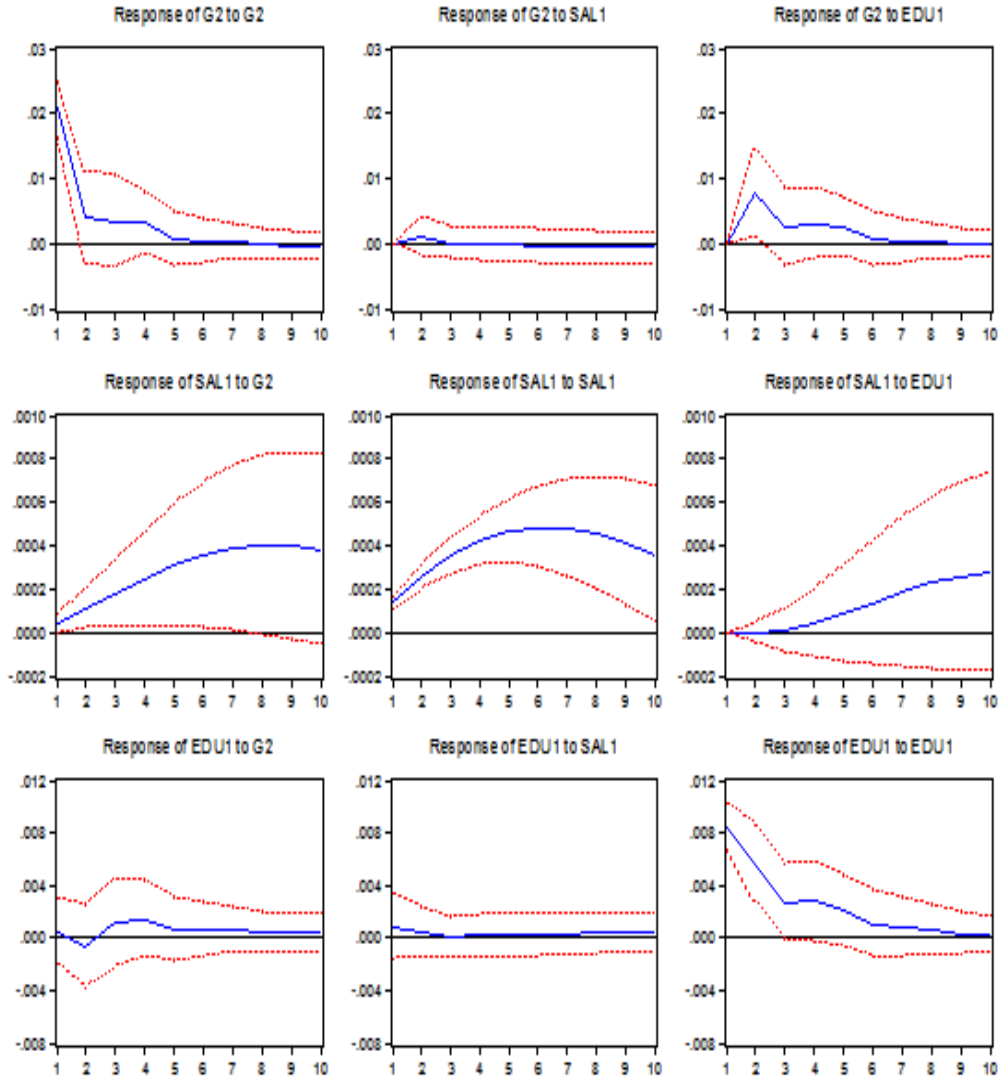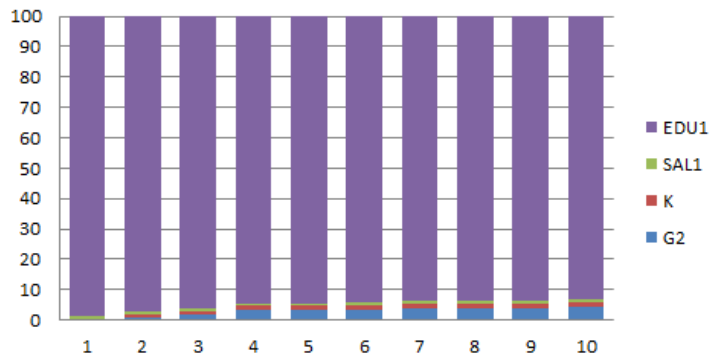
Appendix 2

Decomposition of Variance of model 1

Desc. Var. G

Desc. Var SAL1

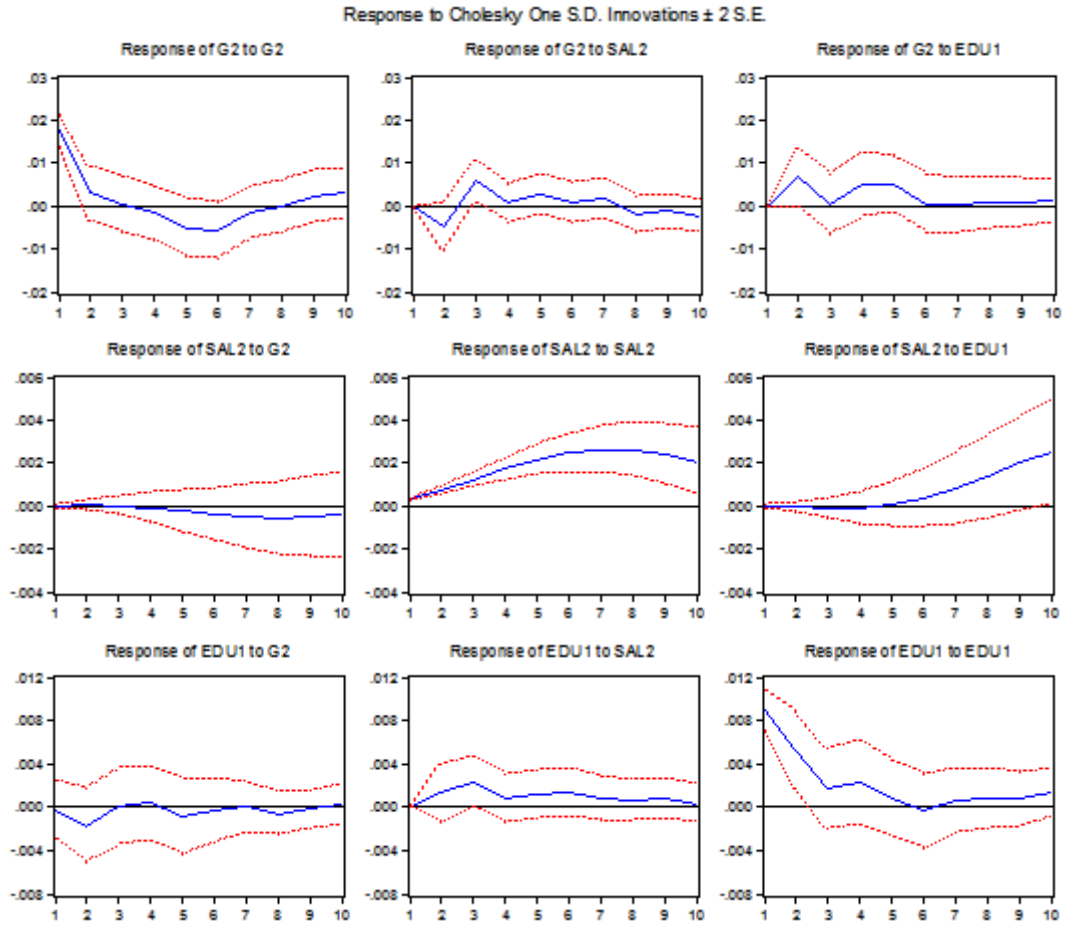

Desc. Var EDU1

Appendix 3

Impulse response model 2

Response to Cholesky One S.D. Innovations ± 2 S.E.

Appendix 4

Decomposition of Variance of model 2
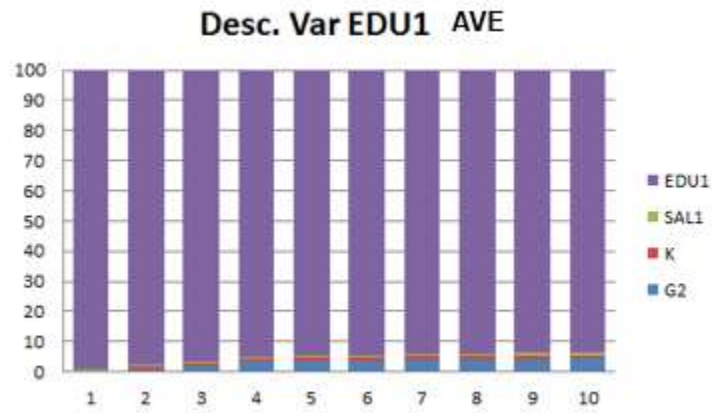
Desc. Var. G
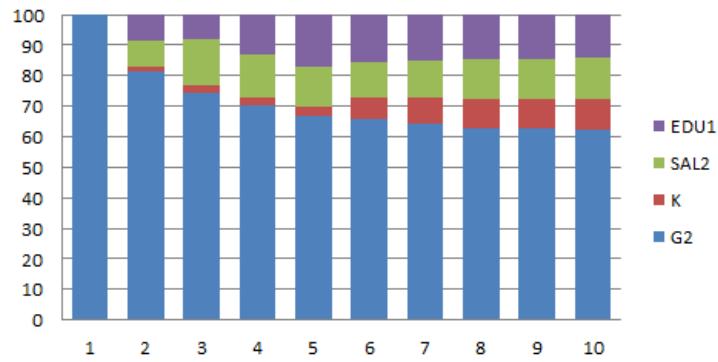
Desc. Var SAL2
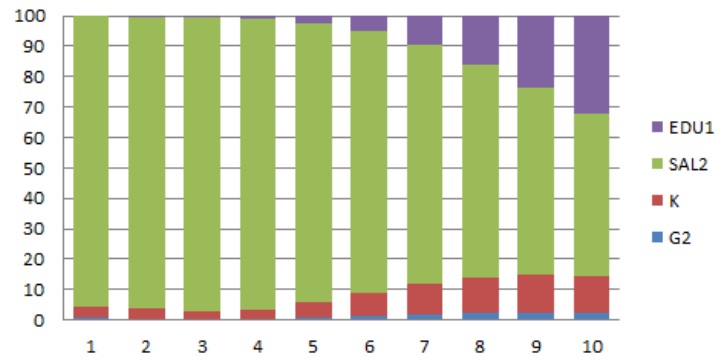
Desc. Var EDU1
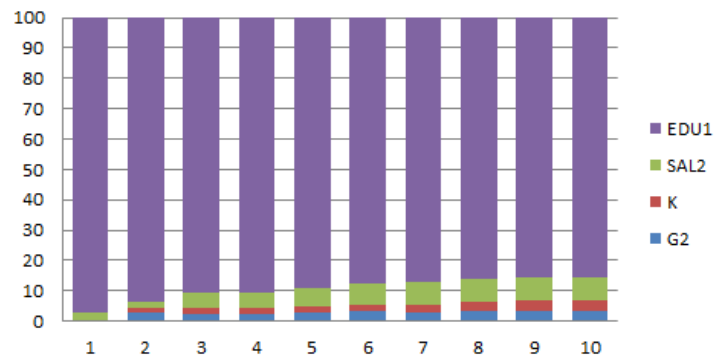
Appendix 5

Decomposition of the Variance of the average model (model 1)

Desc. Var EDU1 AVE

Desc. Var. G2 AVE

Appendix 6

Decomposition of Variance of the average model (model 2)

Desc. Var. G2 AVE

Desc. Var. SAL2 prom.

Desc. Var. EDU1 prom.
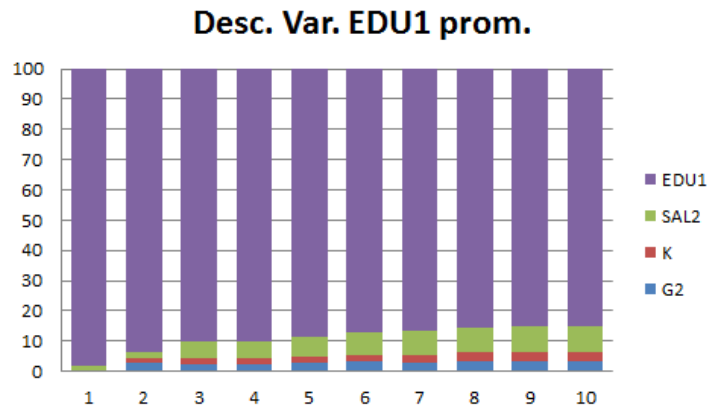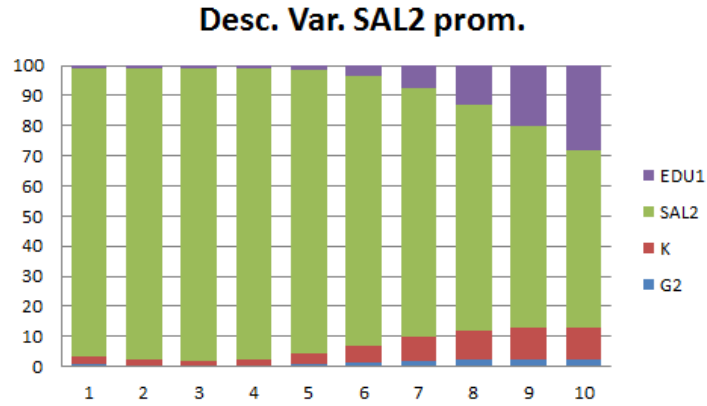
Appendix 7

Impulse response VEC model 1

Response to Cholesky One S.D. Innovations

Response of LPIBPC to LPIBPC	Response of LPIBPC to LESCAL	Response of LPIBPC to LEVN
Response of LESCAL to LPIBPC	Response of LESCAL to LESCAL	Response of LESCAL to LEVN
Response of LEVN to LPIBPC	Response of LEVN to LESCAL	Response of LEVN to LEVN

Decomposition of the variance of the VEC of model 1

Desc. Var. LEVN

Desc. Var. LEVN

Desc. Var. LPIBPC

Impulse response VEC model 2

Response to Cholesky One S.D. Innovations

Response of LPIBPC to LPIBPC

Response of LPIBPC to LESC

Response of LPIBPC to LEVN

Response of LESC to LPIBPC

Response of LESC to LESC

Response of LESC to LEVN

Response of LEVN to LPIBPC

Response of LEVN to LESC

Response of LEVN to LEVN

Decomposition of the variance of the VEC of model 2

Desc. Var. LTM

Desc. Var. LESC

Desc. Var. LPIBPC