

A second-generation endogenous model about health as determinant of economic growth¹

ABSTRACT: The intrinsic value of health as a component of human capital has been increasing with the passage of time and, thus, its relevance as a determinant of economic growth. We present a second-generation endogenous growth model where health plays a crucial role as a determinant of economic growth. In this model, a higher level of the health status and, thereby, of human capital, produces different effects. On the one hand, it elevates the product of both final and intermediate (innovation) goods sectors. On the other hand, it enhances the capacity to learn, and strengthens the adaptability to changes and creative abilities, reducing the cost of each new innovation and generating a higher growth rate. Additionally, any improvement in the rate of depreciation of health status will reduce the cost of innovation, thus generating a higher growth. Thus, the model presented here captures the different channels of influence proposed in economic literature.

KEYWORDS: Health; Endogenous growth; Channels of influence.

JEL Codes: I10; I15; O4

Pablo Daniel
Monterubbianesi*

* Instituto de Investigaciones Económicas y Sociales del Sur (IESS), Universidad Nacional del Sur- CONICET

* Correspondence to: P.D. Monterubbianesi, Instituto de Investigaciones Económicas y Sociales del Sur (IESS), Universidad Nacional del Sur- CONICET, 12 de Octubre 1198, 7th Floor, 8000, Bahía Blanca, Buenos Aires, Argentina, Telephone/ Fax +54291-4595138, Email: pmonteru@uns.edu.ar

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1. Introduction

The expression 'human capital' has undergone many modifications with the passage of time. This not only includes traditional education as it used to exist, but also health. Thus, human capital is a wide concept that includes both education and health.

Economic growth theory has accepted the value of human capital as a determinant of economic growth (Lucas, 1988; Mankiw, Romer and Weil, 1992, etc.). Thus, with the acknowledgment of health as a component of human capital, it assumes relevance in health as a determinant of economic growth.

In this context, economic literature has been developing models where health is incorporated in traditional growth models as being responsible for the existence of economic growth, transforming health as an important determinant of growth. In this sense, it is relevant to mention the contributions of Ehrlich and Lui (1991), Barro (1996), Kalemli-Ozcan, Ryder and Weil (2000), Howitt (2005), and Van Zon and Muysken (2007). From the models built by these authors it is possible to identify different channels to show how health influences economic growth.

Thus, we can observe two main channels that have been widely identified: a direct channel related to the idea that a higher health status generates higher productivity and, thereby, a higher economic growth rate, and an indirect channel related to the idea that higher health status produces a lower rate of depreciation of human capital and a higher life expectancy that generates a higher investment in human capital, and a higher economic growth rate. Moreover, to these main channels, there exist other channels identified that are related to the effect of health on learning and adaptability to changes, capacity, creativity, inequality, and use of resources.

Thus, the authors mentioned above have constructed models capturing some of the mentioned channels present in the literature. Till this moment, there does not exist a complete model that includes all the different channels of influence. Thus, the objective of this paper consists in developing an economic growth model that allows us to capture in one unique model the different channels of influence that health has on economic growth. We follow, mainly, the ideas proposed by Barro and Sala-i-Martin (1995), although we also employ the concepts of Barro (1996) and Howitt (2005).

With the construction of this model, we hope to contribute valuable literature relating to the influence of health on economic growth, elaborating a unified model that shows the different channels of influence, and giving a solid theoretical structure to future theoretical and, especially, empirical analysis in this area.

2. Economic growth theory

Modern economic growth theory is based on the contributions of Solow (1956) and Swan (1956), and the dynamical version of this model, presented by the contributions of Ramsey (1928), Cass (1965), and Koopmans (1965). These authors employ a neoclassical production function where economy will grow in per capita terms at a decreasing rate – determined by diminishing returns – until they reach a certain level. This level of per capita income is called 'steady state'.

The lack of agreement with the stylized facts (those that did not show stagnation in the per capita product growth rate) showed that it was necessary for any element that allowed the approach of the neoclassical model that was close to the stylized facts. Thus, technical progress was incorporated as a determinant of the economic growth rate. The idea was that if we make continuous technological advances such that these advances exceed the effect of the law of diminishing returns, there is no reason for the degradation of the economic growth process. The problem with this explanation was

that the incorporated technical progress was exogenous in the sense that the positive growth rates were generated by an external factor that could not be explained inside the model.

Theories of modern growth elaborate on models where the economic growth rate shows positive as a result of the model and not as a consequence of the incorporation of an external factor. For this reason, these models are known as endogenous growth models.

There is a first group of authors such as Romer (1986), Lucas (1988), Barro (1990) and Rebelo (1991) who have developed models based on these ideas. In these models, they try to eliminate the problem of diminishing returns in an attempt to generate sustainable positive growth rates. Additionally, the concept of 'capital' is amplified to include not only physical capital, but also the skills of workers (human capital). These new models do not present a technological change theory and are known as first-generation models in the new growth theory.

At the same time, it brings out a second group of models characterized by the incorporation of research and development as well as elements exhibited in imperfect competence. These ideas can be seen in Romer (1987, 1990), Aghion and Howitt (1992), and Grossman and Helpman (1991). In these models, technological advances arise from the research and development activities that earn remuneration by holding a monopoly over the patents. This incentive to research and development, and the appearance of new ideas, generate a positive long-term run in the economic growth rate. These models are known as second-generation models.

This endogenous technical progress can be considered from a horizontal or vertical perspective. On one hand, the horizontal technical progress considers that the higher the number of varieties of goods, the higher is the level of technical progress in the economy. Thus, each new innovation gets added to the existing stock of knowledge. On the other hand, vertical technical progress bears relation to the ideas of the economist Joseph Schumpeter who introduces the concept of 'creative destruction', in the sense that any new innovation displaces the older. According to this concept, the analysis of technical progress should be considered from a qualitative point of view.

Taking into consideration the idea that it is not sacrosanct for any new innovation to totally replace the older, we decided to construct an endogenous growth model with horizontal technical progress, where the variety of existing goods indicates the level of technological progress.

On the basis of the economic growth theory, different authors have built models where it is possible to incorporate health in the manner that results in a relevant element determining the economic growth rate. In this context, it is possible to identify different channels of influence that health exerts on economic growth.

3. Health and the economic growth theory

As we mentioned earlier, economic growth theory has identified different channels of influence of health on economic growth. In the following, we will present the contributions of different authors bringing out the relationship between health and growth, identifying the different channels of influence (Monterubbianesi, 2011).

The first consideration of this relationship is the model presented by Ehrlich and Lui (1991), who demonstrate an overlapping generation model where human capital is the element that relates to different generations, and that engenders the process of economic growth. In this model, parents invest in their children expecting that later, in old age, the children will take care of them, generating an inter-temporal optimization process that maximizes growth opportunities.

In this context, the role of health is defined from the probability of a child's survival up to adulthood and into old age. Increments in the parameters that represent longevity (these probabilities) generate an increase in investment in human capital and, thus, in a long-term economic growth rate.

In this sense, Barro (1996) also elaborates in his contribution that presents an amplified version of the neoclassical model. The origin of this contribution is that growth rate depends not only on traditional inputs, but also on a worker's health. The model also presupposes the existence of producer families that maximize the utility in due course of time.

On the basis of this model, it is possible to identify two different channels of influence. On one hand, there exists a direct impact of health on productivity in the sense that a betterment in health enhances the worker's productivity, an impact that is captured by the inclusion of health stock as a crucial factor of production. On the other hand, it exerts an indirect effect that is related to the idea that an improvement in health reduces mortality and illness rates, and thereby reduces the rate of human capital depreciation (health and education), generating a positive effect over productivity.

A third contribution is submitted by Kalemli-Ozcan, Ryder and Weil (2000), with the construction of a model that proposes the existence of conduct of people during their lifetime. The wealth that an individual possesses at birth is zero, and declines further during the education period, reaching a minimal value in the moment that he starts working.

During the initial years of work, individuals repay their debts and begin to show growing signs of their assets and progressive wealth. Although wages generally remain constant during the lifetime of a worker, consumption keeps on increasing.

The path of consumption defined requires that the level of wealth increases along with one's lifespan. Thus, the model supposes that individuals accumulate wealth with the objective of taking advantage of the difference between the rate of interest and the subjective rate of discount.

To take this further, this model proposes the existence of a life cycle. Health is introduced because of its influence over productivity. This analysis indicates to us that a fall in the probability ratio of an individual's death during life elevates the level of schooling and human capital stock, generating a process of growth in the economy. In this manner, it is possible, through this model, to consider the relationship between health and economic growth.

Another contribution we should consider is that of Howitt (2005), who presents a Schumpeterian endogenous growth model, incorporating health through the inclusion of some parameters. On the basis of this dynamic, it is possible to define two groups of countries: those that boast of growth at world technology levels, and those that lag behind in this technology that will grow at a slower rate.

We have now to answer the role that health plays in modifying the equilibrium in this model, and which are the channels of influence on economic growth. Howitt (2005) defines six channels of influence that can be captured by the parameters of the model.

The first channel of influence is the productivity efficiency that is based on the idea that healthier workers are more productive. A second channel of influence of health on economic growth is that of life expectancy that affects the skill depreciation rate, modifying their growth rate. The third is related to the idea that individuals with best health status will have a better learning capacity. An additional channel is related to the idea that individuals with a better health status, mainly in childhood, will also have more assets in facing up to technological changes. A fifth channel consists in the effect of a better health status over creativity. The last channel proposed by the author is related with income distribution. Better health stock affects more unprotected sectors of society, reducing inequality, elevating schooling level and, consequently, the economic growth rate.

Finally, we have to mention the contribution of Van Zon and Muysken (2007), whose construction of a modified version of Lucas' (1988) model, incorporated health as a determinant of economic growth. With this objective, they differentiate between two possible health statuses of population.

Inhabitants can belong to healthier or unhealthier populations. Any individual can change status because of external causes, or causes related to health. The behavior of the model can be established affirming that all individuals were born healthy and only healthier individuals can reproduce themselves. Additionally, people do not die without first being previously ill.

We can, therefore, affirm that the contribution of these authors allow, through some modification to Lucas' model (1988), define the relation between health and economic growth, identifying two channels. On one hand, reductions in the health status of the population can generate a reduction in effective labor supply. On the other hand, health production calls upon resources that have alternatives and more productive destinations.

Thus, it is possible to identify the different channels that the economic growth theory has developed relating to the influence of health on economic growth. Table 1 shows the different channels and gives the names of the authors against each channel.

As we mentioned earlier, we can observe two main channels widely identified in the economic literature about the influence of health on economic growth: a direct and an indirect channel. On one hand, the direct channel is related to the idea that a higher health status generates higher productivity and, thereby, a higher economic growth rate. On the other hand, the indirect channel is related to the idea that higher health status produces a lower rate of depreciation of human capital and a higher life expectancy that generates a higher investment in human capital and a higher economic growth rate.

Moreover, to these main channels, it also shows other channels that are identified by some authors in respect to the influence that health has on economic growth. Howitt (2005) proposed the idea that higher health status increases learning and adaptability to changes in capacity and creativity. Additionally, through the reduction in inequality, it generates an increase in school attendance, thereby producing a positive effect on growth. Van Zon and Muysken (2007) affirm that the higher the health status is, the lower the amount of resources earmarked for health care and more resources being made available for more productive activities producing a higher growth rate.

Table 1. Channels of influence of health on economic growth.

Channels	Authors
Higher health status, higher productivity, higher growth rate	Barro (1996), Howitt (2005), Van Zon and Muysken (2007)
Higher health status, lower depreciation rate, higher life expectancy, higher human capital investment, higher growth rate	Ehrlich y Lui (1991), Barro (1996), Kalemli-Ozcan, Ryder and Weil (2000), Howitt (2005)
Higher health status, higher learning capacity, higher growth rate	Howitt (2005)
Higher health status, higher adaptability to changes, higher growth rate	Howitt (2005)
Higher health status, higher creativity, higher growth rate	Howitt (2005)
Higher health status, lower inequality, higher school attendance, higher growth rate	Howitt (2005)
Higher health status, lower resources assigned to health attention, more resources available to more productive activities, higher growth rate	Zon y Muysken (2007)

(Source: Own elaboration.)

Hence, in the following, we will present a second-generation endogenous growth model in an attempt to capture the importance of health on the growth process, taking into consideration the channels of influence we have mentioned.

4. Health and economic growth: second-generation endogenous growth model

We now present a second-generation endogenous growth model with horizontal technical progress, where technological change is represented by permanent increments in the number of inputs, N , overlooking the existence of the law of diminishing returns.

The model we will develop is based on the contribution of Barro and Sala-i-Martin (1995)¹, although it has characteristics of other contributions like those of Barro (1996) and Howitt (2005).

4.1. Production and technical progress

The production function we propose is defined as follows:

$$Y_i = A H L_i^{1-\alpha} \sum_{j=1}^N (X_{ij})^\alpha \quad (1)$$

Thus, A represents different aspects that affect the product (institutional and political aspects), H represents health status of the population, L_i represents labor, while X_{ij} represents intermediate goods. The production function presents diminishing returns in each input L_i and X_{ij} and scale constant returns.

The principle of additive separability of $(X_{ij})^\alpha$ implies that the marginal product of intermediate goods j is independent of the quantum of intermediate goods utilized j' . It means that a new kind of product is not a direct substitute, neither is it a direct complementary of existent kinds of products. This supposition of independence is important because it implies that the discovery of new kinds of goods does not render obsolete any existent goods (horizontal technical progress).

The quantity of products established in Equation (1) will be defined as

$$Y_i = A H L_i^{1-\alpha} N X_i^\alpha = A H L_i^{1-\alpha} (NX_i)^\alpha N^{1-\alpha} \quad (2)$$

For a given value of N , Equation (2) indicates the existing scale of constant return in L and NX_i . For given amounts of L_i and NX_i , term $N^{1-\alpha}$ indicates product growth as a consequence of increases in N . This effect captures the technical progress that we want to represent in the model. For a given value of L_i , Equation (2) show us that an expansion in intermediate goods NX_i presents constant returns if the expansion is produced by an increase in N for a given X_i . Technical progress, in the form of increments in N , avoids the problems of diminishing returns. This production function characteristic is the fundamental of endogenous growth.

We suppose that goods Y_i produced are identical in each firm and that this product can be used for: (1) consumption, (2) the production of intermediate goods X_j , or (3) be destined to research and development with the objective of inventing new kinds of intermediate goods (increments in N). In the model, all prices are measured in terms of goods Y .

¹ The model presented by Barro and Sala-i-Martin (1995) is based in the contributions of Spence (1976), Dixit and Stiglitz (1977), Eicher (1982) and Romer (1987 y 1990).

As Barro and Sala-i-Martin (1995) affirms, it is possible to consider X_j as durable goods. Firms could rent capital goods and we would have two state variables: aggregate capital and number of varieties of the intermediate good N . However, to simplify the model, and considering that results are similar, we can suppose that X_j represents no durable goods and services, so we will have only one state variable, N . The profit for a producer of final goods will be

$$Y_i - wL_i - \sum_{j=1}^N P_j X_{ij} \quad (3)$$

This means that profits for the producer will be his production minus employed labor valued at current wages, and utilized inputs X_j valued at its prices P . The marginal product can be obtained from the production function (1) and is defined as

$$\frac{\partial Y_i}{\partial X_{ij}} = A H \alpha L_i^{1-\alpha} x_{ij}^{\alpha-1} \quad (4)$$

$$\frac{\partial Y_i}{\partial L_i} = A H \frac{L_i}{Y_i} \quad (5)$$

These producers work in perfect competence, such that the marginal product will be equal to the price of each factor. This means that

$$A H \alpha L_i^{1-\alpha} x_{ij}^{\alpha-1} = P_j \quad (6)$$

and

$$A H \frac{L_i}{Y_i} = w \quad (7)$$

As we have mentioned previously, technology allows producing N varieties of intermediate goods. If we want to increase the number of varieties of intermediate goods, it will necessarily be a technological progress that allows a new kind of intermediate good.

The cost of creating a new intermediate good can be defined in terms of the final product. Thus, it will be require η units of the final good Y to produce a new variety of inputs. The basic problem is that the creation of a new idea or design to produce j is costly but can be utilized in a nonlinear form by all the potential producers of j . To solve this inconsistency, we suppose that the inventor of good j has a monopoly over production and the sellers of good X_j .

The cost of research and development is, as we mentioned, given by η . This cost will be composed by various components. First, we have invested an amount in R&D that will be a fixed number γ of product units. However, we have to take into consideration the role of health in this transition. In this sense, the health status of the economy implies an adaptation to change and learning capacity and creativity determined, affecting the cost of R&D. Additionally, we have to take into consideration that health stock depreciates at a rate δ , affecting, also, the cost of any new innovation. Thus, the cost of producing a new variety of goods will be

$$\eta = \frac{\gamma}{H(1-\delta)} \quad (8)$$

Now we have to define the present value of returns of discovery for intermediate good j for the research. Following Barro and Sala-i-Martin (1995) this return will be

$$V(t) = \int_t^{\infty} (P_j - 1) x_j e^{-\bar{r}(v,t)(v-t)} dv \quad (9)$$

Where

X_j : Amount of good j produced in each period.

$\bar{r}(v, t) : [1/v - t] \int_t^v r(w) d(w)$: Average interest rate between period r and t .

We can suppose that, in equilibrium, the interest rate is constant. The present value of the factor will simplify to $e^{r(r-t)}$.

Now, taking into consideration Equation (9), it will be possible to analyze monopolist behavior and the obtaining of equilibrium. The cost of discovery of a new product η can only be compensated if the selling price P_j exceeds the marginal cost of production (we suppose this marginal cost to be equal to 1) for at least any part of time t .

The monopolist establishes the ruling price P_j , with an intention to maximize the difference between this price and marginal cost. The monopolist will maximize $(P_j - 1)X_j$ where

$$X_j = \sum_i X_{ij} = \left(\frac{AH\alpha}{P_j} \right)^{\frac{1}{1-\alpha}} \sum_i L_i = L \left(\frac{AH\alpha}{P_j} \right)^{\frac{1}{1-\alpha}} \quad (10)$$

X_j is the demanded quantity of X_j . As we mentioned earlier, the producer of good X_j will select P_j that maximizes the flow of benefits of the monopolist in each period. In this manner, the expression to maximize will be

$$(P_j - 1) L \left(\frac{AH\alpha}{P_j} \right)^{1/(1-\alpha)} \quad (11)$$

Price solution for the monopolist will be

$$P_j = \frac{1}{\alpha} > 1 \quad (12)$$

Thus, P_j is the price for all goods j . If we substitute the value of P_j that we obtained in Equation (6), we can determine the aggregate quantity of production for each good j .

$$X_{ij} = L (AH)^{1/1-\alpha} \alpha^{2/(1-\alpha)} \quad (13)$$

If we substitute values of P_j and x_j obtained in Equations (12) and (13) into Equation (9), and we move out the integral from the constant terms, we have

$$V(t) = L AH^{1/1-\alpha} \left(\frac{1-\alpha}{\alpha} \right) \alpha^{2/(1-\alpha)} \int_t^{\infty} e^{-\bar{r}(v,t)(v-t)} dv \quad (14)$$

We assume that to be an inventor, free entry in the market exists in such a manner that anyone can pay the cost of research and development η to get the present value $V(t)$ that we see in Equation (14).

At this point, we can carry out an analysis of the optimal amount invested in research and development. We compare the actual value of return of discovery of the good with the cost of discovery of the good. If $V(t) > \eta$, an infinitive amount of resources will be invested in R&D at moment t , so $V(t) > \eta$ cannot be at equilibrium. If $V(t) < \eta$ there would not be available any resources to invest in R&D, and in this way, the number of goods N would not change with time.

We will concentrate the discussion on equilibrium with positive investment in R&D, and thus, N growing in all moments of time. In that case, we have the equilibrium $V(t) = \eta$.

$$L AH^{1/1-\alpha} \left(\frac{1-\alpha}{\alpha} \right) \alpha^{2/(1-\alpha)} \int_t^{\infty} e^{-\bar{r}(v,t)(v-t)} dv = \eta \quad (15)$$

On the right side of Equation (15), everything except the integral is constant. If the interest rate r is also constant, all the elements will be constant. The integral can be simplified to $1/r^3$. Thus, condition $V(t) = \eta$ requires

$$\begin{aligned} L (AH)^{1/1-\alpha} \left(\frac{1-\alpha}{\alpha} \right) \alpha^{2/(1-\alpha)} \int_t^{\infty} \frac{1}{r} &= \eta \\ r &= (L/\eta) (AH)^{\frac{1}{1-\alpha}} \left(\frac{1-\alpha}{\alpha} \right) \alpha^{\frac{2}{1-\alpha}} \end{aligned} \quad (16)$$

Substituting η of Equation (8) and simplifying further, we have

$$r = \frac{L(1-\delta)}{\gamma} A^{\frac{1}{1-\alpha}} H^{\frac{2-\alpha}{1-\alpha}} \left(\frac{1-\alpha}{\alpha} \right) \alpha^{2/(1-\alpha)} \quad (17)$$

Market structure, technology and health status determine the rate of return at the established value of Equation (17). The marginal intermediate good $N + 1$ that will be just discovered will generate a present value of the monopolist's profit that will just cover the R&D cost η . It means that the condition defined in Equation (17) is satisfied. Because all new products benefit by the same flow of monopolistic profits, the present value of profits for each existent intermediate good must equal to η . In this manner, η is the market value of a firm that produces an intermediate good, and the aggregate market value of these firms will be ηN .

We have analyzed the production side of economy. To obtain the growth rate, it will be necessary to consider the families' behavior and the market equilibrium. We will do that in the next section.

4.2. Families and market equilibrium

We suppose, as it usually occurs in inter-temporal optimization models, that families maximize their utility in an infinite horizon with the following utility function.

$$u = \int_0^{\infty} \left(\frac{C^{1-\theta} - 1}{1-\theta} \right) e^{-\rho t} dt \quad (18)$$

As it usually occurs, ρ is the subjective discount rate of families, and Θ represents the grade of linearity of consumption. Population growth rate is 0. Families possess assets that generate a return rate of r and receive a wage w by a fixed amount of aggregate labor L .

³ If we differentiate the integral respect to t , we obtain this result.

Thus, the budget restriction of the families expressed in per capita terms is

$$\dot{b} = w + rb - c \quad (19)$$

Where b represents per capita assets, $b=B/L$. Maximizing the utility function (18) subject to the budget restriction (19), we obtain the key condition for the optimization process, the consumption growth rate.

$$\dot{b} = w + rb - c \quad (20)$$

Substituting r of Equation (17) in this expression we have

$$\gamma = \frac{1}{\theta} \left[\frac{L(1-\delta)}{\gamma} H^{\frac{2-\alpha}{1-\alpha}} A^{\frac{1}{1-\alpha}} \left(\frac{1-\alpha}{\alpha} \right) \alpha^{\frac{2}{1-\alpha}} - \rho \right] \quad (21)$$

We use γ instead of γ_c because, as it usually occurs in growth models, the same can be applied not only to consumers, but also to the number of designs N and to total product Y . Thus, the expression obtained in Equation (21) is the equilibrium growth rate of economy. This equation is valid only if the underlying parameters give us a positive growth rate $\gamma \geq 0$ in the equation. If $\gamma \leq 0$, potential inventors do not have enough incentives to invest in R&D.

4.3. Growth rate, health effects and channels of influence

Equation (21) shows which variables determine economic growth rate. An improvement in political and institutional factors, A , elevates economic growth rate. At the same time, elevations in the grade of linearity of consumption Θ , and in the subjective discount rate ρ , also reduce the economic growth rate.

In Table 1 we had analyzed the channels of influence of health on economic growth. We had seen the existence of two main channels, a direct one from the effect of productivity and an indirect one related to a lower human capital depreciation rate. Additionally, we mentioned other channels proposed by different authors. These channels were related in the idea that a better health status generates higher learning and adaptability to capacity for changes, higher creativity and lower inequality, with the consequence of higher school attendance. Finally, we also mentioned that an increase in health status allows reallocating resources from health services to more productive activities.

Channels of influence related to inequality and reallocation of resources between health and productive activities require specific and independent models, so we will exclude these channels in our model.

The rest of the channels of influence proposed can be captured in our model. First, we can see that an increase in health status, represented by variable H , generates an increase in productivity. This effect can be represented by the inclusion of health status H in the production function. This is the direct effect proposed in the economic literature.

Additionally, we can analyze the indirect channel in our model. An improvement in health status that produces a reduction in depreciation rate of health status can be captured in the model as a reduction in parameter δ . The reduction in this parameter (lower health status depreciation rate) produces a reduction in the cost of any new innovation and, thus, an increase in the return of any innovation giving place to a higher number of innovations (intermediate goods N) and generating a higher economic growth rate.

Apart from the direct and indirect effects proposed in the economic literature, our model allows to capture the effects related to higher learning and the capacity of adaptation to changes capacity and higher creativity that a higher health status produces. An increase in health status H elevates learning and the capacity to adapt to changes and creativity, reducing the cost of innovation and elevation of the growth rate. This effect can be captured by the inclusion of H as component of innovation cost η .

In this manner, the proposed model captures not only the direct and indirect effect mentioned in the economic literature, but also the effects related to the capacity for learning and adaptability to changes and creativity. If we see Equation (21), this is clear. We saw that in this equation we have health status H . If we compare the effect of an improvement in health status with an improvement in political and institutional factors (A), we can see, considering $2 - \alpha/1 - \alpha > 2/1 - \alpha$, that the effect of an increase in health status on growth is higher than the effect of an increase in A . The reason for this difference is that in addition to the direct effect (common to A and H), an improvement in health status affects growth rate augmenting the capacity for learning and adaptation to changes and creativity and, thereby, reducing the cost of each innovation. Additionally, Equation (21) includes a health status depreciation rate δ . When this rate falls it reduces the cost of each innovation, also generating a higher growth rate. This effect corresponds to the indirect effect proposed in the economic literature.

5. Conclusions

In this paper, we have presented a theoretical model about the influence that health has on economic growth. Our model is based in the contributions of Barro and Sala-i-Martin (1995) and can be characterized as a second-generation model with horizontal technical progression into the new economic growth theory.

The main idea of our model consists in the existence of a sector dedicated to the production of intermediates goods. The increase in the number of intermediate goods represents technological advances, and whoever obtains this innovation will have a monopolistic position in respect to this new intermediate good. The equilibrium in this model will occur when the returns in each period for this monopolist equals the cost of obtaining each new innovation.

Health status influences our model in different ways. A higher health status elevates productivity of the economy. This can be observed with the inclusion of health status in our production function. This is the direct effect of health on economic growth usually mentioned in literature. Additionally, reductions in the depreciation rate of health stock results in the fall in the cost of each new innovation, elevating return rates, augmenting the number of new intermediate goods in each period and, thus, the economic growth rate. This is the mechanism known as 'indirect effect' in economic literature. Finally, an increase in health stock produces the capacity for higher learning and adaptability to changes and higher creativity. Thus, with the proposed model, it is possible to capture the channels of influence that health has on economic growth, which have been described in the literature.

Additionally, our model presents interesting policy conclusions. If we are desirous of elevating economic growth rates, formulate policies destined to improve health status and to reduce its rate of depreciation, these will have important effects through the channels mentioned.

6. References

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