E c o n o m i c s B u l l e t i n

Endogenous longevity, health and economic growth: a slow growth for a longer life?

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Abstract

We establish a theoretical set−up that is able to endogenously integrate growth and longevity. Our model captures three links between them: a longer life expectancy results in an increase in savings as well as an increase in the workforce, but health and growth compete for resources. We find that the key element is the response of longevity to an increase in health resources. Our model suggests that the first two links could be the most important in poor countries, which could explain their experience of simultaneous increases in growth and life expectancy. The reverse result may apply for developed countries.

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1.- Introduction

There is a general consensus that economic development goes hand in hand with important improvements in life expectancy. In fact, part of the literature on economic growth has recently directed its attention to analyzing the growth implications of an increment in longevity. Several elements relating longevity and growth have been considered in the theoretical literature. Some of them generate a positive relationship between both indicators, others a negative one. They can be grouped mainly into two sets of links. The first set is related to the quantity and quality of the labor force. The other examines the impact of declines in mortality on the saving rate.

From the labor force point of view, people can provide effective labor services only if they are alive. As Van Zon and Muysken (2001) point out, to be alive and healthy is a necessary condition for the provision of human capital services that have been acquired from education. In fact, insofar as human capital is inherently tied to individuals, the expansion of life expectancy allows for returns to be obtained over a longer period of time, which encourages its accumulation and, as a consequence, economic growth (Kalemli-Ozcan et al., 2000; De la Croix and Licandro, 1999). In contrast, lengthening life also intensifies the competition for resources between the consumption and health needs of the elderly on the one hand, and investment in children on the other (Zhang et al., 2003). In this sense, an expansion of the health sector may promote growth through increased labor productivity, while a contraction of the health sector could also free the resources necessary to promote the accumulation of human capital (Van Zon and Muysken, 2001). However, the extension of the educational period delays incorporation into production, thereby causing a fall in the activity rate (De la Croix and Licandro, 1999).

Longevity also has implications on the rate of physical capital accumulation. Longer life expectancies promote economic growth by affecting agents' willingness to substitute consumption across time. Individuals with a higher life expectancy are more patient, generate higher levels of savings and, as a consequence, more growth (Reinhart, 1999).

In general, these studies have considered each of these links between longevity and economic growth separately. However, some of them have gone further by trying to detect which of the effects could be the most important and finding that development is a critical element in assessing this issue. In fact, the recent empirical evidence raises the possibility that the relation of economic growth to mortality is non-monotonic. Lee (1994) points out that less developed countries exhibit high mortality rates mostly in children and therefore a reduction in mortality increases the labor force, on one hand, and returns on investment, on the other. On the contrary, in developed countries, life expectancy exceeds the retirement age and so reducing mortality makes the population older but does not expand the labor force nor the returns on investment in formation. Kelley and Schmidt (1995) and Bhargava et al. (2001) find positive effects of declines in mortality on growth in low-income countries. For highly developed countries, the effect was negative.

In this paper we investigate the connection between economic growth and life expectancy through an additional linkage, different to those previously mentioned: the competition for public resources. Our analysis endogenizes life expectancy by allowing the probability of survival to depend on the public expenditure on health care. It seems reasonable to assume that survival probability is increasing the average health level of society, which depends on the quantity of public resources used in the health sector.

However, the provision of public health services competes with the resources for increasing public productive expenditure on infrastructures or services which influence long-run growth. In this sense, our paper is inspired by Drèze and Sen (1989), who distinguish two different experiences with success in the reduction of mortality which they call "growth mediated" and "support-led" processes. The first experience corresponds to countries in which fast economic growth generates the resources required to expand the social health status (South Korea or Hong Kong, for example). This is not the case of Sri Lanka or Costa Rica, countries with slow economic growth, in which the reduction of mortality is the consequence of the priority given to health care to the detriment of other uses of the resources. It seems, then, interesting to try to establish a theoretical set-up that is able to integrate growth, longevity and government spending on health care.

The paper is organized as follows. Section 2 presents the model. The equilibrium is described in section 3, in which we focus on the steady state. In Section 4 we discuss the effects of a reallocation of resources on both longevity and growth. Section 5 summarizes the main results.

2. The model

Population. Given that the goal of our analysis turns on the phenomenon of longevity, we assume that the number of births is constant at each moment in time. Let us assume that N individuals are born at time s, in such a way that they form cohort s. We consider, as in Blanchard (1985), an economy where individuals face an instantaneous probability p of dying at any moment. This probability is constant over the life of every cohort and depends on the social health status h in the birth period. The instantaneous probability of dying at any moment for a member of cohort s is $p(h_s)$, with $p'<0$.

Let X_s denote the time until death of an individual of cohort s. Given h_s, the assumption of a constant instantaneous probability of dying can be represented through a density function $f_{X_s}(x) = prob(X_s = x) = p(h_s)e^{-p(h_s)x}$. In such a context, the life expectancy of any individual of cohort s is given by $E(X_s) = \int_0^\infty xp(h_s)e^{-p(h_s)x}dx = p(h_s)^{-1}$. That is to say, a higher health status implies on average a longer life.

Under these conditions, the population in t, that we call L_t, can be represented as:

$$L_t = \int_{-\infty}^{t} Ne^{-p(h_s)(t-s)}ds\,. \tag{1}$$

Each individual is endowed with one unit of time per period, so that this is also the size of the workforce. Note that since at each moment in time the same number of individuals is born, the only source of population growth is the increase in life expectancy.

Consumers. Individuals' welfare proceeds from the stream of consumption c over the period of living. Assuming that the instantaneous utility derived from consumption is logarithmic, the expected utility of a member of cohort s can be represented as:

$$EU(s) = \int_s^\infty \ln(c_{s,t})e^{-[\rho + p(h_s)](t-s)}dt\,, \tag{2}$$

where $c_{s,t}$ is the goods consumption in t of an individual born in s and ρ is the intertemporal discount rate of the utility.

Since the probability of being alive in any future period diminishes, individuals will then want to protect against the risk of dying without having spent their whole wealth through insurance. Therefore, we assume an insurance system in which competitive insurance firms receive the wealth of individuals in case they die in exchange for paying them a rate p on their wealth in each time over the whole period they are alive[1]. This implies the following budget constraint:

$$\dot{v}_{s,t} = \left[r_t + p(h_s)\right]v_{s,t} + w_t - c_{s,t}, \tag{3}$$

where $v_{s,t}$ denotes the wealth owned by each member of cohort s at time t, r_t is the interest rate and w_t the wage rate. A dot over any variable indicates its variation in time: $\dot{v} = dv/dt$.

Production of final goods. Following Barro (1990), we assume that production of final goods Y_t is the result of combining private capital K_t, labor L_t and productive public services G_{Yt} according to the following technology:

$$Y_t = AK_t^{\alpha} L_t^{1-\alpha} G_{Yt}^{1-\alpha}. \tag{4}$$

An amount G_t of final goods is procured by the government to provide productive as well as sanitary services. The rest is divided between aggregate consumption (C_t) and investment, in such a way that physical capital accumulation follows:

$$\dot{K}_t = Y_t - C_t - G_t. \tag{5}$$

Physical capital is the only component of individuals wealth.

Health. Social health status is the result of two opposite forces. On the one hand, biological processes involve a natural decay of health simply as time passes. We assume that this deterioration takes place at a constant rate δ. On the other hand, modern societies devote important amounts of resources to fighting against that natural deterioration. Health care expenditures are not able to prevent individuals' death but delay the moment of death. We consider that health services G_{ht} are publicly provided by the government.. Social health status accumulates depending on the expenditure on health as a percentage of income (Rivera and Currais, 1999). Therefore, social health status evolves over time according to:

$$\dot{h}_t = \xi \frac{G_{ht}}{Y_t} - \delta h_t. \tag{6}$$

Government. Public revenues proceed from a tax rate τ on individuals' income. Per capita expenditure is distributed between productive services for firms and health services. Let us denote the fractions of per capita expenditure devoted to each activity by θ and $1-\theta$, respectively. Let us assume that public expenditure is financed contemporaneously by taxes. The government budget constraint is then given by $G_t = \tau Y_t$. From this expression, public expenditure on productive services and on health services is given by $G_{Yt} = \theta G_t = \theta\tau Y_t$ and $G_{ht} = (1-\theta)G_t = (1-\theta)\tau Y_t$, respectively.

[1] See Blanchard (1985).

3. Equilibrium

Substituting the previous expression for the productive government services in the technology of production (4) and rearranging, we have:

$$Y_t = A^{\frac{1}{\alpha}} (\theta\tau L_t)^{\frac{1-\alpha}{\alpha}} K_t , \tag{7}$$

In equilibrium, the net interest rate coincides with the net marginal productivity of capital. It is constant and given by:

$$r_t = (1-\tau)\alpha A^{\frac{1}{\alpha}} (\theta\tau L_t)^{\frac{1-\alpha}{\alpha}} . \tag{8}$$

Making use of these results, we can rewrite expressions (5) and (6) as:

$$\dot{K}_t = (1-\tau) A^{\frac{1}{\alpha}} (\theta\tau L_t)^{\frac{1-\alpha}{\alpha}} K_t - C_t , \tag{9}$$

$$\dot{h}_t = \xi (1-\theta)\tau - \delta h_t . \tag{10}$$

Steady State. Since our interest is not the short-run but the long-run performance, we focus on what follows in the steady state. The long-run equilibrium of this economy is characterized by constant health status and life expectancy, which also implies a constant population. Moreover, output, consumption and capital grow at constant and identical rates.

From (10) we can deduce that the steady state health status is given by

$$h^* = \frac{\xi (1-\theta)\tau}{\delta} , \tag{11}$$

where the asterisk denotes the long-run value of any variable. Thus, from the corresponding constant probability of death $p^* = p(h^*)$ we can compute the steady state population as $L^* = \int_{-\infty}^{t} N e^{-p(h^*)(t-s)} ds = N p(h^*)^{-1}$. These results indicate that the society is healthier and individuals' life longer, the higher the productivity of the health sector and the fraction of income devoted to it, and the lower the rate of biological deterioration.

On the part of consumers, given a stable life expectancy, the evolution of aggregate consumption over time can be obtained as[2]:

$$\dot{C} = [\alpha D - \rho] C - p^* (\rho + p^*) K , \tag{12}$$

where $D = (1-\tau) A^{\frac{1}{\alpha}} (\theta\tau L^*)^{\frac{1-\alpha}{\alpha}}$ stands for the (after tax) social productivity of capital; according to (8), the private productivity of capital is αD. On the other hand, if we denote by g the growth rate of both consumption and capital and by $\chi = C/K$ the ratio of the two variables, equations (12) and (9) can be rewritten as

$$g = \alpha D - \rho - p^* (\rho + p^*) \chi^{-1} , \tag{13}$$

[2] See again Blanchard (1985).

$$g = D - \chi \,. \tag{14}$$

This system can be summed up in the following second-degree equation in *g*:

$$\Phi(g) = g^2 + [\rho - (1+\alpha)D]g + (\alpha D - \rho)D - p(\rho + p) = 0\,. \tag{15}$$

From the fact that $\Phi(D) = -p(\rho + p) < 0$ and $\Phi''(g) = 2 > 0$ it follows that equation Φ has two positive roots, one lower than *D* and the other higher than *D*. The latter can be discarded because it implies a negative value of consumption in (14). Moreover, for the former to be positive, the condition $\Phi(0) = (\alpha D - \rho)D - p(\rho + p) > 0$ must hold. Thus, under the assumption that this condition holds, the long-run growth rate g^* can be solved as the lower root of equation (15).

Taking into account that our main goal is to investigate the connection between economic growth and life expectancy through the competition for public resources, we concentrate in what follows on the influence of the distribution of public expenditure both on the growth rate and on life expectancy.

4. Health expenditure, growth and life expectancy

Given the technology of the health sector ξ and the rate of biological deterioration δ, improvements in life expectancy can only be the result of a reallocation of resources in favor of health care. That is to say, a higher fraction of the GDP is devoted to health services. Given that we assume a completely public health system, we must consider the consequences of a reallocation of public expenditure towards health services. From (15) we have:

$$\frac{\partial \Phi(g)}{\partial \theta} = \frac{1-\alpha}{\alpha}\frac{D}{1-\theta}[2\alpha D - \rho - (1+\alpha)g]\left(\frac{1-\theta}{\theta} - \varepsilon_{p,h}\right) - (\rho + 2p)\frac{p}{1-\theta}\varepsilon_{p,h}\,, \tag{16}$$

where $\varepsilon_{p,h} = -(h/p)dp/dh$ denotes the elasticity of the probability of dying with respect to social health status, which in the steady state coincides with the elasticity of life expectancy with respect to social health status. The sign of the above derivative depends crucially on the size of this elasticity. For an elasticity high enough, that is to say, when it exceeds the critical value $\varepsilon_{p,h} = (1-\theta)/\theta$, the derivative has a negative sign, which indicates that *g* and θ move in opposite directions. Thus, an increase in resources devoted to health (a reduction in θ) is accompanied by a faster long-run growth rate of output. Since it also implies a higher health status, in this case life expectancy and growth move in the same direction.

On the contrary, when the elasticity is below $(1-\theta)/\theta$, the sign of (16) is indeterminate and allows the possibility that life expectancy and growth react in opposite directions after the reallocation of resources, in such a way that an increase in the average life span takes place to the detriment of output growth. This possibility appears to be more likely the lower the elasticity.

The reason for this outcome is that the growth rate is affected in several different ways by a reduction in θ. Since this implies a decrease in public expenditure in productive services for firms, a first effect is a reduction in final good firms productivity that reduces the growth rate of output. A second effect is related to the health status: more resources devoted to heath care mean a healthier population with a longer life on average. This in turn drives an enlargement of population and thus –given the reduced form of the technology in (7)- an increase in capital productivity. Therefore, there are two opposite effects on productivity due to a simultaneous reduction in public services and an enlargement of the workforce. Which of them dominates? For high values of the elasticity of life expectancy, this variable increases strongly and thus the effect of a higher workforce in productivity dominates. Otherwise, the effect of population is lower than the effect of the reduction of public productive services and productivity decreases.

In addition to this indeterminate effect through capital productivity, the growth rate is also affected by θ directly through the probability of dying, which is part of the effective discount rate of utility. The reduction in this probability increases the patience of consumers, who decide to consume less in favor of saving more. This, on one hand, will expand future consumption and, on the other, allow for a faster accumulation of physical capital. In turn, this enables a faster growth rate in the long run. Through this link, thus, growth and life expectancy are positively related.

The final effect is that $\partial\Phi / \partial\theta < 0$ when $\varepsilon_{p,h} \geq (1-\theta)/\theta$ and indeterminate otherwise. This implies that when $\varepsilon_{p,h} \geq (1-\theta)/\theta$, a reallocation of resources in favor of health services leads to a simultaneous increase in the growth rate and in life expectancy. In the reverse case, the possibility that life expectancy and growth are negatively related is also allowed. Both patterns can be observed in the experience of some countries, as described in the introduction.

Developing countries are, in general, characterized by a high child mortality and thus a low life expectancy. However, it is relatively easy to provide conditions that improve individuals' health and thus reduce early mortality. That is to say, a few more resources devoted to health can have relatively important consequences on life span. This corresponds to a high elasticity $\varepsilon_{p,h}$. Moreover, the fraction of the GDP devoted to health in these countries is below the average of developed countries. Both characteristics make it very probable that the condition $\varepsilon_{p,h} \geq (1-\theta)/\theta$ will hold. This can explain why the pattern followed in general in developing countries includes parallel increases in growth and life expectancy.

On the contrary, developed countries exhibit longer life expectancy but, in contrast, experience great difficulties in obtaining a further increase in life span. This suggests that investment in health is progressively less effective in enlarging individuals' life and thus the elasticity $\varepsilon_{p,h}$ diminishes as life expectancy enlarges. Taking into account that health expenditure, as a fraction of income, is greater in developed countries, the conditions favor the relationship between the elasticity and the critical value $(1-\theta)/\theta$, holding in the opposite sense for the developing countries. As discussed earlier, for a value of elasticity low enough, the efforts devoted to enlarge life expectancy through a reallocation of resources to the health sector lead to a deceleration of the growth rate of the economy.

From an empirical point of view, although there is evidence in favor of a non-monotonic relationship between economic growth and longevity, there is no conclusive evidence on how public health expenditure influences life expectancy and economic growth depending on structural characteristics of the economy. Further research in this direction would be required.

The above results can be reinforced by some additional effects that the model does not capture explicitly in order to maintain its tractability. The first one refers to the relationship between life expectancy and the age of retirement. With life expectancy exceeding the age at which individuals leave the labor market in developed countries, the positive effect of a longer life on productivity through the enlargement of the labor force does not appear (or, in general, has a very small importance). Thus, productivity, as well as the growth rate, is likely to be reduced. The opposite holds in developing countries in which individuals die while they are active and thus a longer life leads to a parallel expansion of labor supply.

A second important feature that the model does not consider, but that would reinforce the asymmetry between developed and non-developed countries, is a more realistic distribution of the probability of death over life, one in which the probability of death increases with age. As Faruquee (2003) shows, introducing an age-specific mortality (instead of our cohort-specific mortality) makes the propensity to consumption increase over life, intensifying the role of young people in positive saving and the role of old people in negative saving. In such a context, whether better health reduces mortality mainly in old people or young people becomes a key element. Since, in developed countries, the mortality rate declines occur at older ages, when saving is negative, its effect on the saving rate, if any, would be very weak. However, in developing countries a better health status reduces mortality rates at much earlier stages of life and thus leads to strong positive effects on savings. Therefore, the actual pattern of mortality rates over life reinforces the positive relationship between life expectancy and growth in developing countries.

Finally, other simplifying assumptions related to preferences also modify the relative importance of the savings link between longevity and growth. For example, it is well known that our assumption of a logarithmic utility implies a relative risk aversion of the unit, although the actual values seem to be higher. A higher risk aversion implies a higher propensity to consumption and, therefore, a lower saving rate. Thus, the higher the risk aversion, the weaker the positive link between longevity and growth. The importance of this link would also be lower when considering altruistic individuals that derive utility from leaving bequests to their heirs instead of our assumption about the insurance mechanism. Such a specification would be closer to an infinite horizon perspective (the individual derives utility not only from his own consumption but also from wealth passed to his heirs), and, therefore, the higher the degree of altruism, the lower the influence of life expectancy on saving decisions. Alternatively, the consideration of unintended bequests transferred to society when people die (Zhang et al., 2003) increase the capital available for production and thus introduces another link between longevity and economic growth: lengthening life reduces accidental bequests, thus reducing the rate of capital accumulation and growth.

5. Conclusions

Life expectancy, health, and economic growth are three important determinants of human welfare. In this paper we have analyzed the interrelationships between them, focusing on three kinds of links: those which affect saving decisions, those which take place through the labor market and, finally, the competition for resources between the different activities. Since these forces act in opposite directions, there is no clear result about whether longevity and growth are positively or negatively related in the long run. In order to shed more light on this issue, we have built a model in which average longevity is endogenously determined by public investment in health, while growth is driven by public expenditure in productive services that enhance private firms' productivity. Despite the trade-off between longevity and growth determined by the allocation of resources between the two, a longer life expectancy leads to a higher savings rate and to an expansion of the workforce that could speed up growth. Indeed, which of these forces prevails depends on structural characteristics of the economy.

Thus, we have shown that the effectiveness of health expenditure in reducing mortality is a key element. If expanding the resources devoted to improve social health status has an important impact in terms of reducing mortality, the effects of higher savings and a bigger labor supply are the most important. As a consequence, the increase of longevity goes hand in hand with an acceleration of the long-run growth rate. This is the pattern corresponding to less developed countries, whose high mortality rates can be reduced easily by measures that do not, in general, require important amounts of resources. Conversely, longer life has become a hard and expensive task in developed countries, which makes it more likely that the efforts devoted to this purpose have a negative effect on long-run growth, a result that empirical analyses have pointed out recently.

Although our framework is too simplistic in many aspects, the main results would prevail in more sophisticated specifications, as discussed above. Nevertheless, we think that some extensions like the introduction of a private health sector or the consideration of the links between longevity, investment in education and productivity could provide a deeper insight into the complex relationship between life expectancy and growth.

Appendix: list of main variables and parameters

A	Productivity index
$c_{s,t}$	Consumption in t of an individual of cohort s
C	Aggregate consumption
D	Social productivity of capital
g	Growth rate (of output, consumption and capital)
G	Aggregate public expenditure
G_h	Public expenditure on health services
G_Y	Public expenditure on productive services
h_s	Health status of an individual of cohort s
K	Physical capital
L	Size of the population
N	Number of individuals born at any time
p	Probability of death
r	Interest rate
$v_{s,t}$	Wealth in t of an individual of cohort s
w	Wage rate
X	Time until death
Y	Output
α	Elasticity of output with respect to capital
δ	Rate of biological deterioration
$\varepsilon_{p,h}$	Elasticity of longevity with respect to social health status
θ	Fraction of public expenditure on productive services for firms
ξ	Productivity of health sector
ρ	Intertemporal discount rate
τ	Tax rate

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