E C O N O M I C S   B U L L E T I N

Can population promote income per-capita growth? A balanced perspective

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Abstract

We develop a model in which technical progress, human capital and population interact endogenously to examine the impact of population growth on economic development. We find that population growth can be positively or negatively correlated with the growth rate of income per-capita. The outcome depends on the relative contribution of population and human capital to the determination of output growth.

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1 Introduction

The idea that people's standard of living can continue to grow over-time along with an increasing population causes a continuing debate in economic literature. Kelley (1988), Ehrlich and Lui (1997) survey the empirical and theoretical literature dealing with the connections between population and economic growth. It looks like a complete agreement about the consequences of population on income per-capita growth has not emerged. Some take the view that a larger population is harmful for economic development (Barro, 1991; Mankiw, Romer and Weil, 1992). The argument is that a larger population leads to a dilution of available resources. In growth theory, this kind of effect is captured in a simple way in the basic exogenous growth literature (Solow, 1956; Cass, 1965; Koopmans, 1965) further extended to include endogenous fertility choices (Barro and Becker, 1988; 1989).

In contrast, advocates of the 'population push hypothesis' argue that population growth is beneficial to economic development (Boserup, 1965; Simon, 1981; Lee, 1988). The reason is that technical progress being non-rival, the cost of inventing new technologies is independent of the number of individuals who use it: there is a scale effect. That is, for a constant share of resources allocated to the development of new technologies, a larger population stimulates the rate of technological progress, so the rate of income growth. Kremer (1993) validates this concept from an historical perspective considering the period of time one million years B.C. to 1990. On the theoretical side, semi-endogenous growth models (e.g. Jones, 1995; Kortum, 1997; Segerstrom, 1998), built upon the R&D-based literature initiated by Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1992) share this view: in these settings, the long-run growth rate of income per-capita is determined by the (exogenous) growth rate of population.

The goal of this paper is to shed a new light on the debate depicted above in order to reconcile both the pessimistic and optimistic views about the consequences of population on per-capita income growth. We claim that each theory is one different side of the same story. This notion comes within the scope of the "revisionist interpretation" of Malthusianism (Kelley, 1988). This literature points out that, depending on the country, population growth may contribute, deter or even have no impact on economic development. This ambiguous result is explained by the fact that the effects of population growth change over-time. For example, a higher fertility rate can have a short-term negative effect caused by the cost of expenditures on children whereas it has a long-run positive effect through the larger labour force it generates (Crenshaw, Ameen and Christenson, 1997).

In the present article, the idea is that, among other things, population growth affects indirectly per-capita income growth through the channels of technical progress and human capital accumulation. We focus essentially on these two variables for two reasons. First, there is a common agreement in growth literature stating that they are two major ingredients to sustain long-run growth. Second, it is a simple way to combine elements from each theory (optimistic and pessimistic views about the impact of population) to reconcile in a single framework their divergent conclusions.

To conduct the analysis, we construct a growth model in which technical progress as well as human capital and population growth interact endogenously. To our knowledge no published paper treats all three elements endogenously at once, although some deal with the connections between two of them: Becker, Murphy and Tamura (1990), Schou (2002) treat fertility choices and human capital; Redding (1996), Arnold (1998), Blackburn, Hung and Pozzolo (2000), Dalgaard and Kreiner (2001), Strulik (2005), Boonprakaikawe and Tournemaine (2006) develop models with endogenous technical progress and endogenous accumulation of human capital; and finally, Jones (2003), Connolly and Peretto (2003) and Tournemaine (2007) account for endogenous technical progress and fertility choices.

In the present paper, there are two key elements. First, the rate of technical progress is determined both by the level of education of individuals and their total number. This implies that, for a given level of skills, the higher the number of individuals is, the greater the rate of technical progress will be. This may be referred to as the scale effect which emerges in R&D-based endogenous growth models with economic growth depending positively on the size of the economy (e.g., see Jones, 1995). Second, population growth is the outcome of the choice of fertility of individuals. As raising children and acquiring skills require resources among which time is a primary factor, this implies a negative relationship between human capital and population growth. As explained by Becker, Murphy and Tamura (1990), there is a quality-quantity trade-off regarding the decisions on children. Therefore, as income per-capita growth is determined by the growth rates of technical progress and human capital, we find that population and income per-capita growth can be either negatively or positively correlated. The outcome depends on the relative contribution of population and human capital in the determination of the growth rate of income per-capita. A higher fertility rate may promote growth through its effects on the rate of technical progress (scale effect), while a contraction in the fertility rate could also free the resources necessary to promote growth by means of an increase in human capital accumulation activities (quality-quantity trade-off).

Closely related to the present paper is probably the framework of Strulik (2005). He also finds that long-term growth can be positively or negatively correlated with the population growth rate. However, although technical progress and human capital accumulation interact endogenously, population growth is exogenous in his model. Thus, the consequences of an explicit family policy in the form of fertility taxes or subsidies cannot be analysed. By allowing for endogenous fertility choices, we can raise this issue which may find some application in the real world. For instance, since the beginning of the 80's, China has carried out a population control policy. In this country, couples are taxed if they have more than one children.

The remainder of the paper is organized as follows. Section 2 presents the model. Section 3 examines its key properties regarding the relation between population and income per-capita growth. Section 4 concludes.

2 Model

To keep the analysis simple and to focus on the key feature of the problem, we choose to present a basic framework. Time, denoted by t, is continuous. It goes from zero to infinity: $t \in [0, \infty)$. The economy is populated by a representative dynastic family whose members are identical. Each one of them is endowed with one unit of time that she allocates between working and non-working activities. Non-working activities consist in rearing children and attending school. Working activities consist in the production of a consumption good (output). Following Barro and Becker (1988, 1989) we assume that the members of the family are linked together by altruism: parents care not only about their welfare but also that of their descendant. As shown by Barro and Sala-i-Martin (2004, ch. 9), preferences of the head of the dynastic family can be represented by the utility function

$$U = \int_0^\infty e^{-\rho t} \left[\ln c_t + \varepsilon \ln n_t + \beta \ln L_t\right] dt, \tag{1}$$

where $\varepsilon > 0$, $\beta > 0$, $\rho > 0$ is the rate of time preferences, c_t is per-capita consumption, n_t is the choice of fertility and L_t is the size of the family that evolves through time according to

$$\overset{\bullet}{L}_t = (n_t - m) L_t, \tag{2}$$

where $m > 0$ is the exogenous mortality rate.

Raising children to adulthood is time intensive. Following Barro and Becker (1988; 1989), Becker, Murphy and Tamura (1990), the technology of production for children is given by

$$n_t = b l_{nt}, \tag{3}$$

where $b > 0$ and l_{nt} is the amount of time devoted to bring up children.

Individuals accumulate human capital, h_t, to enhance their productivity: they learn basic knowledge at school. Following Lucas (1988), human capital per-person evolves through time according to

$$\overset{\bullet}{h}_t = \psi u_t h_t - \delta h_t, \tag{4}$$

where $\psi > \rho$, $\delta > 0$ is the depreciation rate of human capital and u_t is the amount of time allocated to school.

Production of output per-capita is given by

$$y_t = (A_t)^\nu (l_{yt} h_t), \tag{5}$$

where $\nu > 0$, $l_{yt} \equiv 1 - l_{nt} - u_t$ is the amount of time devoted to the production of output and A_t is technical progress (scientific knowledge). Technology (5) exhibits constant returns to scale with respect to the quantity of human capital devoted to the production of output, $h_{yt} \equiv l_{yt} h_t$, and increasing returns with respect to human capital, h_{yt}, and technical progress, A_t, taken together. This assumption follows from the replication argument and reflects the non-rival property of scientific knowledge. The strength of increasing returns is measured by ν. We will see later that this parameter plays an important role in the results we obtain.

Following Ziesemer (1991), the technology for technical progress is given by

$$\overset{\bullet}{A}_t = \varphi \left(H_{yt} \right), \tag{6}$$

where $\varphi > 0$ and $H_{yt} \equiv l_{yt} h_t L_t$ is the aggregate quantity of human capital devoted to the production of output. Technology (6) is similar to the learning by doing process analyzed by Arrow (1962) and Romer (1986) except that, here, knowledge is the outcome of educated brains. That is, while individuals engage in the production of output, they simultaneously learn new pieces of knowledge that accumulate over-time and benefit the whole economy.

It would be possible to assume that knowledge is the outcome of a costly innovative activity performed by profit-maximizing firms in an imperfectly competitive market as it is done in the basic R&D-based literature. However, it would not alter the qualitative results of the paper and its insight. The key idea is that the rate of technical change is driven both by the evolution of total population, L_t, and the average quality of individuals, h_t. The choice of the technology (6) is mainly technical as it simplifies the analysis: it allows us to consider a perfectly competitive equilibrium, although technical progress arises endogenously. Moreover, it allows us to obtain a closed form solution in equilibrium.

3 Equilibrium

3.1 Characterization of the steady-state

In this section, we characterise and analyse the equilibrium of the model. We assume that the government can influence the choice of fertility of individuals by means of a family policy such as a tax/subsidy τ_t charged on children. For simplicity, we assume that the proceeds are redistributed to each member of the family through a lump-sum transfer, t_t, and that the budget constraint of the government is balanced at any moment. One has $\tau_t n_t L_t = t_t L_t$.

The head of the dynastic family chooses plans for consumption, c_t, education, h_t, and family size, L_t. Since technical progress is taken as an external effect, her problem is simply to maximize her utility (1) subject to (2), (3), (4) and (5). After manipulation, the current-value Hamiltonian of this problem is $\Gamma = \ln c_t + \varepsilon \ln n_t + \beta \ln L_t + \lambda_t [(A_t)^{\nu} (1 - n_t/b - u_t) h_t - c_t - \tau_t n_t + t_t]$, where λ_t, μ_t and ξ_t are the multipliers associated to the constraints. The first order conditions are: $\partial\Gamma/\partial c_t = 0$, $\partial\Gamma/\partial u_t = 0$, $\partial\Gamma/\partial n_t = 0$, $\partial\Gamma/\partial h_t = -\overset{\bullet}{\mu}_t + \rho\mu_t$, $\partial\Gamma/\partial L_t = -\overset{\bullet}{\xi}_t + \rho\xi_t$. The transversality conditions are $\underset{t\to\infty}{lim} \mu_t h_t e^{-\rho t} = 0$, $\underset{t\to\infty}{lim} \xi_t L_t e^{-\rho t} = 0$. Computation leads to the following first order conditions:

$$\frac{1}{c_t} = \lambda_t, \tag{7}$$

$$\lambda_t (A_t)^\nu = \mu_t \psi, \tag{8}$$

$$\frac{\varepsilon}{n_t} + \xi_t L_t = \frac{\lambda_t (A_t)^\nu h_t}{b} + \lambda_t \tau_t, \tag{9}$$

$$\frac{\lambda_t}{\mu_t} (A_t)^\nu \left(1 - \frac{n}{b} - u_t\right) + \frac{\dot{h}_t}{h_t} + \frac{\dot{\mu}_t}{\mu_t} = \rho, \tag{10}$$

$$\frac{\beta}{\xi_t L_t} + (n_t - m) + \frac{\dot{\xi}_t}{\xi_t} = \rho. \tag{11}$$

We now proceed to the characterization of the equilibrium. Proposition 1 summarizes the results we obtain. Equilibrium values are denoted with the symbol "$*$" and the growth rate of any variable x is denoted g_x. The proof of the Proposition shows that that there are no transitional dynamics and that the term $\tau_t / \left[(A_t)^\nu h_t\right]$ must be constant over-time. Thus, we assume that the government chooses a growth path for the family policy such that $g_\tau = \nu g_A + g_h$ at any moment. This implies that $\tau_t / \left[(A_t)^\nu h_t\right] \equiv \tau_0 / \left[(A_0)^\nu h_0\right]$ for all t, where τ_0, A_0 and h_0 denote the initial values of τ_t, A_t and h_t, respectively.

Proposition 1 *At equilibrium the fertility rate and the time allocated to education and production of output are constant. Their values are given by:*

$$n^* = \frac{\varepsilon b \rho}{\psi - \beta b + b\psi\tau_0 / \left[(A_0)^\nu (h_0)\right]},$$

$$u^* = 1 - \frac{\varepsilon \rho}{\psi - \beta b + b\psi\tau_0 / \left[(A_0)^\nu (h_0)\right]} - \frac{\rho}{\psi},$$

$$l_y^* = \frac{\rho}{\psi}.$$

The growth rates are given by

$$\begin{aligned} g_L^* &= n^* - m, \qquad g_h^* = \psi u^* - \delta, \\ g_A^* &= g_h^* + g_L^* = \psi u^* - \delta + n^* - m, \\ g_y^* &= g_c^* = \nu g_A^* + g_h^* = (1+\nu)(\psi u^* - \delta) + \nu (n^* - m). \end{aligned}$$

Proof. *Combining (2) and (11), one gets* $\beta + (\dot{\xi_t L_t}) = \rho \xi_t L_t$ *which implies that* $\xi_t L_t = \beta/\rho$ *at any moment for the existence of a steady-state. Differentiating (7) and (8) with respect to time yields* $g_c = -g_\lambda$ *and* $g_h - g_{l_y} = -g_\mu$*, respectively. From (4), (5) and (6), one gets* $g_h = \psi u - \delta$, $g_c = \nu g_A + g_h + g_{l_y}$ *and* $g_A = g_h + g_L + g_{l_y}$*. Plugging (8) in (10) and using the previous results, one gets* $\psi l_{yt} + g_{l_y} = \rho$*,which is a Ricatti's differential equation. Denoting by* $z_t \equiv 1/l_{yt}$*, that gives* $\dot{z}_t = -\dot{l}_{yt}/(l_{yt})^2$*, the differential equation reads* $\dot{z}_t = \rho z_t - \psi$*. Its solution is* $z_t e^{\rho t}[z_0 - \psi/\rho] + \psi/\rho$*. Using the fact that* $c_t = y_t$*,* *with (5), (7), (8), one gets $\mu_t h_t = 1/(\psi l_{yt}) = z_t/\psi$. That is, the transversality condition $\lim_{t\to\infty} \mu_t h_t e^{-\rho t} = \lim_{t\to\infty} z_t e^{-\rho t}/\psi = 0$ is satisfied if and only if $z_t = 1/l_y = \psi/\rho$ at any moment. Thus, l_y jumps immediately to its steady-state value. Then, manipulation of (7), (8), (9) with $\xi_t L_t = \beta/\rho$ and (5) leads to $l_y = \rho n_t / \{b[\varepsilon\rho + (\beta - \rho\tau_t/c_t) n_t]\}$. From this result and the labour-time constraint $1 = n/b + u + l_y$, one finds n^* and u^*. Note that the existence of the steady-state requires that $\tau_t/c_t = \tau_t/[(A_t)^\nu (l_y h_t)]$ is constant at all times. Thus, there are no transitional dynamics. It is implicitly assumed that the parameters of the model take values so that n^*, u^*, l_y^* are all strictly positive and strictly lower than one.* ■

Examination of Proposition 1 shows that the relationship between population and income per-capita growth is ambiguous. This is because both human capital, h_t, and technical progress (scientific knowledge), A_t, constitute the driving forces of income per-capita growth and are both indirectly affected by the fertility choices of individuals. Formally one has $g_c^* = \nu g_A^* + g_h^*$, with $g_A^* = g_h^* + g_L^*$: human capital affects income growth directly via the production of output and indirectly via its effect on technical progress, while population affects income per-capita via technical progress only. Thus, for a given growth rate of human capital, a larger population drives the rate of technical progress up, ultimately the growth of income per-capita (scale effect). The crux of the problem is that a larger population requires to bear more children which diverts time from education then reduces the growth rate of human capital (quality-quantity trade-off effect).

3.2 Discussion

To understand more accurately the mechanisms carrying out in the model, we examine the impact of the family policy tool, τ_0, on the amount of time allocated to school and child bearing, respectively. Let us assume that the government decreases marginally the level of the tax rate, τ_0. This policy corresponds to a reduction of the cost of raising children. Thus, the head of the dynastic family increases the fertility rate by an amount $dn^*/d\tau_0$ which drives the population growth rate up by $dg_L^*/d\tau_0 = dn^*/d\tau_0$. At the same time, the policy change also alters the amount of time allocated to human capital accumulation. From Proposition 1, one has $n^*/b + u^* = l_n^* + u^* = 1 - \rho/\psi$. That is, when individuals allocate an additional unit of time to rear children, they reduce the amount of time devoted to education by an amount $du^*/d\tau_0 = -dl_n^*/d\tau_0 = -(dn^*/d\tau_0)/b$. This reflects the trade-off between fertility and education. Using (4), the reduction in the growth rate of human capital is given by $dg_h^*/d\tau_0 = \psi du^*/d\tau_0 = -\psi(dn^*/d\tau_0)/b$. Thus, the effect on income per-capita growth is given by $dg_c^*/d\tau_0 = (\nu+1) dg_h^*/d\tau_0 + \nu dg_L^*/d\tau_0 = [\nu - \psi(\nu+1)/b] dn^*/d\tau_0$. This last result allows us to establish the sign of the correlation between population and income per-capita growth:

Proposition 2 *Income per-capita and population growth are positively (resp. negatively) correlated if $b\nu > \psi(\nu + 1)$ [resp. $b\nu < \psi(\nu + 1)$].*

From the above computations, the term νb can interpreted as the marginal contribution of an additional individual to output-per-capita growth, while $\psi(\nu + 1)$ stands for the marginal contribution of an additional unit of time devoted to education. As a result, the simple condition on the parameters given in Proposition 2 highlights the important feature of the model. That is, the scale of an economy plays an important role for the relationship between population and income per-capita growth. Indeed, if scientific knowledge is not a productive input for output, ($\nu = 0$), a higher fertility rate will always generate a negative impact on human capital accumulation, then on per-capita growth. This situation can be interpreted as a special case of the model that goes back to more standard frameworks with endogenous fertility in which human capital accumulation is the only engine of growth. However, once we account for (non-rival) scientific knowledge in the production of output, ($\nu > 0$), the conclusion becomes ambiguous: the outcome depends on the relative contribution of fertility and education in the determination of income per-capita growth.

Basically, when $b\nu < \psi(\nu + 1)$, the scale effect is weak relative to the quality-quantity trade-off effect. As a result, this induces a negative relationship between population and output growth. However, when $b\nu > \psi(\nu+1)$, the scale effect is strong enough to offset the quality-quantity trade-off effect which induces a positive relationship between population and output growth. This consideration may explain why population control policy may not be effective in the long run. For instance, Scotese and Wang (1995) show that the one-child policy in China has no long-run effect on output growth.

4 Concluding remarks

There are disparities of conclusions about the sign of the relationship between population and income per-capita growth. The goal of this paper has been to reconcile both the pessimistic and optimistic views about the consequences of population on per-capita income growth. We have developed a simplistic model in which technical progress, human capital and population interact endogenously. The main idea is that population growth alters economic growth indirectly through the channel of the two other variables which are the driving forces of income per-capita growth. We have shown that population and income per-capita growth can either be positively or negatively correlated.

It should be noted that the model does not imply that population growth is essential for economic growth. As long as individuals invest in human capital, sustained per-capita long-term growth is possible, even with a constant population. In this case, the growth rate of per-capita consumption is driven by human capital accumulation. The results, on the other hand, suggest that population growth can either accelerate or slow down the process of economic development. Concerning the impact of fertility on welfare, it should be noted that individuals do not account for the wide benefits of their investments in children and human capital. Thus, the model implies that the equilibrium can lead either to an excessive or an insufficient level of growth in the long-run compared to the optimum. The outcome depends on which of the scale effect or quality-quantity trade-off dominates.

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