

# Health, Demographic Transition and Economic Growth

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## Abstract

This paper develops a link between four central components of the demographic transition: survival rates; fertility decisions; altruistic intergenerational transfers from workers toward their parents; and economic growth. An increase in child survival is found to reduce

the fertility rate and altruistic transfers, and thereby increase the savings rate and the productivity growth rate. The analysis illustrates the key role of child health in the demographic transition.

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This paper—a product of the Economic Policy Sector, Poverty Reduction and Economic Management in Latin American and Caribbean Region—is part of a larger effort in the department to understand the economic implications of population dynamics in less developed economies. Policy Research Working Papers are also posted on the Web at <http://econ.worldbank.org>. The author may be contacted at [ojorgensen@worldbank.org](mailto:ojorgensen@worldbank.org).

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# HEALTH, DEMOGRAPHIC TRANSITION AND ECONOMIC GROWTH<sup>1</sup>

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## 1. Introduction

Most countries have seen child and adult survival rates increase during the first stage of their demographic transition. This has usually been followed by a decline in fertility in the second stage and, thus, strongly decreasing dependency ratios. As a result, the demographic transition provides a window of opportunity for economic growth by releasing resources for capital savings and human capital formation. According to Bloom and Williamson (1998) approximately one-third of the increase in economic growth for the East-Asian “tigers” can be explained by purely demographic factors, i.e. the declines in mortality and fertility. This demographic “dividend” therefore entails a real chance to reduce poverty.

This paper considers an increase in survival rates for both children and adults, and traces the effects through the key mechanisms in the economies of less developed countries (LDCs): fertility decisions, altruistic intergenerational transfers and capital savings. These mechanisms translate a change in health conditions into prospects for economic growth. The existing literature has already analyzed some of these components together, but has failed to include them all into one unified framework. It would be too simplistic, in the context of LDCs, not to incorporate one or more of these central mechanisms when analyzing the first stage of the demographic transition with reductions in (child) mortality. The present analysis features, therefore, one possible channel for the trade-off between children and capital as savings mechanisms when child survival increases. To our knowledge, this has not been attempted before.

Capital savings are a key variable in an economy’s demographic transition towards sustained economic growth.<sup>3</sup> In a model with exogenous fertility and without the care by workers for the subsistence of their parents, Chakraborty (2004) finds that a higher adult survival rate will increase the capital stock and per capita income. The reason is that capital savings increase when people expect a longer retirement period.<sup>4</sup> However, in LDCs, children can also be considered a form of savings because they tend to care for their parents in old age, i.e. the higher number of children per household the more altruistic transfers can be expected in old age (Ehrlich and Lui, 1991).

In order to trace the effects on capital savings, these mechanisms should be accounted for in the analytical framework. We accomplish this by endogenizing fertility and altruistic intergenerational transfers. Consequently, the net effect on capital savings may not necessarily be an increase, because workers may choose to “save” through having more children and, in turn, dis-save through capital. The result in Chakraborty (2004), that improved health conditions will increase capital savings and economic growth, may therefore not hold when the economy is modeled with endogenous fertility decisions and altruistic transfers—in accordance the empirical observations in LDCs (see, e.g., Caldwell, 1982).

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<sup>3</sup> Increased capital savings will produce a higher capital-labor ratio and, in line with standard growth theory (see, e.g., Diamond, 1965), also the potential for higher per capita output.

<sup>4</sup> In Chakraborty’s model, investments in health increase proportionally to the increasing income, which in turn leads to a longer life span. So the economy enters a positive spiral of better health, longer lives, more capital savings, and higher per capita income.

In addition to our personal joy of having children, to which we seem to be more or less genetically programmed (Dasgupta, 1993; p. 356), the motivation for having children can indeed be considered an economic one. Children can provide labor that will benefit the household; they can provide care for parents in old age; and they may be an instrument of altruism from parent to child (Barro and Becker, 1989). Another motivation for having children is the expectation of receiving altruistic intergenerational transfers from one's children after retirement (Ehrlich and Lui, 1991; Wigger, 2002). Higher capital savings would substitute these intergenerational transfers to the effect of lowering the transfer rate and further reducing the need for having children as an old age security "device".<sup>5</sup>

Concurrent with the child survival response, parents also face the quantity/ quality trade-off (Galor and Weil, 1996, 2000). With a fixed amount of resources available to devote to the children of the household, parents make the decision to have many (few) children and invest little (more) in each. The incentive for the latter will grow as the return to human capital increases parallel to the technological development. In this paper, we abstract from human capital investments since the effects thereof are well established.

Improved adult health (proxied in the literature by higher life expectancy; longer retirement period) is generally found to have an increasing effect on output per capita (see, e.g., Bloom et al., 2007, Chakraborty, 2004, Jensen and Jorgensen, 2008, Jorgensen and Jensen, 2009). In the presence of perfect capital markets and no social security arrangement, we would envision longer life expectancy to have no effect on the savings rate as the extension of working life is proportional to the extension of life expectancy. However, in the presence of social security arrangements, where the retirement age is fixed, an increase in life expectancy increases the years of retirement disproportionately to the working years. This is a case where the intertemporal prices of consumption in the first relative to the second period change, and if they do not change in equal proportions then the savings rate will be affected (Chang, 1990; Jensen and Jorgensen, 2008, Jorgensen and Jensen, 2009).<sup>6</sup>

Higher adult survival can also have incentive effects that may be important for capital savings: investments in human capital will be encouraged as the time horizon over which returns to investment can be earned is extended (Weil, 2007; Finlay, 2006). Adult survival may also represent a proxy for experience: the longer one is alive the larger the work experience. Although this theory is dispelled by Bloom et al. (2004), who control for labor market experience, they found that increased adult survival

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<sup>5</sup> The choice of how many children to have is, to a large extent, a function of child survival (Pritchett, 1994; Barro and Becker, 1989) and of access to family planning (Bongaarts, 1990, 1994). A family plan to have their desired number of (live) children, and in an environment of high child mortality the differential between the number of desired children and births widens (Fink, 2007). As the child survival rate improves, families need fewer births to achieve their desired number of children.

<sup>6</sup> The retirement age as a policy instrument could be adjusted to offset this effect (Jensen and Jorgensen, 2008, and Jorgensen and Jensen, 2009). Bloom et al. (2005) show, however, that this life-cycle savings model is incomplete, and that an increase in life expectancy can actually have a negative effect on the savings rate. They argue that if the retirement age is endogenously determined, then a rise in life expectancy may lead to a more or less than proportional rise in the retirement age so the effect on the savings rate is ambiguous. This result is driven by a wealth effect of the longer working life. Jorgensen and Jensen (2009) finds a similar result in a model with endogenous labor supply, where the wealth effect due to distortionary taxation more than outweighs the sum of substitution and income effects when life expectancy increases.

had a positive effect on savings and economic growth. Alternatively, if adult survival is considered a proxy for health, then better health can lead to higher worker productivity and promote economic growth (Barro and Lee, 1994; Bloom et al., 2004; Zhang and Zhang, 2005; Finlay, 2006).

While existing literature mainly studies changes in adult survival as a proxy for life expectancy, this paper separates the effects from higher child survival and adult survival, respectively. Thereby, we can isolate the unique effects from each survival rate on variables central to the demographic transition. The economic implications of changes in child survival have been explored to a much lesser extent than adult survival in the theoretical literature. To account for this shortcoming, this paper illustrates a channel of dynamics that can unfold, in which the motivation for having children will shape the resource allocation through endogenous fertility decisions. The child and adult survival rates are incorporated into the working and retirement periods, respectively, as implicit prices on consumption. This framework is combined with altruistic transfers from working age members of the household to their retired parents.

While others have modeled endogenous fertility decisions together with both one-sided and two-sided altruistic intergenerational transfers (see, e.g., Blackburn and Cipriani, 2005), nobody has incorporated survival rates in the context of both endogenous fertility decisions and altruistic transfers. Adult survival rates have frequently been incorporated into life-cycle models (see, e.g., Blackburn and Cipriani, 1998, 2002; Bohn, 2001; Chakraborty, 2004; Jorgensen and Jensen, 2009) but have not been analyzed in conjunction with altruistic transfers. This paper brings together this literature by combining these elements into a unified endogenous growth model.

Having explored the theoretical benefits of improved survival rates, we then take this a step further and ask: Can economic policy be targeted at health interventions in order to provide incentives for having fewer children, and could such a fertility decline potentially promote higher per capita economic growth? Assuming that better health is the cause of increasing survival rates, we trace increases in the child survival rate, as well as the adult survival rate, to their impacts upon fertility, altruistic transfers, capital savings and economic growth, respectively.

We next consider how public pay-as-you-go pensions can potentially reduce the need for children as an old age security device, and through these dynamics increase capital savings and economic growth. It is well known that pensions crowd out the physical capital stock, but in a setup with children as a savings mechanism the reduction in household savings may be directed towards children rather than towards capital. As a result, if fertility is high then capital accumulation may also be higher than previously believed because altruistic intergenerational transfers are operative at low levels of development. This issue was also addressed by Wigger (2002), but he does not incorporate survival rates into his model and is therefore not in a position to study the demographic transition (triggered by low child mortality) and the implications for sustained growth it entails.

The paper is structured as follows: in section 2 the model is outlined, and in section 3 there is solved for the competitive equilibrium. Comparative statics are then conducted in section 4, where exogenous increases are imposed in, first, the child survival rate and, second, the adult survival rate. Next, the experiment with a composite increase in the child and adult survival rates is performed.

Finally, section 5 provides perspectives on the potential of public pensions to promote the dynamics of the demographic transition, discusses some model limitations, and provides suggestions for future research. Section 6 concludes.

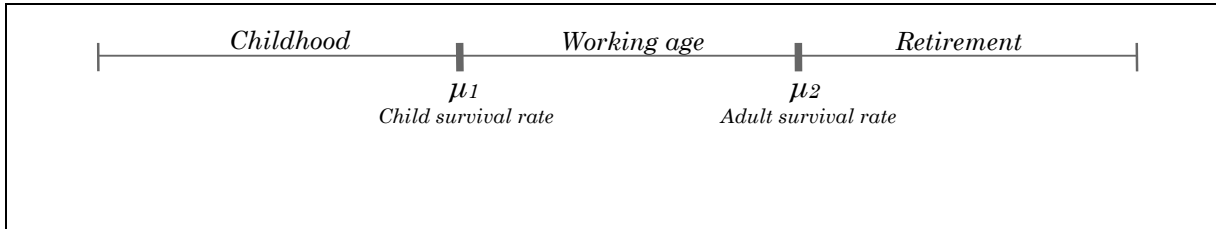
## 2. The Model

The overlapping generations (OLG) model is outlined in this section. We owe the basic structure of the model to Wigger (2002), who incorporates altruism and endogenous fertility decisions into an OLG model, ad modum Diamond (1965), which leads to an old age security motive for having children.<sup>7</sup> Our model extends this structure by incorporating child and adult survival rates, respectively. We assume that improved health conditions generate higher survival rates.<sup>8</sup> We follow Jorgensen and Jensen (2009) in their incorporation of the survival rates in order to analyze their impact on savings, fertility and economic growth. The model consists of different building blocks: demographics, budget constraints, household behavior and technology. We present these in turn, before outlining the solution method in section 3.

### 2.1 Demographics

Individuals are assumed to live, as shown in Figure 1, for three periods: as children, as working age adults, and as retired adults.

**Figure 1. Child and Adult Survival Rates**



Source: Author

Parents are assumed to make economic decisions on behalf of their children. The child survival rate,  $0 < \mu_1 \leq 1$ , is assumed to denote the survival of children immediately before they enter the labor force as adult workers. In that way, a higher  $\mu_1$  translates into a larger labor force. A higher adult survival rate,  $0 < \mu_2 \leq 1$ , is incorporated such that more workers survive into retirement. Labor is inelastically supplied by workers,  $N_t$ , and is assumed to grow by  $1+n_{t-1} = N_t/(\mu_1 N_{t-1})$ , where  $n > -1$  is the growth rate. If child survival or fertility increases then the labor force will grow at a higher rate.

<sup>7</sup> Blackburn and Cipriani (2005) also investigate the dynamics of fertility and altruistic intergenerational transfers in the context of the demographic transition. Neither they nor Wigger (2002) incorporate survival rates (or length of life) into their models. As a result, they are unable to investigate the role of child mortality in the first phase of the demographic transition. This is exactly the link that this paper provides.

<sup>8</sup> We do not, however, incorporate a government health sector or private investments in health. Higher health investments would otherwise be expected to increase survival rates in line with Chakraborty (2004), but since we are interested in a closed form solution for key variables, which Chakraborty does not provide, a framework with endogenous health expenditure that endogenously affects survival rates will remain an issue for our future research.

## 2.2 Budget constraints

Workers earn wages,  $w_t$ , and choose savings,  $S_t$ , in accordance with (1).

$$S_t = [1 - z_t - \kappa(1 + n_t) - \theta] w_t - \mu_1 c_{1t} \quad (1)$$

Different costs must be serviced by workers: first, there exists a pay-as-you-go (PAYG) pension system with a contribution rate,  $\theta$ .<sup>9</sup> Secondly, the cost of raising  $(1+n_t)$  number of children is denoted by  $\kappa w_t$ , where  $\kappa$  is the share of income that covers the costs per child. Consequently, if either the number of children per household increases, if the cost of rearing a child increases, or if pension contributions increase, there will be less income available for first period consumption,  $c_{1t}$ , and savings.

Workers are assumed to be altruistic towards the subsistence of their retired parents, to whom they have the option of transferring income (gifts). If, however, retirees already have enough consumption, and thus adequate utility, workers will reduce the gift rate,  $z_t$ , to whichever level their degree of altruism supports. Second period consumption,  $c_{2t+1}$ , is determined in (2) by last period's savings that yield a gross return of  $R_t=1+r_t$ .

$$c_{2t+1} = \frac{R_{t+1}}{\mu_2} S_t + [(1 + n_t) z_{t+1} + \lambda_{t+1}] w_{t+1} \quad (2)$$

An increase in  $\mu_2$  would force more retired members of the household to spend their savings at a lower rate,  $1/\mu_2$ . Retirees may receive altruistic transfers from their working age children, depending on the number of children they have and the wage rate. Consequently, the more children you have to support you in old age, the more altruistic transfers you will probably receive. An additional child will provide you with more intergenerational gifts in old age, but you also have to support them whilst working, implying less consumption and capital savings. The trade-off therefore (also) depends upon the fact that children possess the same degree of altruism as you, so that you can be certain to receive in old age what you expected when deciding on your number of children.<sup>10</sup> Finally, retirees receive variable pension benefits in accordance with the PAYG system in (3)

$$\mu_2 \lambda_t w_t N_{t-1} = \theta w_t N_t \quad (3)$$

where the fixed contribution rate is scaled by the relative survival rates in (4).

$$\lambda_t = \theta \frac{\mu_{1t}}{\mu_{2t}} (1 + n_{t-1}) \quad (4)$$

In case retirees face a higher survival rate they are forced to spend their benefits at a lower rate. When children, on the other hand, face a higher survival rate, the labor force increases and more workers will pay fixed contributions to the PAYG system. This will allow their retired parents to spend pension benefits at a higher rate. Equivalently, if workers decide to have more children, they can also expect higher pension benefits in old age.<sup>11</sup>

<sup>9</sup> A very small contribution rate is assumed in line with the features of pension schemes in developing economies.

<sup>10</sup> This is in principle a game-theoretic issue as analyzed by, e.g., Zhang and Nishimura (1993) and Nishimura and Zhang (1995). In this paper it is assumed that all generations are equally altruistic.

<sup>11</sup> The PAYG system does not necessarily need to be characterized by fixed contributions. It could also be a fixed benefits system, where the contribution rate is flexible. The PAYG system would then be re-stated as  $\theta_t = \lambda \frac{\mu_{2t}}{\mu_{1t}} (1 + n_{t-1})$ . This would imply that if workers had more children, or if the child survival rate decreased, they

### 2.3 Household behavior

The utility of individuals in (5) is assumed to, first, be composed of  $c_{1t}$  and  $c_{2t+1}$ , where  $\rho > 1$  is the discount rate:

$$u_t = \mu_1 [\ln c_{1t} + \phi \ln(1 + n_t)] + \mu_2 \rho \ln c_{2t+1} \quad (5)$$

Secondly, workers are assumed to be “genetically programmed” to value children (Dasgupta, 1993, p. 356), where  $\varphi > 0$  is the weight on children in utility. Children are therefore (also) considered to be “consumption equivalent” goods. The idea to incorporate survival rates into the utility function is inspired by Jorgensen and Jensen (2009), such that if  $\mu_1$  ( $\mu_2$ ) increases, more workers (retirees) will survive to enjoy consumption and children. The altruistic element in (6) is captured by

$$U_t = u_t + \chi u_t \quad (6)$$

where  $\chi$  measures the degree of altruism from workers towards their retired parents, by weighting your parents’ utility relative to your own. The number of children is therefore determined by two fertility motives: the “genetic motive” and the “savings motive”, where the former is incorporated in the positive effect of children in utility (5), while the latter arises through (6) because parents are assumed to be certain that their children will support them in old age.<sup>12</sup>

### 2.4 Technology

The production structure is also based on Wigger (2002) and assumes the endogenous growth set-up inspired by Arrow (1962) and Romer (1986). Identical firms are assumed to employ labor and capital,  $K_t$ , in order to produce output,  $Y_t$ , in accordance with a standard production:  $Y_t = F(K_t, A_t N_t)$ , which is assumed to have constant returns to scale. Labor productivity,  $A_t$ , is endogenized by assuming a linear relationship in (7) between productivity and capital per worker due to a positive spill-over externality from investments on productivity

$$A_t = \frac{1}{a} \frac{K_t}{N_t} \quad (7)$$

where  $\alpha > 0$  is a positive technology parameter. This means that  $f(k_t) \equiv F(k_t, 1)$ , and that the capital stock in efficiency units is  $k_t = K_t / A_t N_t$ , such that the interest rate is  $r_t = f'(k_t)$ , and the wage rate is  $w_t = A_t [f(k_t) - k_t f'(k_t)]$ . This Arrow-Romer approach implies that the interest rate is constant, and that the wage rate is determined by

$$w_t = A_t [f(\alpha) - f'(\alpha)\alpha] = \omega \frac{K_t}{N_t} \quad (8)$$

where  $\omega = [f(\alpha) - f'(\alpha)\alpha] / \alpha$  is the “external return” on capital caused by the spill-over of cumulated investment upon labor productivity (see Wigger, 2002). Consequently, if  $N_t$  rises the capital-labor

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would not receive more in pension benefits anyway, since the rate,  $\lambda$ , would be fixed. Therefore, there would be no need to have more children for that reason, so fertility might fall. This is an issue for our future research.

<sup>12</sup> This is in terms of voluntary intergenerational gifts and statutory fixed pension contributions.

ratio will fall and the economy-wide level of technology will decrease: then  $A_t$  falls and  $k_t$  will remain constant. Productivity growth in (9) is linked to the growth in the wage rate

$$1 + g_t = \frac{w_{t+1}}{w_t} = \left( \frac{K_{t+1}}{K_t} \right) \left( \frac{N_t}{N_{t+1}} \right) \quad (9)$$

and is determined by the growth in endogenous production factors. The capital market equilibrium condition in (10) completes our model:

$$K_{t+1} = N_t S_t \quad (10)$$

## 2.5 The competitive equilibrium

In this section we derive and interpret the first order conditions of the individual optimization problem. We furthermore transform the model into a reduced form system of equations, in terms of the variables we are interested in, which fully describes the dynamic path of the economy. Our results are similar to those of Wigger (2002), on which we build our formal analysis, but all expressions are now adjusted for the child and adult survival rates. To our knowledge, this extension is unique.

By combining (5) and (6), individuals face the following optimization problem where aggregate utility in (11) is maximized subject to the intertemporal budget constraint in (12):

$$\max U_t = \mu_t \left[ \ln c_t + \phi \ln(1 + n_t) \right] + \mu_2 \rho \ln c_{2t+1} + \chi \rho \mu_2 \ln c_{2t} \quad (11)$$

$$\text{Subject to } \mu_1 c_{1t} + \frac{\mu_2}{R_{t+1}} c_{2t+1} + \left( \kappa w_t - \frac{\mu_2}{R_{t+1}} z_{t+1} w_{t+1} \right) (1 + n_t) = (1 - z_t - \theta) w_t + \frac{\mu_2}{R_{t+1}} \lambda_{t+1} \quad (12)$$

Assuming an internal solution the first order conditions hold with equality. The first optimality condition is the Euler equation that optimally allocates first and second period consumption intertemporally:

$$\frac{c_{2t+1}}{c_{1t}} = \rho R_{t+1} \quad (13)$$

The second optimality condition is more complicated:

$$u_{1t} \phi w_t = u_{2t} z_{t+1} w_{t+1} + u_{3t} \quad (14)$$

The fraction  $u_{1t} \phi w_t$  in (14) determines the opportunity cost of having an additional child, measured in terms of the marginal value of the lost first period consumption. The right-hand side shows the sum of two components: the marginal value of the gifts that current workers will receive from their children in the next period, and the marginal value of having another child. Altogether (14) shows the benefits and losses of having another child in terms of marginal utilities  $u_{1t}$ ,  $u_{2t}$  and  $u_{3t}$ . By substituting these, we find a positive correlation between fertility and first period consumption in (15)

$$\frac{\mu_1 \phi w_t}{c_{1t}} = \frac{\mu_2 z_{t+1} w_{t+1} \rho}{c_{2t+1}} + \frac{\mu_1 \phi}{1 + n_t} \quad (15)$$

and thus an inverse relationship between fertility and savings. The third optimality condition (16) describes your trade-off between consuming an additional unit yourself and transferring that unit for your parents to consume.<sup>13</sup>

$$\frac{c_{2t}}{c_{1t}} = \mu_2 \rho \chi (1 + n_{t-1}) \quad (16)$$

A higher degree of altruism,  $\chi$ , and a larger adult survival rate (an increase in  $\mu_2$ ) induce workers to value their parents' marginal utility of consumption to a greater extent. If you have many siblings ( $1+n_{t-1}$  is large) who cooperate in supporting your parents, less of your income is needed to support them, and they consequently become “cheaper” to care for. This means that the “price” of supporting your parents goes down, and you choose to shift consumption from yourself to your parents.

In this paper we are mainly interested in interpreting the effects of changes in survival rates on the variables: fertility rate,  $n$ , productivity growth rate,  $g$ , savings rate,  $s$ , and the altruistic gift rate,  $z$ . The Arrow-Romer production structure allows us to derive the savings rate in (17) by combining (10) with (7)

$$s_t = (1 + g_t)(1 + n_t) \frac{\mu_1}{\omega} \quad (17)$$

For developing countries we would be interested in seeing an increase in capital savings. The direct positive effect on the savings rate of a change in child survival is evident from (17), but the net effects on the savings level will become clear in our later derivations in general equilibrium. We therefore solve the model by reducing it to a system of equations in the variables  $g$ ,  $n$  and  $z$ : substitute into the optimality conditions (13)–(16) the constraints (1) and (2), the wage rate (8) and the constant interest rate, the pension benefit rate (4) and, finally, the capital market equilibrium condition in (10). Note, that the resulting expressions in (18), (19), and (20) incorporate the child and adult survival rates:

$$\begin{aligned} \frac{\rho}{\mu_1}(1+r) \left[ (1+z_t - \kappa(1+n_t) - \theta)\omega - (1+n_t)\mu_1(1+g_t) \right] = \\ \left[ \frac{\mu_1}{\mu_2}(1+r) + \left( z_{t+1} + \theta \frac{\mu_1}{\mu_2} \right) \omega \right] (1+n_t)(1+g_t) \end{aligned} \quad (18)$$

$$\begin{aligned} \rho(1+n_t)\theta(1+r)\omega - \frac{\mu_2}{\mu_1}\rho z_{t+1}\omega(1+n_t)(1+g_t) = \\ \frac{1}{\mu_1} \phi \left[ (1+r)\mu_1 + (z_{t+1} + \theta) \omega \frac{\mu_1}{\mu_2} \right] (1+n_t)(1+g_t) \end{aligned} \quad (19)$$

$$\begin{aligned} \frac{\mu_1}{\mu_2}(1+r) + \left( z_t + \theta \frac{\mu_1}{\mu_2} \right) \omega = \\ \frac{\mu_2}{\mu_1} \chi \rho \left[ (1-z_t - \theta(1+n_t) - \theta)\omega - (1+n_t)\mu_1(1+g_t) \right] \end{aligned} \quad (20)$$

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<sup>13</sup> The third optimality condition in (16) is derived by lagging  $c_{2t+1}$  to be  $c_{2t}$  and subsequently combining the resulting expression with IBC in (12) over  $z_t w_t$ .

This procedure has defined the competitive equilibrium as a sequence of only  $\{n_t, g_t, z_t\}_{t=0}^{\infty}$ : fertility, productivity growth and altruistic gifts. It is our aim, in the following section, to analyze the effects of the higher survival rates on these three key variables.

### 3. Comparative Statics

The purpose of this section is to apply our model to study the effects of higher child and adult survival rates on fertility, productivity growth and altruistic intergenerational transfers. We first derive a closed form solution for those variables.

#### 3.1 Fertility, productivity growth and altruistic transfers

To derive a closed form solution for the three key variables ( $z$ ,  $g$  and  $n$ ) in order to perform comparative statics on the balanced growth path, we employ the steady state versions of (18), (19) and (20).<sup>14</sup> It is clear that the survival rates ( $\mu_1$  and  $\mu_2$ ) affect their steady state paths.<sup>15</sup> The expressions are identical to those in Wigger (2002), with the exception that ours are adjusted for the child and adult survival rates, respectively:

$$z(\mu_1, \mu_2) = \frac{(1-\theta)\chi w \rho^{\frac{\mu_2}{\mu_1}} - \left(\frac{\mu_1}{\mu_2} + \frac{\phi}{\mu_1} + \rho\right)(1+r) - \omega\theta(\phi + \mu_1\mu_2)}{\left(1 + \rho(1+\chi)\frac{\mu_2}{\mu_1} + \phi\frac{1}{\mu_2}\right)\omega} \quad (21)$$

$$g(\mu_1, \mu_2) = \frac{(1+r)\omega\kappa\rho\mu_2}{\phi(1+r)\mu_1 + \omega\phi\theta\frac{\mu_1}{\mu_2} + \omega\left(\rho\frac{\mu_2^2}{\mu_1} + \phi\frac{\mu_1}{\mu_2}\right)z(\mu_1, \mu_2)} - 1 \quad (22)$$

$$n(\mu_1, \mu_2) = \frac{\left(1+r + \omega\theta\frac{1}{\mu_2}\right)\phi\mu_1}{\chi\rho\omega\kappa\mu_2^2} + \frac{\left(\frac{\mu_2^2}{\mu_1}\rho + \phi\frac{\mu_1}{\mu_2}\right)}{\chi\rho\kappa\mu_2^2}z(\mu_1, \mu_2) - 1 \quad (23)$$

The purpose of the following three subsections is to interpret these relationships—both theoretically and numerically. The aim is then to employ them in policy reflections on savings, fertility and economic growth. This involves calibrating the model using what is believed to be realistic parameter values in Table 1. We initially calibrate the child and adult survival rates by  $\mu_1=1$  and  $\mu_2=1$ , but in the simulations experiments are conducted with increases in these rates. In section 4.2 we study increases in only the child survival rate, while in section 4.3 only the adult survival rate is assumed to increase. Ultimately, a composite increase in both survival rates is studied in section 4.4.

<sup>14</sup> To obtain the steady state version of (20), divide (18) by (20) such that the resulting expression,  $\chi\mu_2(1+n)(1+g)=(1+r)$ , relates the return to savings to the economy's growth factor in steady state,  $(1+n)(1+g)$ , scaled by the degree of altruism and the adult survival rate.

<sup>15</sup> To derive  $z$  in (21), insert the steady state version of (19) and (20) into the steady state version of (18) and isolate  $z$ . The productivity growth rate,  $g$ , in (22) is found by isolating  $g$  in the steady state version of (18). By combining (22) with the steady state version of (20) we arrive at the expression for fertility in (23).

**Table 1. Calibration of the Model**

<i>Parameter</i>	<i>Calibration</i>	<i>Interpretation</i>
$\chi$	0.9	Degree of altruism
$\mu_1$	1	Child survival rate
$\mu_2$	1	Adult survival rate
$\phi$	0.8	Consumption discount rate
$\eta$	0.4	Weight on children in utility
$r$	4	Interest rate
$\theta$	0.1	PAYG contribution rate
$\kappa$	0.1	Cost of rearing a child
$\omega$	20	External return on capital

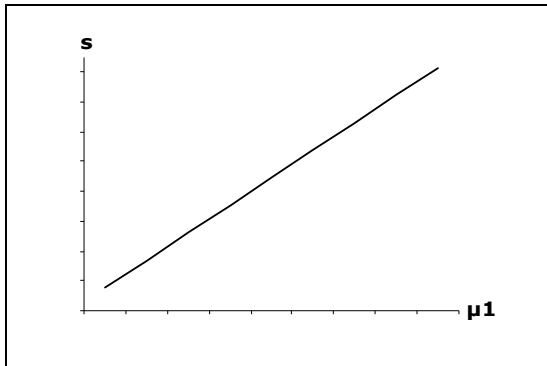
Source: Author

### 3.2 Child health

In this section we simulate the impact of an increase in the child survival rate,  $\mu_1$ , on four variables: the productivity growth rate,  $g$ , the fertility rate,  $n$ , the altruistic gift rate,  $z$ , and the savings rate,  $s$ . The impact on these four variables is illustrated in Figures 2 through 5.

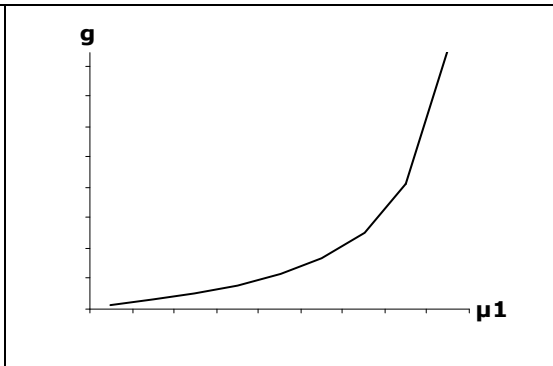
We identify three key effects that govern the dynamics of the model when  $\mu_1$  increases: first, when more members of the household survive, consumption must also be divided among those additional members. This yields less individual first period consumption, and consequently renders second period consumption more attractive in comparison. Equivalently, the relative price of first to second period consumption increases at the same rate as  $\mu_1$  increases (see the intertemporal budget constraint in (12). Therefore, the savings rate in (17) increases proportionally to the increase in  $\mu_1$  (Figure 2).

**Figure 2. Child Survival & Saving Rate**



Source: Author

**Figure 3. Child Survival & Productivity**



Source: Author

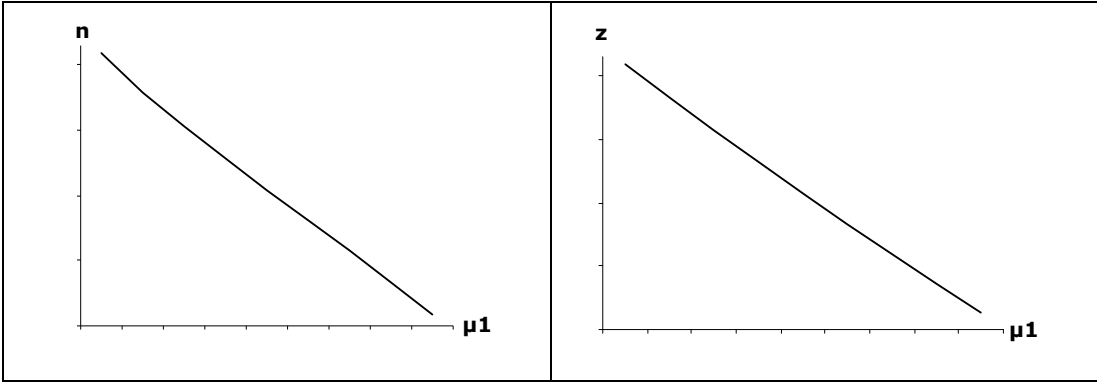
Second, the costs of using children as an indirect savings mechanism (rather than saving through capital investments) will increase because the savings rate and thus wages and productivity increase. This increases the opportunity cost of rearing children, and thus renders children less attractive as an old age savings mechanism, given the constant return on capital savings. Third, individuals gain higher utility in their working period by surviving at a higher rate. This increases the marginal utility

for first period consumption so savings fall. These three key effects yield an ambiguous net result on savings, but our simulations show that the two positive effects outweigh the single negative effect.

A larger steady state capital stock generates knowledge spillovers and increases labor productivity in Figure 3, in accordance with (22). There is an offsetting effect, however, because the size of the labor force also increases when more children survive into the working age. This reduces, but does not dominate, the effect on wages and the productivity growth rate. Since it is costly to rear children for the purpose of providing for old age consumption, the need for children as a savings device falls when savings, and thus second period income, increase. This exerts downward pressure on fertility,  $(1+n)$  (Figure 4). For the same reason the altruistic gift rate also decreases (Figure 5).

**Figure 4. Child Survival & Fertility**

**Figure 5. Child Survival & Transfers**



Source: Author

Source: Author

There are consequently feedback mechanisms through savings and fertility: the more  $\mu_1$  increases, the more the savings rate and productivity growth will increase, and the more fertility and altruistic gifts decrease. When fertility falls, more resources are released for consumption and savings, so the capital stock increases and further enhances productivity growth.

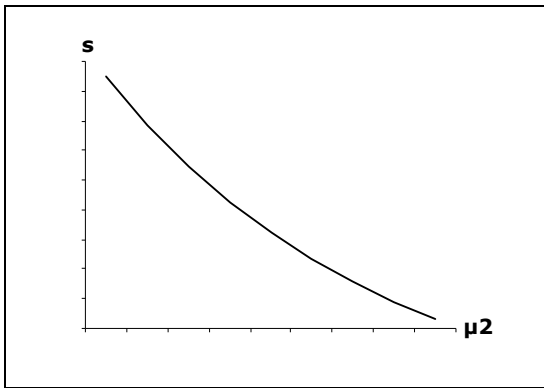
An additional mechanism through which second period income increases is the PAYG system. In accordance with (4), the more  $\mu_1$  increases, the higher will be the number of workers who pay fixed pension contributions—leading to higher benefits per retiree. This increases second period income, and reduces the altruistic transfers through less need for costly children as a savings mechanism. In this case where pension contributions are fixed, current workers know that the more children they have, the higher will be the number of future workers to pay fixed contributions to them—generating more retirement benefits. This effect is an additional element that causes high fertility, but even though a system with fixed contributions is included in Wigger (2002), Wigger does not analyze this link, and so leaves out the importance of the incentives for high fertility caused by the fixed contributions—and the potential gains of switching regime to a fixed benefits PAYG system.<sup>16</sup>

<sup>16</sup> The latter argument implies that, no matter how many children workers have, the old age pension benefits will remain the same. Incorporating such a system will lead to two important effects: first, the fertility incentive of pension benefits is removed so fertility (and therefore also altruistic gifts) can be expected to fall and productivity growth can be expected to increase. Second, if workers need fewer children to finance old age consumption, they will finance this through the other available channel: capital savings. More savings lead to a higher capital stock

### 3.3 Adult health

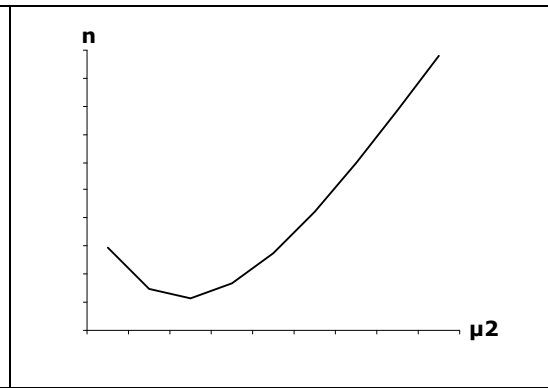
This section provides the other leg of interpreting health improvements in the demographic transition by analyzing an increase in adult survival. There is again an effect on the savings rate originating from the intertemporal price structure of consumption: the prices are seen to depend directly on  $\mu_1$  and  $\mu_2$  in the intertemporal budget constraint (12). Consequently, when their ratio changes so will the optimal intertemporal smoothing of resources for consumption (i.e. the savings rate). As such, the increasing price ( $\mu_2/R$ ) of second period consumption produces a decline in the savings rate (Figure 6). A counteracting effect is present when  $\mu_2$  increases, however, because the marginal utility of second period consumption increases, exerting upward pressure on savings.<sup>17</sup>

**Figure 6. Adult Survival & Saving Rate**



Source: Author

**Figure 7. Adult Survival & Fertility**



Source: Author

The net impact upon fertility when  $\mu_2$  increases is illustrated in Figure 7. The increase in the price of second period consumption automatically reduces the relative price on children,  $(\kappa w_{t-2} z_{t+1} w_{t+1} \mu_2 / R_{t+1})$ , which increases the fertility rate. When the increase in  $\mu_2$  is small, fertility will initially fall, and will then, due to the quadratic terms in  $\mu_2$  in  $n(\mu_1, \mu_2)$  in (23), increase the larger  $\mu_2$  is.

Since the savings rate initially fell, the wage rate will also fall, providing households with less income for all types of goods:  $c_1$ ,  $c_2$  and  $(1+n)$ . This will initially reduce fertility, but the more  $\mu_2$  increases, the less income is available in old age and the savings motive for having children exerts upward pressure on altruistic gifts and thus fertility. As a strategy to finance old age consumption, workers therefore increase fertility because children now become relatively cheaper than capital savings. An amplifying impact on fertility and savings again originates from the PAYG system. There is a counteracting effect on pension benefits, though: there will be more retirees per household, for any given number of children, and this will generate fewer benefits to be distributed among retirees. The net effect on benefits is ambiguous, but the effect on fertility, to at least keep benefits unchanged, is clearly positive and increasing in the size of  $\mu_2$ .

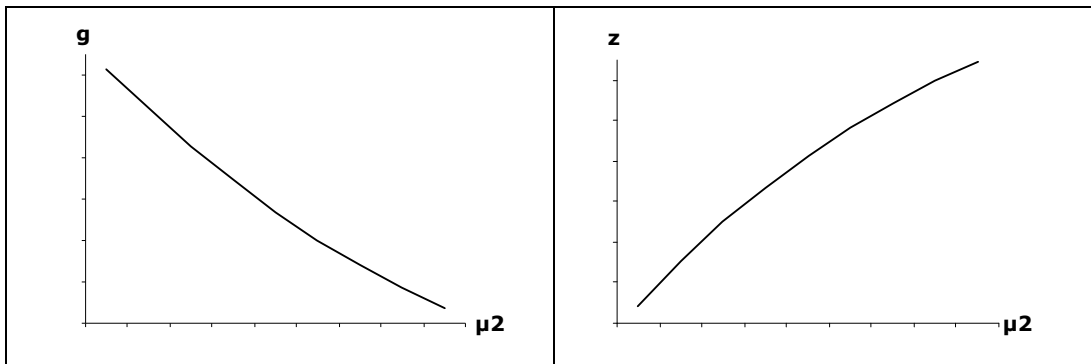
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and a higher productivity growth rate. These dynamics can be elaborated on analytically by reformulating the PAYG system in terms of fixed benefits, but this is outside the scope of this paper to consider.

<sup>17</sup> This is the most well-known effect on savings, which is analogous to the result from the literature on ageing, where workers save more to finance a longer retirement period (see Chakraborty, 2004; and Finlay, 2006; Jensen and Jorgensen, 2008).

Since the net effect on savings is negative—due to the presence of altruistic transfers and endogenous fertility—the productivity externality on the wage rate diminishes, and consequently productivity growth will decrease (Figure 8). The fall in second period income, due to lower net returns to the declining capital stock, will render altruistic gifts relatively more important as a means of financing old age consumption. As a result, the gift rate in Figure 9 increases.

**Figure 8. Adult Survival & Productivity**      **Figure 9. Adult Survival & Transfers**



Source: Author

Source: Author

Increases in, for instance, government health spending or general exogenous improvements in living conditions are likely to improve health, but it is not clear that such developments only cause higher survival rates for children and not for adults—or the reverse. It is more reasonable to assume that both survival rates increase when health investments increase. Having identified, and analyzed in isolation, the key dynamics of changes in child and adult survival rates on economic variables, we move on to study a composite change where both child survival and adult survival rates increase simultaneously.

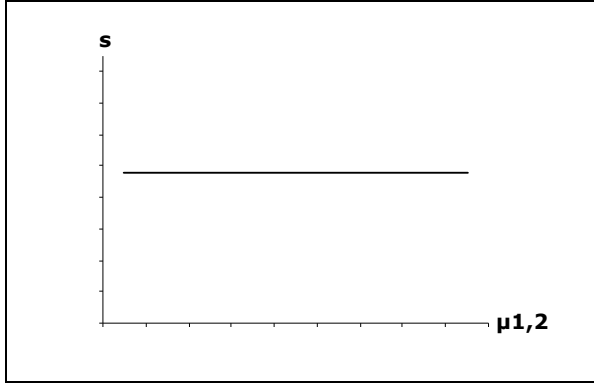
### 3.4 Child and adult health

The simultaneous and equi-proportional increase in child and adult survival will produce a combination of the effects analyzed above. An increase in  $\mu_1$  ( $\mu_2$ ) led to a higher (lower) savings rate—thus the composite shock entails perfectly offsetting effects on the savings rate (Figure 10). This is because the ratio of the implicit prices on first and second period consumption remains unchanged.

We have identified three effects on savings following an increase in child survival,  $\mu_1$ . Since the effect from intertemporal prices is absent for a composite increase in survival rates, the positive effect on savings is due to the effect from a lower price of children being larger than the effect from a higher marginal utility of first period consumption. The net effect of  $\mu_2$  on savings, on the other hand, was negative and dominated by the fact that children could be used as an old age savings mechanism. Savings also tended to rise because an increase in  $\mu_2$  would increase the marginal utility of second period consumption. The net increase in savings for a composite increase in survival rates will, for those reasons, generate similar effects on fertility, productivity growth and altruistic gifts as studied in

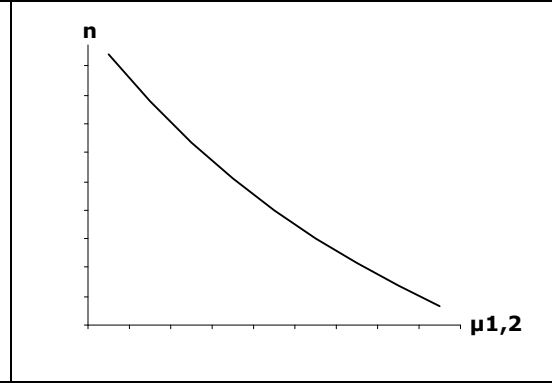
section 4.2 for  $\mu_1$ , albeit at a lower scale because the effects on these economic variables are counteracted by the impacts of  $\mu_2$ .

**Figure 10. Composite Shock & Saving Rate**



Source: Author

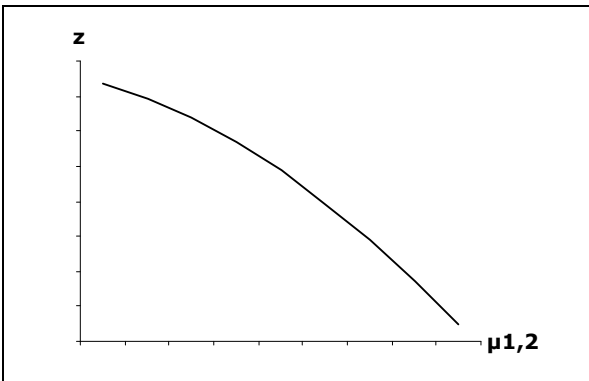
**Figure 11. Composite Shock & Fertility**



Source: Author

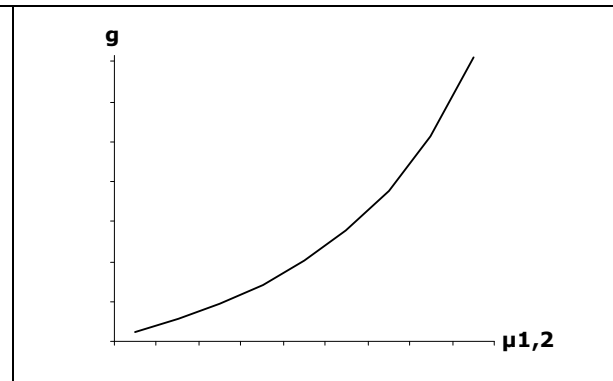
The sum of effects on fertility is a clear decline (Figure 11), due to increased savings, which leads to more capital per worker, more second period income, and less need for children as a mechanism for old age consumption. In addition, children become relatively cheaper when  $\mu_2$  increases (see the price of children:  $\kappa w_t - z_{t+1} w_{t+1} \mu_2 / R_{t+1}$ , so fertility falls even further (hence, altruistic gifts also fall; Figure 12). Regarding productivity growth, the increased knowledge spillovers on the wage rate will yield a higher rate of productivity growth (Figure 13).

**Figure 12. Composite Shock & Transfers**



Source: Author

**Figure 13. Composite Shock & Productivity**



Source: Author

The results above rest upon the assumption that  $\mu_1$  and  $\mu_2$  increase in equal proportions such that all effects on the savings rate net out. In a case where the increase in  $\mu_1$  is larger (smaller) than the increase in  $\mu_2$ , the increases in fertility and productivity growth will also be larger (smaller).

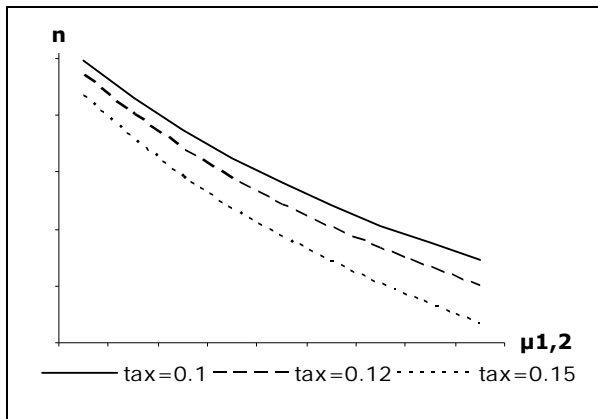
#### 4. Discussion

An increase in the child survival rate increases the number of dependents and reduces household resources. Furthermore, an increase in adult survival encourages savings, as we expect to live longer. This implies that improvements in child survival should have negative effects on economic outcomes, while improvements in adult survival should have positive effects. However, once we take three aspects into account: first, the negative fertility response to child survival, second, the possibility of intergenerational transfers and, third, the compounding effect on capital savings from adult survival due to substitution for less expensive children as a savings mechanism, then we observe that child survival has a net positive effect on economic outcomes compared to the negative effect on savings from adult survival.

Existing literature only captures the positive effect of adult survival on capital savings, which is usually modeled in terms of increasing life expectancy. In our model, when fertility has declined to a certain level, there will be no altruistic transfers as retirees obtain more and more income through capital savings. As a result, the “savings motive” for having children, facilitated by altruistic transfers, gradually disappears and workers only have children based on the “genetic motive”. The model will then collapse to feature a standard OLG model with endogenous fertility—however, still with survival rates incorporated. When adult survival then increases further, the impact upon capital savings will be positive, in line with existing literature (e.g. Chakraborty, 2004; Jorgensen and Jensen, 2009). The existing literature, therefore, is mainly targeted at developed countries, since it does not take into account the developing country feature of children as an old age security device.

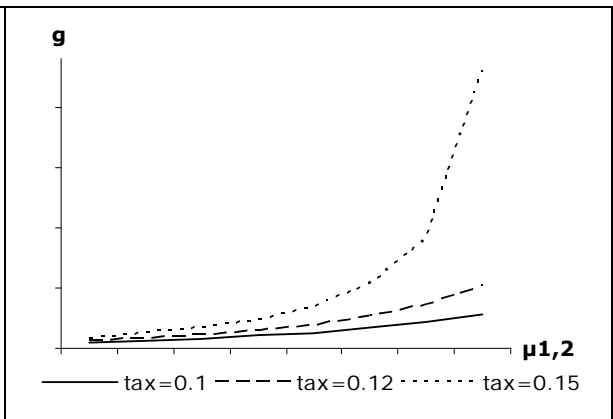
In the model, we have incorporated the child and adult survival rates (in line with Jorgensen and Jensen, 2009) into the basic setup in Wigger (2004). Wigger’s key argument is that an increase in public pensions will reduce fertility and increase productivity growth. He cannot study these dynamics in the context of the demographic transition with increasing survival rates. However, based on the results reported in this paper we can show that his argument still holds: we examine the results from our simultaneous and equi-proportional increase in child and adult survival rates (from section 4.4) for an increasing pension contribution rate,  $\theta$ . We find that the fertility path (Figure 14) and productivity growth path (Figure 15) will move in favorable directions: the path for fertility (productivity growth) decline will shift downwards (upwards). This finding is in line with empirical research that shows a strong correlation of fertility reduction with government provided pensions through children’s care for retired parents via old age transfers (see, e.g., Boldrin et al., 2005). These dynamics occur because increasing pension benefits to retirees will reduce their need for altruistic transfers. Thus, they can save resources on child rearing, and make these available for consumption and capital savings. This suggests that increasing public pensions will increase productivity growth, which is a controversial assertion.

**Figure 14. Fertility and Pensions**



Source: Author

**Figure 15. Productivity and Pensions**



Source: Author

The key dynamics to take into account is the presence of altruistic transfers and endogenous fertility. When the economy reaches the point in the demographic transition where fertility has declined so much that the only motive for having children is the genetic motive, parents realize that they can no longer save child-rearing resources by switching to capital savings and away from having children as an old age savings mechanism. After this point, an increase in public pensions will reduce the steady state capital stock in line with conventional wisdom. However, while altruistic transfers are still operative, a rise in public pensions increases productivity growth and reduces fertility—and therefore speeds up the process by which a country will go through the demographic transition.

We have argued in this paper that a shift from a fixed contributions PAYG system towards a fixed benefits system would even further reduce fertility and increase productivity growth. This will happen as parents realize that having more children will not provide them with more pension benefits, but only draw down on their resources. While this is an issue for our future research, we expect that the fertility paths would shift down (up) even further than in Figure 14 (15).

The model incorporates perfect capital markets, which is a limitation that should be addressed in future work on this topic. We would expect that if capital markets were imperfect, the return on capital savings would fall and children be rendered more attractive as a savings mechanism.<sup>18</sup> Over the course of economic development capital markets would develop, and the relative return on capital savings would increase—depressing further the savings motive for having children, as illustrated in this paper.

In our model we chose to abstract from education. The effects of education in an intertemporal setting are well understood: the quality/quantity trade-off informs us that an increase in child survival will lower fertility and thus increase the resources (for education) devoted to each child. In this context, an issue for our future research is to incorporate human capital formation alongside a two-sided altruism formulation of utility (modifying (6) such that  $U_t = \pi_1 u_{t-1} + u_t + \pi_2 u_{t+1}$ ). This would allow us

<sup>18</sup> In most developing countries an enormous problem is access to credit (very high interest rate), savings, insurance and other capital market instruments—especially in rural areas, where microfinance is often the only option for small-scale credits.

to trace the effects of better health in the demographic transition through a framework with two-sided altruism, two fertility motives and human capital formation as an additional feature of endogenous economic growth.

## 5. Conclusion

Developed countries have all gone through the demographic transition at some point in history. However, several developing countries have not even passed through the first stage of low mortality, and many other countries have still not entered the second stage of low fertility. As a result, these countries are restrained from the enormous potential for economic gains that are associated with lower dependency ratios.

In order to reduce poverty, it is essential for these countries to obtain high survival rates in order to quickly reduce fertility rates. In this paper, we find that a policy rule of child health will aid countries in achieving this objective. An additional key finding is that by increasing (or modifying) public pensions there is scope for reaching even more favorable paths for fertility reductions and productivity growth.

Life expectancy is a measure that contains information about the age specific survival rates: a rise in child survival will increase life expectancy, as will an increase in adult survival. Our decomposition of life expectancy into child and adult survival, respectively, is unique relative to the existing literature on this topic, where only adult survival (as a proxy for life expectancy) is modeled. We derive our results by reflecting on two motives for having children: the "savings motive" and the "genetic motive", respectively, and facilitate the former by incorporating, into an OLG model with endogenous fertility, the possibility for altruistic transfers from workers to their retired parents.

If either the relative opportunity cost of having children or the relative return on capital savings falls, we find a decline in capital savings and an increase in fertility through the savings motive for having children. Such relative price changes occur when child and adult survival rates change disproportionately, and we find a positive (negative) net effect on capital savings when child (adult) survival increases. In the case where both child and adult survival rates increase simultaneously, and in equal proportions, we find no change in the savings rate, due to our modeling of survival rates as implicit intertemporal prices. Our model consequently provides us with important insights into the savings behavior that evolves as a country goes through the demographic transition.

This setup leads us to conclude that an increase in child survival will promote capital savings and discourage savings through children as an old age security device. Such dynamics will ultimately lead to lower fertility and higher productivity growth. In contrast to conventional wisdom, we find that as long as altruistic intergenerational transfers are operative, an increase in adult survival is likely to be detrimental to productivity growth.

The existing literature indicates that increases in the adult survival rate will increase capital savings and thereby economic growth, but this result is modified in the stages of economic development where the subsistence of retired parents to some degree depends upon financing by their working-age children: increasing adult survival (life expectancy) will not unambiguously lead to

economic growth when there is a savings motive for having children. As economies develop, children become less important as a savings mechanism, and in that process adult survival gradually becomes a key to increased capital stocks—equivalent to the finding in the existing literature.

In sum, by targeting health conditions for all generations, but especially for children, we find that there is a potential for stimulating the demographic transition with lower fertility and higher productivity growth.

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