World Demographic Association

University of St.Gallen

The WDA – HSG Discussion Paper Series

on Demographic Issues

Fertility, Human Capital, and Economic Growth over the Demographic Transition

by Ronald Lee
and Andrew Mason

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This discussion paper series is kindly supported by the Ecoscientia Foundation

Fertility, Human Capital, and Economic Growth over the Demographic Transition

Ronald Lee (Corresponding Author)
Departments of Demography and Economics
University of California
2232 Piedmont Ave
Berkeley, CA 94720
E-mail: rlee@demog.berkeley.edu
Phone: 1-510-540-8986
Fax: 1-510-643-8558

Andrew Mason
Department of Economics
University of Hawaii at Manoa, and
Population and Health Studies
East-West Center
2424 Maile Way, Saunders 542
Honolulu, HI 96821
E-mail: amason@hawaii.edu

Key words: demographic transition, human capital, quantity-quality, population aging, economic growth, fertility

Research for this paper was funded by parallel grants from the National Institutes of Health to Lee and Mason, NIA R37 AG025247 and R01 AG025488, as well as by grants from MEXT.ACADEMIC FRONTIER (2006-2010) and UNFPA (RAS5P203) to NUPRI in Japan. We are grateful for help from Gretchen Donehower, Timothy Miller, Pablo Camalato, and Amonthep Chawla, and grateful to all the country research teams in the NTA project for the use of their data.

Abstract

Over the demographic transition, declining fertility leads to rising support ratios and consumption during the first dividend phase, followed by falling support ratios as population ages. Might human capital investments rise sufficiently as fertility falls to preserve the initial gains? Using a new cross-national data set, we estimate that a constant share of life time labor income is invested in human capital, so that the proportion invested per child is inversely proportional to the number of children. We draw from the literature an estimated elasticity of labor productivity with respect to human capital. Combining these, we simulate the effect of fertility variations over an exogenous demographic transition, including varying child and old age dependency, on consumption. In the baseline simulation, the increased human capital investments due to lower fertility initially reduce consumption as fertility falls but subsequently raise consumption despite population aging and increased transfers to the elderly.

Introduction

Low fertility in Europe and East Asia is leading to important changes in age structure and to slowing or negative population growth. The immediate impact of low fertility is to reduce the number of children in the population and to increase the share of the population concentrated in the working ages, raising the support ratio and correspondingly raising per capita income. We refer to this phenomenon as the first demographic dividend; others use different language (Bloom and Canning, 2001; Kelley and Schmidt, 1995; Mason and Lee, 2006). Later, as smaller cohorts of children reach the working ages, the share of the working age population declines, the share of the older adults increases, and the population ages. The support ratio falls, reducing per capita income. These shifts of the population age distribution have important macroeconomic consequences that feature prominently in discussions of the economic outlook in Europe and elsewhere. In Europe, however, the share and sometimes absolute number in the working ages is in decline raising concerns that the economic gains in recent decades will be lost. While some consequences of the changing support ratios can be understood through straightforward accounting, others are subtler, including effects on accumulation of physical and human capital.

A large literature spanning many decades explores other effects of these demographic changes. The conventional view is that low fertility and slower population growth will lead to increased capital intensity and higher per capita income. These effects are mediated by changing savings rates and labor force growth rates (Modigliani and Brumberg, 1954; Tobin, 1967; Mason, 1987; Higgins and Williamson, 1997; Kelley and Schmidt, 1995; Lee et al, 2000). In the standard Solow-Swan growth framework, low fertility leads to higher per capita consumption because slower labor force growth leads to capital deepening. This is the case if the saving rate is given (Solow 1956) or is golden-rule (Deardorff 1976). Samuelson raised the possibility, however, that in a model with age distribution and a retirement stage, over some relevant range lower population growth may reduce welfare because workers will have to support a larger number of elderly (Samuelson 1975; 1976). One purpose of this paper is to revisit Samuelson's conjecture. Elsewhere we have argued that the response of life cycle saving when fertility and mortality are low will lead to an increased capital – labor ratio (a "second demographic dividend") which offsets the growing burden of old age dependency, provided that old age is not too generously supported through public or familial transfer programs (Mason and Lee 2006).

The effects of demographic change on human capital have received less attention, although there have certainly been important contributions, mostly but not entirely theoretical (e.g. Becker, Murphy and Tamura, 1990, Mankiw, Romer and Weil, 1992; Jones, 2002; Montgomery, 2000). To draw a simple parallel with the Solow-Swan model, a constant rate of investment in human capital inevitably leads to an increase in human capital per worker if labor force growth slows. A deeper understanding of these processes, however, requires that two important issues be addressed. The first is how investment in human capital affects economic growth. The second issue, which receives more emphasis in this paper, is how demographic change interacts with investment in human capital. The central idea, however, is the following. If small cohorts of workers have high levels of human capital because parents and/or taxpayers have invested more in each child, standards of living may rise despite the seemingly unfavorable age structure.

The first contribution of this paper is to review previous research on the linkages between fertility, human capital, and economic growth so as to lay a foundation for the analysis that follows. The objective is to distill an important and somewhat unsettled literature to provide focus on the important issue emphasized here.

The second contribution is to offer new empirical evidence about the tradeoff between human capital investment and fertility based on data from the National Transfer Accounts (NTA) project (Lee, Lee and Mason 2008; Mason, Lee, Tung et al. forthcoming). The paper will present new estimates of public and private spending on education and health for children for a cross-section of countries, considering only expenditures and not time costs. It will answer the simple empirical question of whether lower fertility at the national level is associated with higher human capital investment per child and whether this holds for both public and private sector investment in human capital. We are not able to draw any inferences about causality.

Based on these estimates and a simple model, we will then simulate the effects of changing fertility over the demographic transition on human capital, per capita GDP, and lifetime consumption, on the assumption that the estimated cross-sectional relationship .between fertility and human capital investments held throughout the transition and will hold in the future. We show that based on reasonable parameter estimates an increase in human capital associated with lower fertility may offset the greater cost of supporting the elderly in the older population. Because there is considerable uncertainty in the literature about the effects of education on growth at the national level, however, we cannot come to a definitive conclusion on this point.

Quality expenditures and human capital

In the literature on the quantity and quality of children (Becker and Lewis, 1973; Willis, 1973), all expenditures on children are combined and treated as investments in child quality. In a later literature all parental expenditures on children are viewed as raising future earning prospects for children which is the operational definition of quality (Becker and Barro, 1988). Our approach here differs from this tradition. We suggest that some expenditures on children have mainly consumption value for those children and yield vicarious consumption value for the parents, while others augment the children's human capital (HK). Specifically, we treat public and private expenditures on health care and on education as HK investment, and ignore all other kinds of expenditures on children, such as food, clothing, entertainment and housing.

The extended theoretical treatment of investments in child quality (e.g. Willis 1973; Becker and Lewis 1973) views quality as produced by inputs of time and market goods and services. It would certainly be desirable to include parental time inputs in the production of HK, but National Transfer Accounts, our data source, do not include time use so we are not able to do so. Furthermore, the literature on investment in education emphasizes the opportunity costs of the children who stay in school to receive further education, and often this is the only cost of education that is considered when private returns to schooling are estimated. These opportunity costs are certainly relevant, but for now we have included only direct costs in our measure.

Increased investment in HK can take place at the extensive margin by raising enrollment rates, which implies higher opportunity costs as in the traditional analysis. But it can also take place at the intensive margin through greater expenditures per year of education, through variations in class size, complementary equipment, hours of education per day, or teacher quality and pay rate. In East Asia much of the private spending appears to be of this sort, as children are sent to cram schools or tutors after the public school education is completed for the day. Such increased expenditures do not necessarily have an opportunity cost of the sort measured in traditional studies, and the increase in years of schooling would underestimate the increase in HK investment. In Europe, on the other hand, education through apprenticeship may entail low costs and little lost time in the labor force.

Cross-national Estimates of Human Capital Spending in Relation to Fertility

The National Transfer Accounts project provides the requisite data on age patterns of human capital investments per child and labor income for eighteen economies, rich and poor: the US, Japan, Taiwan, S. Korea, Thailand, Indonesia, India, Philippines, Chile, Mexico, Costa Rica, Uruguay, France, Sweden, Finland, Austria, Slovenia, and Hungary. Data are for various dates between 1994 and 2004. See Lee et al (2008) and Mason et al (in press). More detailed information is available at www.ntaccounts.org.

For each country, we have age specific data on public and private spending per child for education and health. We sum spending per child on education across ages 0 to 26, separately for public and private. We do similarly for health care, but this time limit the age range to 0-17. These are synthetic cohort estimates. We also have data on labor income by age and we have calculated average values for ages 30-49, ages chosen to avoid effects of educational enrollment and early retirement on labor income. The data are averaged across all members of the population at each age, whether in the labor force or not, and include both males and females. They include fringe benefits and self employment income, and estimates for unpaid family labor which is very important in poor countries. We express the HK (human capital) expenditures relative to the average labor income. This is our basic estimate of human capital investment. For fertility we take the average Total Fertility Rate (TFR) for the most recent five year interval preceding the HK-NTA survey date, using United Nations quinquennial data. The TFR is also a synthetic cohort measure.

<New Table 1 about here..>

Figure 1 plots the natural log of total HK expenditures (that is, public and private, health and education, summed over the ages indicated above) per child relative to labor income on the vertical axis, against the log of the Total Fertility Rate on the horizontal axis. The corresponding descriptive regression is:

$$\ln(HK) = 1.92 - 1.05 * \ln(TFR), \qquad R^2 = .624$$
$$(.14) \quad (7.3)$$

An elasticity of -1.0 would imply that a constant share of labor income is spent on human capital investments regardless of how many children a couple has, so that a country with a TFR of 3 would spend one third as much per child relative to labor income as a country with a TFR of 1. The point estimate for the elasticity is -1.05, which is not significantly different than -1.0.

Further analysis indicates that this association results primarily from variations in public spending on education, and therefore it would not be apparent in micro-level analyses within countries. Heavy spending on private education is limited to Asia, where three countries spend more on private than on public. In Europe, all six NTA countries spend at least 7.5 times as much on public as on private, and none of the non-European NTA countries spends this much. There is also evidence of substitution between public and private spending on education across NTA countries.

How the Empirical Pattern is Related to the Quantity-Quality Tradeoffs Model

In the basic quantity-quality tradeoff model of fertility choice (Becker and Lewis, 1973; Willis, 1973), a couple has the utility function u(x,n,q) where x is parental consumption, n is number of children, and q is the quality of each of the identical and symmetrically treated n children. For our purposes x includes all the ordinary consumption by the children as well as the parents. We reserve qp_q=HK for human capital spending per child. The parents' budget constraint is $Y=p_x x + p_q nq$, which is nonlinear in the numbers and quality of children.

In pedagogical presentations of the model (Becker, 1991:Ch5 or Razin and Sadka, 1995:Ch3) it is assumed for simplicity that the parents have already decided how to divide their income between own consumption and spending on children (which is $p_q nq$), and the analysis focuses on the allocation of this chosen amount between numbers of children and spending on each, that is quantity and quality.

Consider Figure 1 in light of standard quantity-quality tradeoff theory. We suggest that under a specific assumption, it shows us a meta budget constraint for the quantity quality tradeoff, in the sense that the quantity-quality choice point for any country will fall somewhere on this line. To see this, let n be the number of children, q be real human capital investments per child, and p_q be the unit price of these investments. Then total HK spending (H for short) per child is qp_q. Suppose a couple with total income Y chooses to allocate a proportion of it equal to γY^{θ} for total investment in all children's HK, so that the total expenditure on HK is $\gamma Y^{\theta+1}$. Now, just as we did for Figure 1, let us standardize the HK variable by dividing by the couple's income, Y, giving us the proportion of their income that is spent on each child's HK. (We have actually divided by average labor income in Figure 1, but the factor of 120 can be folded into the coefficient γ.) We will call this standardized amount H^*. We now have the equation:

$$\gamma Y^{\theta} = H^* n$$

Taking logs and rearranging, we find:

$$\ln\left(H^* n\right) = \ln\left(\gamma\right) + \theta \ln\left(Y\right) \quad (0.1)$$

This suggests estimating the relation of the share of spending on HK relative to a couple's income by regressing the ln(TFR*HK) on ln(Y) cross nationally. When we do this, we find (t-statistics in parentheses):

$$\text{Ln}(H^* n) = \underset{(0.75)}{.57} + \underset{(1.75)}{.14} \ln(Y) \qquad R^2 = .15$$

The estimated on ln(Y) is insignificantly different than 0. Setting $\theta = 0$ and rearranging, we get:

$$\ln\left(H^*\right) = \ln\left(\gamma\right) - \ln\left(n\right) \quad (0.2)$$

This is the relationship plotted in Figure 1. We interpret this, then, as a budget constraint common to the 19 NTA countries. Of these, different countries are located on different points along the budget constraint, for a wide variety of reasons.

In our empirical exploration, we calculate the ratio of HK expenditure per child in money terms to the average labor income for age 30 to 49. A couple's life time labor income in a synthetic cohort sense is 80 times this average, reflecting 40 years each of labor income for husband and wife. If labor income is two thirds of total household income Y then Y is roughly 120 times average labor income. The constant in the regression, 1.92, estimates ln(γ). Therefore γ is about 6.8, and the share of HK expenditures out of labor income is roughly 8.5% or 1/12 (=6.8/80) of life time labor income, or 5.7% of total income.

The standard theory suggests that as income rises, fertility falls and investments in human capital rise, due to the interaction of quantity and quality in the budget constraint and the greater pure income elasticity of quality than of quantity. However, within the framework of the theory, there are a number of other factors that may influence the choice of fertility versus HK along the budget constraint. These include cultural differences in valuation of numbers versus quality; differences in the relative price of parental consumption, p_x and human capital, p_q;. the changing availability of new parental consumption goods; differences in child survival; differences in the rate of return to education or by older age survival probabilities may influence choices. The model can be expanded to include a fixed price of number of children, p_n, not shown in the equations above (see Becker, 1991). Examples are financial incentives or disincentives for child bearing such as family allowances in Europe or the fines of the one child policy in China. The availability of contraceptives can also be interpreted as influencing the price of numbers of children.

For all these reasons and more, we can meaningfully consider the effects of an exogenous change in fertility on human capital investment, and the effects of an exogenous change in human capital investment on fertility. Furthermore, the list of factors suggests some possible instruments for identifying these effects, that could be useful in future research. In the simulations to which we turn later, we will take the time path of fertility as exogenously determined, and attempt to trace out its implications for human capital investment and income growth.

Education and Economic Growth in Recent Theoretical and Empirical Literature

In a prominent article, Becker, Murphy and Tamura (1990) assign a central role to human capital as the main driver of economic growth, with output of consumption goods proportional to the stock of human capital (constant returns), and human capital per child proportional to the human capital of the parent generation. If it escapes a Malthusian trap, then the system converges to a steady state growth path with constant fertility, growing human capital per person, and a growing rate of return to human capital. In models of this sort human capital obviously has a very important role and declining fertility could apparently lead to faster aggregate economic growth.

In the endogenous growth model of Jones (2002), some returns to education are captured by the national economy, but the biggest payoff is global and shared, with population growth raising the numbers of educated people participating in research and development, which drives global technological progress. Fertility reduction in one country would permit greater investments in HK per child and higher per capita income, and the country could continue to benefit from new ideas generated abroad. A global downturn in population growth would probably reduce per capita income growth in this model, however, although it is hard to be sure, since Jones does not link population growth and per capita investments in education.

A large empirical literature assesses the individual and aggregate returns to investment in education. Most of the literature estimates private rates of return to education based primarily on the opportunity cost of the time of the student who invests in an incremental year of education, although sometimes tuition costs are also included. Card (1999) provides an analytic overview of this literature and reviews many IV studies, finding that in general the IV studies report even higher rates of return to education than do the OLS studies, with a broad range centered on about 8% per year. Heckman et al (2008) estimates rates of return for the US based on extended Mincer-type regressions allowing for various complications, and also including tuition, but without IV to deal with the endogeneity of schooling. They report rates of return in the range 10 to 15% or higher for the contemporary US (for a college degree, given that one already has a high school degree).

For our purposes this literature has two main problems: it focuses exclusively on the extensive margin of years of schooling (as opposed to increased investment at a given age) and it focuses exclusively on private rates of return rather than including social rates of return, which could be higher (due to externalities) or lower (due to inclusion of direct costs).

Another literature assesses the effect of education on per capita income or income growth rates at the aggregate level. These estimates should reflect both full costs of education and spillover effects. One approach treats HK in a way similar to K, as a factor of production for which an output elasticity can be estimated. Studies taking this approach sometimes report similar estimated elasticities of output with respect to labor, HK, and K (e.g. Mankiw, Romer and Weil, 1992; Lau, 1996). Another approach views HK as raising the rate at which technological changes can be adopted so HK is said to raise the growth rate of output rather than its level (Nelson and Phelps, 1966).

The earning functions fit on individual data are generally specified in semi-logarithmic form, which suggests that the underlying function linking the wage w to years of schooling has the form: $w = e^{\psi E}$ where ψ is the rate of return to years of education E. This suggests that human capital H or HK in relation to schooling level also has this form. Cross-national estimates of aggregate production functions including human capital as an input, from this perspective, should have the form $Y = AK^{\alpha}(HL)^{1-\alpha} = AK^{\alpha}(e^{\psi E}L)^{1-\alpha}$, where L is the labor force and HL is therefore the total amount of human capital given (Jones, 2002).

However, this is not the form that these cross-national regressions take. Instead, variables like median years of schooling completed or proportions enrolled in secondary education are used to measure H (e.g. Mankiw et al, 1992 or Barro and Sala-i-Martin, 2004:524). The difference is important. Under the exponential version, the human capital increment associated with the 15th year of schooling is four or five times larger than that associated with the first year of schooling, when ψ=.1. Our analysis, not shown here, concludes that when we take into account the time costs of schooling at the aggregate level, the micro approach described above implies aggregate level output elasticities that are in the neighborhood of one third. Therefore our baseline assumption is an elasticity of .33 for output with respect to human capital.

A Simple Model of Fertility, HK investment, and Economic Growth

Here we develop a simple model of a population with three age groups, children, workers, and retirees. Only children and workers are relevant to human capital and wage dynamics. Later, the number of retirees becomes important when we balance the advantages and disadvantages of low fertility.

In what follows, H is human capital investment per child, subscripted by the children's generation, t. F is the Net Reproduction Ratio per generation, so survival from birth to adulthood is folded into it, although we will refer to it as "fertility" for simplicity. It is subscripted by the parental generation. W is the wage of the working generation, that is parents. Nx is the size of generation x, where x=0,1,2 refers to children, workers and retirees, respectively. T is the total wage bill indexed on generation of current workers.

In our simple model the births of one period are the workers of the next period. We do not distinguish between the working age population, N1, and the labor force, L.
$N1_{t+1} = F_t N1_t$.
Here time is measured in generations. The proportion of workers surviving to retirement is s: $N2_{t+1} = s_t N_t$.

Investment in human capital relative to parental generation wages is a function of the level of parental fertility:
$H_{t+1}/W_t = h(F_t)$ = expenditure on human capital H relative to wages W by parental generation t per child in generation t+1. Thus when the parental generation has more education, and hence a higher wage, their children will receive greater HK investment at any level of fertility.
$W_t = g(H_t)$ gives wage as a function of human capital equal to the amount of HK investment a generation received in the preceding period.
Therefore:

$$H_{t+1} = h(F_t)W_t = h(F_t)g(H_t)$$

$$W_{t+1} = g(H_{t+1})$$

(0.3)
$$W_{t+1} = g\left[h(F_t)W_t\right]$$

Note that these equations introduce a lag of one generation between investment in the human capital of a generation of children and its effect on their labor productivity when they enter the labor force.

The growth rate of total wages is:

(0.4)
$$T_{t+1}\big/T_t = F_t g\left[h(F_t)W_t\right]\big/W_t$$

Now consider the special case in which g and h are constant elasticity functions, as follows:
$h(F_t) = \alpha F_t^{\beta}$
$g(H_{t+1}) = \gamma H_{t+1}^{\delta}$

Then we have the growth rate of wages:
(0.5) $W_{t+1}/W_t = (\alpha^{\delta}\gamma)F_t^{\beta\delta}W_t^{\delta-1}$

Noting that *βδ<0*, we have the plausible result that for a given level of parental human capital and wages, lower fertility leads to higher wages in the next generation. Closely related to this result, we see that lower fertility leads to higher wage rate growth from generation to generation. We also see that the growth rate of wages is inversely proportional to the initial level of wages, for a given level of fertility.

We can also find the equilibrium level of wages, $\hat{W}$ for a given level of fertility by setting the growth ratio to unity:

$$(0.6) \qquad \left(\frac{1}{\alpha^{\delta}\gamma}\right)^{\frac{1}{\delta-1}} F_t^{\beta\delta/(1-\delta)} = \hat{W}$$

Since *$\beta\delta<0$*, this expression tells us that higher fertility is associated with lower wages in equilibrium, with an empirical elasticity of roughly -.5 (since estimated β=-1 and δ=1/3, the exponent of F is -.5).

We can also find the growth rate of total wages, or the wage bill:

$$(0.7) \quad T_{t+1}/T_t = \alpha^{\delta}\gamma W_t^{\delta-1} F_t^{1+\beta\delta}$$

Our descriptive elasticity of fertility and HK was close to -1. This non-causal estimate suggests that $\beta<0$ (higher fertility leads to lower *HK* investments), while other estimates establish that $\delta>0$ (higher human capital leads to higher wages). Given our descriptive estimate of β, it seems highly likely that $1+\beta\delta>0$. From equation (0.7), this suggests that lower fertility will raise the rate of growth of the wage bill (and presumably GDP).

We also see that a higher value of parental wages, W_t, leads to a lower rate of growth of the wage bill, so long as $\delta<1$ which is very likely to be satisfied. This reflects diminishing returns to human capital, so that the greater the human capital of the parental generation, the smaller the wage gain from investing more in their children's human capital.

To this point we have focused our attention exclusively on the dynamic inter-relationship between wages, human capital, and fertility. Although this is the driving force in our analysis, the outcomes of particular interest are per capita income and consumption. In the simple OLG model employed here the wage is equivalent to lifetime earnings. In the absence of intergenerational transfers, the wage would be equivalent to lifetime consumption. A decline in fertility would unambiguously lead to an increase in lifetime consumption or the standard of living. The reality is that intergenerational transfers are pervasive. Consumption by children is almost exclusively financed through intergenerational transfers. Analysis of the sources of support for the elderly in the National Transfer Accounts project have to this point identified only one country – Thailand – in which the elderly rely on intergenerational transfers for less than half of their support.

In the simple theoretical model employed here, the consumption of children and the elderly is supported exclusively by intergenerational transfers. This is a highly stylized and unrealistic assumption, but it is useful to consider whether low fertility could lead to lower consumption under these extreme circumstances, i.e., if the elderly are supported entirely by transfers from workers.

The relationship between the wage in this simple model and per capita income is readily incorporated into recent research on age structure and per capita income growth (Bloom et al., KS) that emphasizes the share of the working age population in the total. In this model we know that the relationship between the wage and per capita income is given by:

(0.8) $$GNP_t / N_t = w_t \left(N_{1t} / N_t \right)$$

Where the demographic variable in parentheses on the right-hand-side is the ratio of the working-age population to the total population.

Earlier we discussed changes in the working-age population during the demographic transition and the first demographic dividend, followed by population aging. These are discussed in more detail below in the context of our simulations.

The evolution of consumption over the demographic transition is very important because different development paths require that current generations forego consumption to varying degrees. To do so involves sacrifice of current living standards. Analysis of income rather than consumption ignores this fundamental tradeoff.

Changes in per capita consumption deviate from changes in wages for two reasons. One reason is compositional, that is the first demographic dividend. This is incorporated into the analysis in a straightforward way, similar to the way that age structure influences GNP per capita. A second issue is that the share of GNP (or the wage) that is consumed varies with the rate at which production is invested in human capital. Note that in many analyses and in national income and product account human capital investment is treated as consumption. Here we treat it as investment. Altruistic parents derive utility indirectly from the anticipated effect that investment in their children's human capital will have on their children's future productivity and wellbeing, but the human capital expenditures would not yield this indirect utility were they not investments.

Our model is easily extended to include consumption by subtracting from total wages the amount spent on human capital investment:

(0.9) $$C_t = T_t - w_t N_{0t} h(F_t)$$

The share of aggregate production that is consumed is given by:

(0.10) $$C_t / T_t = 1 - F_t h(F_t)$$

In our constant elasticity special case, this becomes:

(0.11) $$C_t / T_t = 1 - \alpha F_t^{1+\beta}$$

The consumption rate is either increasing or decreasing in F depending on the elasticity of human capital spending with respect to F. In the simplest case emphasized above, the elasticity β is -1, so 1+β=0 and human capital spending as a share of total income is constant at 1-α, and, hence, the consumption ratio is constant.

From equation 2, the growth rate of consumption is given by:

(0.12)
$$C_{t+1}/C_t = \alpha^{\delta}\gamma W_t^{\delta-1} F_t^{1+\beta\delta} \frac{1-\alpha F_{t+1}^{1+\beta}}{1-\alpha F_t^{1+\beta}}$$

The right-hand-side ratio captures the period to period change in the consumption ratio. If $\beta = -1$ the ratio is equal to 1 and the change in consumption is equal to the change in wage bill.

To complete the picture we must also incorporate into the analysis that consumption "needs" vary with age. Thus, to track consumption we use consumption per equivalent adult.

(0.13)
$$c_t = C_t / (a_0 N0_t + N1_t + a_2 N2_t)$$

Simulation Analysis

The simulation treats the elasticity of human capital investment per child with respect to fertility in our descriptive regression as if it were the true causal elasticity, such that exogenous variations in fertility would generate the corresponding changes in human capital investment. The simulations take all demographic variables, fertility and adult survival, as exogenous. The parameters, their values, and sources are provided in Table 2. Note that there is no technological progress in this simulation. Changes in wage levels and consumption result entirely from changing population age distribution and changing investments in human capital.

<Table 2 about here>

The baseline simulation analyzes the transition in F, the NRR, from a peak value of 2.0, to replacement level, F=1, after one period. Fertility continues to decline for two periods reaching a minimum of 0.6. Thereafter, fertility gradually recovers eventually reaching replacement level. The baseline simulation also incorporates a rapid transition in adult mortality with the proportion surviving to old age rising from 0.3 to 0.8 over the course of the demographic transition.

The model is initialized by assuming that a pre-transition steady-state existed in t = -2. The NRR increased from 1.2 in t = -2 at a constant rate to reach 2 in t =0, reflecting declining infant and child mortality. Adult survival is held constant during this period. The age structure at t = 0 reflects these early demographic changes.

The key demographic variables are presented in Table 3.

<Table 3 about here>

The simulation covers seven periods (generations) or roughly two centuries during which there are three distinct phases, as follows:

Boom: Temporarily high net fertility which leads to an increase in the share of the population in the working ages as measured either by the percentage of the population who are workers or the support ratio.[1] The boom lasts for a single generation of thirty years.[2]

Decline: Declining fertility is leading to a decline in the share of the working age population and the support ratio. In the simulation this lasts for two generations or approximately 60 years.

Recovery: The share of the working age population and the support ratio rise as a consequence rising fertility with a one generation lag. In the baseline simulation, recovery last for two generations or approximately 60 years.

For the final two periods of the simulation, net fertility is held constant at the replacement rate.

Note that the timing of fertility decline and recovery are not based on any particular historical experience. A number of countries have reached very low fertility rates similar to those in the baseline simulation, but it is unknown when they might recover. Japan has had a TFR of 1.5 or less for almost two decades at this point.

Table 4 reports human capital variables for the baseline simulation. The share of the wage or labor income invested in the human capital of each child is reported in the first column. Human capital spending per child is low in period 0 because there are so many children relative to the number of workers. The investment in human capital in children in period 0 is actually less than the human capital of the current generation of workers who were members of a smaller cohort. The large cohort enters the workforce in period 1 leading to the first demographic dividend. Note that the average wage has declined from period 0 to 1 because members of the large cohort have less human capital than the previous generation of workers. During the first dividend period, then, the favorable impact of the entry of a large cohort of workers is moderated because the large cohort is disadvantaged with respect to its human capital.

The impact of low fertility on human capital occurs during the fertility decline phase. Human capital spending per child increases from 4.7 percent of the average adult's wage in period 0 to 10.0 percent in period 1 to 17.5 percent in period 2. With a one generation lag this leads to greater human capital and a higher wage. The peak in human capital investment per child is reached in period 2 and the peak in human capital is reached in period 3.

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[1] The support ratio is calculated as the number of workers adjusted for age variation in productivity divided by the number of consumer adjusted for age variation in consumption "needs".

[2] Using more detailed age data, estimates of the first dividend stage are typically between one and two generations long. For East and Southeast Asia, a region with rapid fertility decline, Mason estimates the first dividend period lasts 46 years on average.

Note that the trend in human capital investment depends both on the share of the wage invested in human capital per child and also on the wage. Thus, human capital has a multiple effect. The wage or the human capital of the current generation of workers depends on the human capital investment they received and also the human capital investment received by their parents' generation.

During the recovery period fertility is rising and, hence, human capital investment is declining. With a lag the human capital of the workforce declines as does the average wage until an equilibrium is reached at replacement fertility.

<Table 4 about here>

Key macroeconomic results are reported in Figure 2. The support ratio is of interest because it marks the three demographic phases of interest and also because it tells us how consumption and income would vary in the absence of investment, human capital or otherwise. If all labor income is consumed and none invested, consumption per equivalent adult exactly tracks the support ratio. Following the boom period labor income would increase by about 20 percent. Thereafter, foregoing the second dividend, fertility decline would have a severe effect leading to a decline in consumption by one-third. As fertility recovers and the working population rises relative to the older population, consumption would recover but only to about 5 percent below the pre-transition level. Thus, the first dividend would not only be entirely transitory but very low fertility would have a strongly adverse effect on standards of living with a one generation lag.

<Figure 2 about here>

With human capital investment the outcome is very different. GNP per capita grows about as rapidly as the support ratio during the first dividend period. However, consumption per equivalent adult consumer grows much more slowly because much of the gain in per capita output is invested in human capital. The returns on this investment are realized in the next two periods when consumption rises at the same time that the support ratio falls due to population aging. At the peak GNP per capita is 50 percent above the pre-transition level. Per capita GNP declines as fertility increases and spending on human capital declines, but per capita GNP stabilizes at a level about forty percent above the pre-transition level.

Consumption per equivalent adult rises much more slowly than per capita GNP or the support ratio during the boom period. The reason for this is two-fold. First, the share of GNP devoted to human capital increases moderately so less is available for consumption. Second, the decline in the relative number of children has a larger impact on per capita GNP (children count as 1) than on C per equivalent adult (children count as 0.5). Thereafter consumption per equivalent adult rises markedly achieving a 20 percent increase as compared with period 0. Consumption stabilizes at a higher level – between 15 and 20% above the pre-dividend level.

They key feature of this simulation is that human capital investment has allowed the first dividend to be converted into a second dividend. The affects of population aging are reversed as large cohorts of less productive members are replaced with small cohorts of more productive members.

Variations in parameters and demographics

How sensitive are the results to variations in parameter values and demographic variables? We have carried out a variety of sensitivity tests for variations in the values of the key elasticities. If the elasticity of investment with respect to fertility is set at -1.5 rather than the -1 of baseline, then the consumption gains from low fertility are greatly increased. If the elasticity is set at -.7 then the gains are much reduced and consumption more nearly tracks the support ratio. When the elasticity of the wage with respect to human capital is set at .5 versus the baseline value of .33, the benefits of fertility decline are much larger, but when it is set at .16 the benefits of low fertility vanish in the long term, and population aging overwhelms the higher labor productivity. When the two high (in absolute value) elasticities are used at the same time, the effects on consumption are three or four times as great as baseline. When the two low values are used, however, consumption tracks the support ratio quite closely and the gains from low fertility are small. Clearly the results depend on the parameter values.

A final set of simulations explores how features of the fertility transition influence the path of consumption given the baseline parameters values (Figure 3). Three scenarios are considered. In the first, the fertility rate declines slowly, over two generations rather than one, to replacement level and declines no further. In the second scenario fertility declines rapidly, over one generation, to replacement fertility and declines no further. In the third scenario, fertility declines slowly to sub-replacement level, 0.6 as in the baseline scenario, and recovers at a speed similar to that in the baseline. Note that in all cases the demography at the end of the simulation is identical. Hence, steady-state consumption per equivalent adult will be the same at the end of the simulations. Our interest here is in the paths to that steady-state. In the simulation results presented here steady-state has not yet been entirely realized. By period 9 (not charted) steady-state has been reached with consumption per equivalent adult 16 percent higher than in period 0.

Perhaps the most striking difference in the simulations is that the slow fertility transition to replacement fertility, given the baseline parameter values, results in a consumption path that declines when the first large birth cohort enters the workforce and only begins to increase when the second large birth cohort enters the workforce in period 2. In this scenario the rise in the old age population never is sufficient to depress consumption per equivalent adult. In the other three scenarios, consumption declines in one period because of the increase in the share of the population at older ages.

<Figure 3 about here>

Conclusion

A number of potentially important issues related to changes in population age structure are explored in this paper, albeit in a very preliminary way. The key idea is that it is insufficient to focus on the relative number of people in age groups. The productivity of those individuals also matters. Because investment in human capital and fertility are closed connected, the total amount produced by a cohort will not decline in proportion to its numbers. Indeed, it is possible that it could rise as cohort size falls.

In the context of the demographic transition the potential tradeoff between productivity and numbers raises interesting questions. First, does the first dividend have a diminished effect on per capita income because the large entering cohorts of workers will have lower human capital per capita than preceding cohorts? Second, is investment in human capital a mechanism by which the first dividend can be invested in future generations – generating a lasting second dividend? The third question concerns Samuelson's conjecture. Does lower fertility and slower population growth always lead to higher standards of living or can fertility be too low in the sense that rising old age dependency ratios more than offset the human capital gains?

The implication of rising fertility for human capital investment and economic growth is relevant at two points over the demographic transition as modeled in this paper. Before childbearing begins to decline the net reproduction rate increases due to reduced infant and child mortality. Also during the recovery period the rise in fertility leads to a decline in human capital investment. In both cases rising fertility leads to an increase in the share of the working population and a demographic dividend, but one that will be more modest if the larger generation of workers is less productive than the preceding one. This is an interesting possibility but the evidentiary base is weak. The data used to estimate the tradeoff between fertility and human capital investment come from countries that differ in the extent to which their fertility rates have declined, but no country is represented prior to the onset of fertility decline or at early stages of the decline. The existence and magnitude of the quantity-quality tradeoff may be very different during other phases of the demographic transition and dividend.

Our empirical results suggest that human capital expenditures per child are substantially higher where fertility is lower, to the extent that the product of the Total Fertility Rate and human capital spending per child is roughly a constant share of labor income across countries, although total spending per child falls with fertility. About one twelfth of parental life time labor income is spent on human capital investments, in countries like Austria, Slovenia, Hungary and Japan with TFRs near one, and in poorer countries like Uruguay with a TFR of 2.5 or the Philippines with a TFR of 3.6 (at the time of observation in Figure 1). This suggests that during the demographic transition, a portion of the first demographic dividend is invested in human capital, reinforcing the economic benefits of fertility decline. It also suggests that the very low fertility in some countries like Austria, Slovenia, Hungary, Japan, Taiwan or S. Korea is associated with an increased human capital investment per child that might reduce or at least postpone the support problems brought on by population aging.

Second, human capital investment is a potentially important mechanism by which a second demographic dividend can be generated. Fertility decline leads to substantial population aging and a rising dependency burden. As measured by the support ratio, the dependency burden can be as great or greater at the end of the transition as at the beginning. Although we have not emphasized this feature of the simulation model, the transfers from workers to the elderly are very substantial at the end of the transition. Standards of living as measured by consumption per equivalent adult can be sustained at relatively high levels, however, if the quantity-quality tradeoff is sufficiently strong and if human capital has a sufficiently strong effect on productivity. If the rate of growth is raised sufficiently by human capital investments, then even the share of output transferred to the elderly need not rise much.

The third issue is whether slower population growth is always better. This question can be answered using simulation results not reported in the main body of the paper. We allowed the elasticity of human capital with respect to fertility to vary as in the sensitivity analysis reported above. Steady-state consumption per equivalent adult was calculated using NRRs of 1.2, 1, 0.8, and 0.6. If the elasticity of output with respect to human capital is set to the baseline value of 0.33, slower population growth leads to higher consumption per equivalent adult for any of the elasticities used to measure the quantity-quality tradeoff. If the elasticity of output with respect to human capital is set to 0.16 (well below the level implied by rate of return estimates as discussed earlier), and if the elasticity of human capital with respect to fertility is set to -0.7 rather than -1.0, however, consumption per equivalent adult is higher for an F of 1 than for an F of 0.8 or 1.2.

There are many important qualifications that should be kept in mind in considering these results. First, the model of the economy is highly stylized in several important respects. We do not allow for capital, although this is an issue that we have explored extensively elsewhere. There is no technological innovation, although we believe this can be introduced with little effect on the conclusions. By using only three age groups we are relying on a very unrealistic characterization of the population and the economy. A model with much greater detail would be better suited to providing a quantitative assessment of the issues being explored here, and we believe we can construct one from the building blocks introduced here.

Second, the role of human capital in economic growth is unsettled in the literature. Estimates of the importance of human capital vary widely. It is very likely that the effect of human capital varies across countries depending on a host of factors that are not explored here. At this point we can do no better than allow for a wide range of possible effects.

Third, the empirical basis for quantifying the quantity-quality tradeoff is also weak, although it is widely accepted that such a tradeoff exists. An interesting result here is that the tradeoff is a feature of public spending rather than private spending. Caution should be exercised in interpreting the results presented here because we are not asserting any particular causal relationship between fertility and human capital. Thus it would be quite inappropriate to argue for fertility policy of any sort based on the simple cross-sectional relationship between human capital spending and fertility. We are only saying that countries with lower fertility are spending more on human capital per child. Because this is so, low fertility and population aging may not have the adverse affects on standards of living that are widely anticipated. This conclusion holds even though the elderly rely entirely on transfers from workers for their material support.

Population aging entails growing transfers from workers to the elderly in industrial nations today, through rising payroll tax rates and family support burdens. These transfers are becoming increasingly painful. It may ease that pain to realize that this same population aging is intrinsic to the processes that continue to bring us an highly educated population and comfortable standards of living. We can’t have one without the other.

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Figure 1. Per Child HK Spending (Public and Private) vs. Fertility

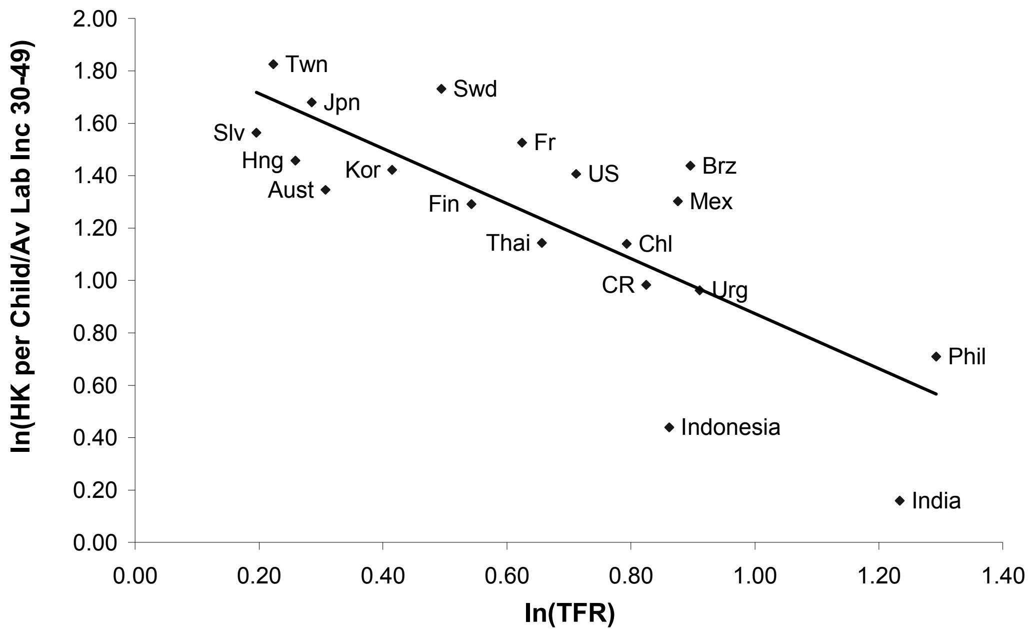
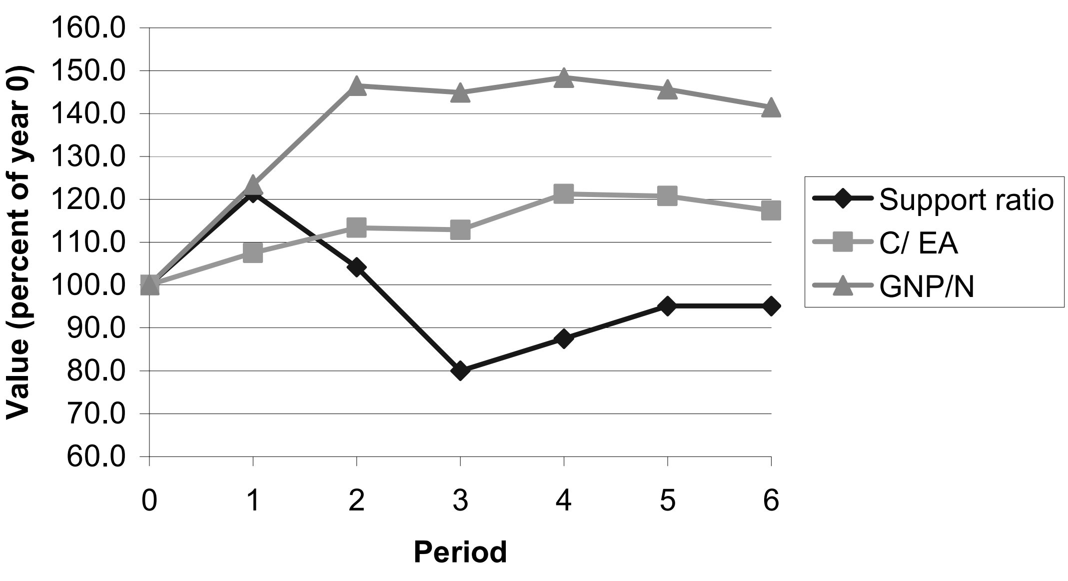


Figure 2. Macro Indicators: Baseline Results



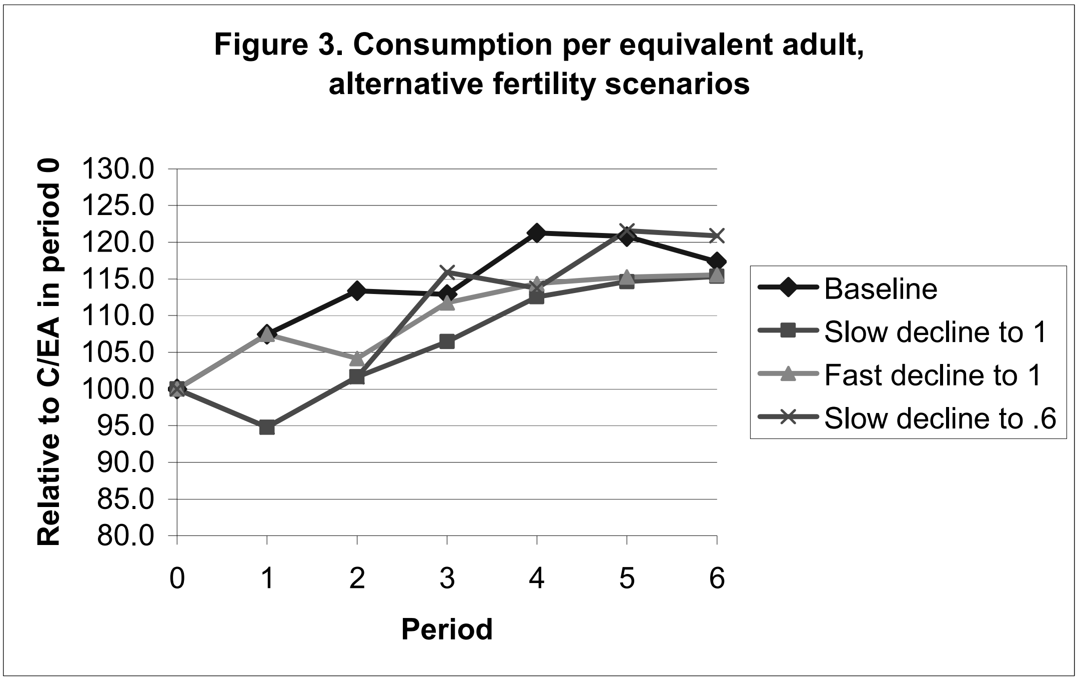


Table 1. Human capital spending and components, recent years, countries for which National Transfer Account estimates are available.

	Mean	Minimum	Maximum
Human capital	3.73	1.17	6.21
Health	0.54	0.17	0.94
Health, public	0.33	0.09	0.52
Health, private	0.21	0.01	0.50
Education	3.18	0.52	5.44
Education, public	2.32	0.16	4.99
Education, private	0.86	0.05	3.60

Note. All values are normalized on annual per capita labor income of persons in the age group 30-49.
Source. National Transfer Accounts, www.ntaccounts.org.

Table 2. Parameter values and sources.

	Value	Source
α	0.1	In data, spending was 3.8 years worth of prime adult labor income; total years of prime age adult labor was 39.4. Investment rate of 3.8/39.4 = approximately 0.1.
β	-1.1	Regression from NTA estimates. See text.
γ	1	Arbitrary (doesn't matter)
δ	0.33	Mankiw, Romer, and Weil; consistent with micro–level empirical literature when translated into macro context.
a_0	0.5	Estimated NTA consumption profile for developing countries.
a_2	1.0	Estimated NTA consumption profile for developing countries.

Table 3. Demographic Variables, Baseline Simulation

Period	NRR	Survival to old age	Growth rate	Percent of population: Children	Workers	Elderly	Support ratio
0	2.0	0.3	0.019	62.7	31.4	8.8	0.457
1	1.0	0.6	0.012	43.5	43.5	5.9	0.556
2	0.6	0.8	0.001	25.0	41.7	13.0	0.476
3	0.8	0.8	-0.008	25.5	31.9	33.3	0.366
4	1.0	0.8	-0.009	33.3	33.3	42.6	0.400
5	1.0	0.8	-0.002	35.7	35.7	33.3	0.435
6	1.0	0.8	0.000	35.7	35.7	28.6	0.435

Table 4. Human Capital Variables

Period		Human capital spending per child/Wage	Wage	Human capital spending per child	Average human capital of workers	Human capital spending/ GDP
0	Boom	0.047	0.263	0.012	0.017	0.093
1	Decline	0.100	0.234	0.023	0.012	0.100
2		0.175	0.290	0.051	0.023	0.105
3	Recovery	0.128	0.374	0.048	0.051	0.102
4		0.100	0.367	0.037	0.048	0.100
5		0.100	0.336	0.034	0.037	0.100
6		0.100	0.326	0.033	0.034	0.100

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World Demographic Association

P.O. Box 2239
CH-9001 St.Gallen, Switzerland

phone: +41 (0)71 242 79 79
www.wdassociation.org

fax: +41 (0)71 242 79 78
info@wdassociation.org