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

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**Abstract** Do low fertility and population aging lead to economic decline if couples have fewer children, but invest more in each child? By addressing this question, the paper extends previous work in which the authors show that population aging leads to an increased demand for wealth that can, under some conditions, lead to increased capital per worker and higher per capita consumption. This paper is based on an OLG model which highlights the quantity-quality tradeoff and the links between human capital investment and economic growth. It incorporates new national level estimates of human capital investment produced by the National Transfer Accounts project. Simulation analysis is employed to show that, even in the absence of the capital dilution effect, low fertility leads to higher per capita consumption through human capital accumulation, given plausible model parameters.

**Keywords** Demographic transition · Human capital · Quantity-quality · Population aging · Economic growth · Fertility

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## 1 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 (Kelley and Schmidt 1995; Bloom and Canning 2001; Mason 2006; Kelley and Schmidt 2007). 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; Kelley and Schmidt 1995; Higgins and Williamson 1997; Lee, Mason et al. 2001; Kinugasa and Mason 2007). 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 (Becker, Murphy et al. 1990; Mankiw, Romer et al. 1992; Montgomery, Arends-Kuenning et al. 2000; Jones 2002). 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 provide a simple model of fertility and human capital that follows very closely from the work of Becker, Willis, and others. The second contribution 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 third 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 et al. 2008; Mason, Lee 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 do not draw any inferences about a causal relationship between fertility and human capital investment.

Based on these estimates and a simple model, we will then simulate the effects of changing fertility and human capital over the demographic transition on 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.

## 2 A Model of Fertility, Human Capital Investment, and Economic Growth

The population consists of three age groups: children ($N_t^0$), workers/parents ($N_t^1$), and retirees ($N_t^2$). The number of children in period t depends on the fertility rate ($F_t$), or the net reproduction rate to be more accurate, and the number of workers/parents in year t. The number of workers in year t is equal to the number of children in the preceding period. And the number of retirees in year t depends on the number of workers in the preceding period and the proportion surviving to old age ($s_t$):

$$\begin{aligned} N_t^0 &= F_t N_t^1 \\ N_t^1 &= N_{t-1}^0 \\ N_t^2 &= s_t N_{t-1}^1 \end{aligned} \tag{1}$$

The total population is designated $N_t$.

The annual wage earned by workers ($W_t$) depends on the worker's human capital ($H_t$):

$$W_t = g(H_t) \tag{2}$$

Human capital is acquired during childhood and depends on human capital investment by parents during the preceding period:

$$H_t = h(F_{t-1})W_{t-1} \tag{3}$$

where $h(F_{t-1})$ is the fraction of the parents wage invested in human capital per child.

There is no physical capital in the model. Hence, income is equal to the wage. A further implication of this assumption is that the consumption of children, the consumption of retirees, and human capital investment are all funded via transfers from workers. Income is allocated between two uses: consumption and human capital spending. Designating per capita consumption by $X_t$ and $P_t$ as the relative price of consumer goods (and setting the price of human capital investment to 1), the social budget constraint is:

$$W_t N_t^1 \geq P_t X_t N_t + H_t N_t^0 \tag{4}$$

Investment in human capital is not considered part of consumption. Consumption includes all other spending on children and consumption by workers and retirees.

The budget constraint from the perspective of the average or representative worker or decision-maker in this model is:

$$W_t \geq P_t X_t / SR_t + H_t F_t \tag{5}$$

where $SR_t = N_t^1 / N_t$ is the support ratio and $F_t = N_t^0 / N_t^1$ is the number of children per parent.

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 the number of children, and q is the quality of each of the identical and symmetrically treated n children. In our model X includes all consumption: that by the children, excluding human capital spending, as well as the consumption of all adults, not just parents, and quality consists only of human capital spending. In our model quality (q) is human capital investment (H).

In pedagogical presentations of the model (Becker 1991: Ch 5; Razin, Sadka et al. 2002: Ch 3) it is assumed for simplicity that the allocation decision can be viewed as a two-step procedure. Parents decide how to divide their income between own consumption and spending on children, and the analysis focuses on the allocation of total child spending between numbers of children and spending on each child, that is the quantity and quality of children. We employ the same approach here. Workers allocate their income between consumption of all members of their family and human capital spending. Having done so, they select the number of children and human capital spending so as to maximize their utility.

Note that in this formulation the decision-makers (workers/parents) are making their allocation decision without explicit reference to the future. But implicit in the decision is a weighing of current standards of living versus future standards of living. The greater is spending on human capital the lower will be current consumption and the greater will be future consumption. The actual consumption during retirement of current workers is beyond their control, however. It depends on the decision of the next generation of workers (their children) about allocating resources between consumption and human capital investment and allocating consumption across generations.

## 2.1 The Support Ratio and the First Dividend

Per capita income in this simple model is the product of the wage and the support ratio. Letting the total wage bill be represented by $T_t$, and the support ratio by $SR_t$:

$$T_t / N_t = W_t SR_t \tag{6}$$

The support ratio is determined by fertility and old age survival. Using the demographic relationships in equation (1), per capita income is equal to:

$$\frac{T_t}{N_t} = \frac{W_t}{1 + F_t + s_{t-1}/F_{t-1}} \tag{7}$$

Holding the wage constant, a decline in fertility in the current period leads to a contemporaneous increase in the support ratio and in per capita income. In the following period, however, the number of elderly dependents increases and, thus, the support ratio and per capita income decline. The magnitude of the decline depends on the old age survival rate. The higher the survival rate the greater the decline in the support ratio and per capita income. Given the fertility rate an increase in the survival rate leads to a decline in the support ratio and per capita income.

The population dynamics in this simple model are not realistic but they capture some of the important features of much more detailed analyses of the effects of age structure on per capita income analyzed in a number of recent studies (Bloom and Williamson 1998; Bloom and Canning 2001; Kelley and Schmidt 2001; Lee, Mason et al. 2001; Bloom, Canning et al. 2002; Lee, Mason et al. 2003; Mason and Lee 2006; Kelley and Schmidt 2007; Mason and Lee 2007).

## 2.2 Wage and Income Dynamics

Per capita income depends on changes in wages in addition to age structure. The existence of the quantity-quality tradeoff means that a decline in fertility will lead to an increase in human capital in the same period and an increase in wages in the subsequent period. Substituting for human capital in equation (2) from equation (3) yields:

$$W_t = g[h(F_{t-1})W_{t-1}] \tag{8}$$

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:

$$T_{t+1} / T_t = F_t g\left[h\left(F_t\right)W_t\right] / W_t \tag{9}$$

A decline in fertility has two effects on growth in total wages. The average wage increases while the number of workers declines relative to those values for the preceding generation.

Considering a special case allows a more detailed analysis of the dynamics. Suppose that *g* and *h* are both constant elasticity functions as follows:

$$\begin{gathered} h(F_t) = \alpha F_t^{\beta} \\ g(H_{t+1}) = \gamma H_{t+1}^{\delta} \end{gathered} \tag{10}$$

where $\beta < 0$ and $\delta > 0$. The growth of wages is given by:

$$W_{t+1} / W_t = \left(\alpha^{\delta}\gamma\right) F_t^{\beta\delta} W_t^{\delta-1} \tag{11}$$

Noting that $\beta\delta < 0$, 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.

The equilibrium level of wages, for a given level of fertility, is found by setting the growth ratio to unity:

$$\left(\frac{1}{\alpha^{\delta}\gamma}\right)^{\frac{1}{\delta-1}} F_t^{\beta\delta/(1-\delta)} = \hat{W} \qquad (12)$$

Since $\beta\delta < 0$ it follows from equation (12) that higher fertility is associated with lower wages in equilibrium, provided that $\delta<1$.

The growth rate of total wages and total income in this model is:

$$T_{t+1}/T_t = \alpha^{\delta}\gamma W_t^{\delta-1} F_t^{1+\beta\delta} \qquad (13)$$

Fertility decline leads to more rapid growth in total wages if $1+\beta\delta > 0$. Empirical evidence on this point is discussed below. A higher wage leads to a lower rate of growth of wages if $\delta < 1$.

## 2.3 Consumption

Human capital spending increases wages but at a cost – resources must be diverted from consumption to achieve higher productivity (and consumption) in future periods. Thus, consumption is measured by subtracting human capital investment from total wages. Letting $C_t = P_t X_t$ represent total consumption, the relationship between fertility and total consumption is:

$$C_t = T_t - W_t N_t^0 h(F_t) \qquad (14)$$

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

$$C_t/T_t = 1 - F_t h(F_t) \qquad (15)$$

In our constant elasticity special case, this becomes:

$$C_t/T_t = 1 - F_t^{1+\beta} \qquad (16)$$

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, an elasticity of -1, human capital spending as a share of total income is constant at $\alpha$ and, hence, the consumption ratio is constant at $1-\alpha$.

The growth rate of consumption is given by:

$$C_{t+1}/C_t = \alpha^{\delta}\gamma W_t^{\delta-1} F_t^{1+\beta\delta} \frac{1-\alpha F_{t+1}^{1+\beta}}{1-\alpha F_t^{1+\beta}} \qquad (17)$$

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 total wages.

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

$$c_t = C_t \big/ (a_0 N_t^0 + N_t^1 + a_2 N_t^2) \tag{18}$$

## 3 Empirics

### 3.1 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 (H). Specifically, we treat public and private expenditures on health care and on education as human capital investment, and treat all other kinds of expenditures on children, such as food, clothing, entertainment and housing consumption.

The extended theoretical treatment of investment 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 human capital, 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 human capital 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 human capital investment. In Europe, on the other hand, education through apprenticeship may entail low costs and little lost time in the labor force.

### 3.2 Cross-National Estimates of Human Capital Spending in Relation to Fertility

The National Transfer Accounts (NTA) project provides the requisite data on age patterns of human capital investments per child and labor income for nineteen economies, rich and poor: the US, Japan, Taiwan, S. Korea, Thailand, Indonesia, India, Philippines, Brazil, 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 (forthcoming). 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 human capital expenditures relative to the average labor income. In terms of the theoretical model presented above, our human capital measure is essentially H/W, the average child's human capital claim on labor income. This is our basic estimate of human capital investment. For fertility we take the average total fertility rate (F) for the most recent five year interval preceding the H-NTA survey date, using United Nations quinquennial data. The total fertility rate is also a synthetic cohort measure.

<Figure 1 about here>

Mean, minimum, and maximum values of H/W and its components are reported for the 19 economies for which NTA estimates were available. On average 3.7 times the value of one year of prime age (30-49) adult labor is invested in human capital over the (synthetic) childhood. On average, over 80% of that investment is in education whereas 20% is in health spending. Public spending is much greater than private, especially for education.

<Table 1 about here.>

Figure 1 plots the natural log of H/W expenditures (that is, public and private, health and education, summed over the childhood 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:

$$\ln(H/W) = \underset{(.14)}{1.92} - \underset{(7.3)}{1.05}*\ln(F), \quad R^2 = .624$$

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 couples have, so that a country with a TFR (F) of 3 would spend one third as much per child relative to labor income as a country with a TFR (F) of 1. The point estimate for the elasticity is -1.05, which is not significantly different than -1.0.

Further analysis not detailed here 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, while none of the non-

European NTA countries rely so heavily on the public sector. There is also evidence of substitution between public and private spending on education across NTA countries.

### 3.3 How the Empirical Pattern is Related to the Quantity-Quality Tradeoff Model

Consider Figure 1 in light of the standard quantity-quality tradeoff theory. If preferences are homothetic, Figure 1 represents a meta budget constraint for the quantity-quality tradeoff, i.e., the quantity-quality choice point for any country will fall somewhere on this line. Homothetic preferences imply that the share of income devoted to human capital spending (HF/W) is constant.[1] If so, then $\ln(HF/W) = \ln(\gamma)$ where $\gamma$ is the share of income devoted to human capital spending. Rearranging terms we have $\ln(H/W) = \ln(\gamma) - \ln F$. Given that the coefficient of ln F is not significantly different than -1 this is essentially the relationship plotted in Figure 1.

An alternative but essentially equivalent approach is to consider whether the share of income devoted to human capital spending changes with income. When we do this, we find (t-statistics in parentheses):

$$\underset{}{\ln(HF/W)} = \underset{(0.75)}{0.57} + \underset{(1.75)}{0.14}\ln(W) \qquad R^2 = .15$$

The coefficient of ln(W) is insignificantly different than 0. Thus, we interpret Figure 1 as a budget constraint common to the 19 NTA countries.

The empirical exploration uses average labor income for those aged 30-49, rather than per capita income. A couple's life time labor income in a synthetic cohort sense is approximately 80 times this average, reflecting 40 years each of labor income for husband and wife. If labor income is two thirds of total 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.

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[1] This would be true, for example, with Cobb-Douglas utility as a function of parental consumption and total investment in children's human capital, $N_t^1 H_t$.

For all these reasons and more, countries move along the meta tradeoff line that represents the quantity-quality tradeoff. In general, we know that over the demographic transition countries move from low F and high H to high F and low H. Our purpose here is not to identify the exogenous changes that are responsible for that transition. Our purpose is to show that the economic implications of low F can not be considered usefully without simultaneously considering that high H accompanies low F.

### 3.4 Returns to Human Capital

The literature on the returns to health investment is relatively under-developed as compared with the returns to education. Analysis of historical evidence leads Fogel to conclude that nutrition and health have played a very important role in development (Fogel 1997). Many studies of contemporary developing countries support this view (Barro 1989; Bloom and Canning 2001; World Health Organization 2001; Kelley and Schmidt 2007). On the other hand, Acemoglu and Johnson argue that the importance of health to development is overstated (Acemoglu and Johnson 2007). In contrast with the literature on education, the literature on health provides little guidance about the rates of return to education. Note also that health is a much smaller component of human capital investment than is education.

For these reasons we rely on the large empirical literature that 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 instrumental variable (IV) studies, finding that in general the IV studies report even higher rates of return to education than do the ordinary least squares 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 human capital in a way similar to capital, as a factor of production for which output elasticities can be estimated. Studies taking this approach sometimes report similar estimated elasticities of output with respect to labor, human capital, and capital (e.g. Mankiw, Romer and Weil 1992). Another approach views human capital as raising the rate at which technological changes can be adopted. Thus, human capital 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 $\psi$ is the rate of return to years of education *E*. This suggests that human capital 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 (this approach is taken from Jones 2002, and Hall and Jones 1999).

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 human capital (Mankiw, Romer et al. 1992; 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 $\psi$=.1. (Note also that our measure of human capital is conceptually closer to that in Klenow and Rodriguez-Clare (1997) than to Mankiw et al (1992), because like the former ours reflects all levels of education and not just secondary).

The following analysis shows that if we take into account the time costs of schooling at the aggregate level, then the micro approach described above implies aggregate level output elasticities that are in the neighborhood of one third. E is both the years of education acquired, and the years spent acquiring it. Suppose that absent education, there are T potential years of work, so that actual years worked is (T– E). If N is the number of potential workers, then L=N(T-E)/T is labor supplied in a stationary population. Assume that our HK expenditure measure is proportional to E, with a scaling factor absorbed in A. Substituting into (0.4), taking the derivative with respect to E, and simplifying, we find:

$$\frac{dY/Y}{dE} = (1-\alpha)\left(\psi - \frac{1}{T-E}\right) \tag{19}$$

Evaluating this at $\psi = .1$, T=55, E=10, and α=2/3, we find that increasing the average education of the working age population by one year, from 10 years to 11 years, would raise GDP by about 5% if $\psi = .1$, .03 if $\psi = .07$ and .08 if $\psi = .14$.

Mankiw et al (1992) and Lau (1996) found roughly equal coefficients for capital, human capital, and raw labor. Based on this specification, we have:

$$\frac{dY/Y}{dE} = \frac{1}{3E} \tag{20}$$

Evaluating again at E=10, this gives .033, which is reasonably close to the .05 or .03 we derived above, but rather different than the .08. This exercise suggests that after translation, the micro estimates and the macro estimates yield reasonably consistent results. Our baseline assumption will be that the elasticity of output with respect to human capital is .33, which is consistent with a micro level elasticity $\psi = .07$, which is lower than Card's estimate and only about half of Heckman's. We also report results for aggregate elasticities of .16 and .50, to reflect the great uncertainty.

### 3.5 Summary of Estimates and Qualitative Implications

The empirical work of others and the analysis of NTA data described above yields estimates of the key parameters of the model presented in section II. The values, given in Table 2 below, are used in the simulation exercises reported in the next section. They can also be used to reach certain qualitative conclusions based on the analysis presented above. The important parameters are the elasticity of wages with respect to education (0.33) and the elasticity of quality, i.e., human capital spending, with respect to quantity (-1.1). Given these parameters,

- Lower fertility leads to higher wages in the next period.
- Lower fertility leads to higher wages in equilibrium.
- The growth of total wages is essentially unaffected by fertility.
- The consumption ratio is independent of fertility and thus consumption will grow at the same rate as total wages.

These are not intended as causal statements. They are descriptive statements about the aggregate patterns we should observe given a tradeoff between fertility and human capital investment, on the one hand, and the effect of human capital investment on productivity on the other.

## 4 Simulation

The simulation holds the estimated elasticity of human capital investment per child with respect to fertility fixed and considers how exogenously driven interlinked changes in {H,F} over the demographic transition influence key features of the economy. Adult survival is also assumed to be 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 changes in H, F, and adult survival.

<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. F 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 corresponding changes in human capital are reported below.

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. 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 of rising fertility with a one generation lag. In the baseline simulation, recovery lasts 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.

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.

[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 (2005) estimates the first dividend period lasts 46 years on average.

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 (boom, bust and recovery) 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, 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.

## 5 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>

## 6 Conclusions

A number of potentially important issues related to changes in population age structure are explored in this paper, albeit in a highly stylized 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 closely 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, but there is no data available to assess this.

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.

## References

Acemoglu, D. & Johnson, S. (2007). Disease and development: The effect of life expectancy on economic growth. *Journal of Political Economy*, *115*, 925-985.

Barro, R. J. (1989). A cross-country study of growth, saving and government. Harvard University.

Barro, R. J. & Sala-i-Martin, X. (2004). *Economic Growth*. Cambridge: MIT Press.

Becker, G. (1991). *A Treatise on the Family, enlarged edition*. Cambridge: Harvard University Press.

Becker, G. & Lewis, H. G. (1973). On the interaction between the quantity and quality of children. *Journal of Political Economy*, *84*(2 pt. 2), S279-288.

Becker, G., Murphy, K. M., et al. (1990). Human capital, fertility, and economic growth. *Journal of Political Economy*, *98*(Part II), S12-37.

Becker, G. S. & Barro, R. J. (1988). A reformulation of the economic theory of fertility. *Quarterly Journal of Economics, 103*(1), 1-25.

Bloom, D. E. & Canning, D. (2001). Cumulative causality, economic growth, and the demographic transition. In N. Birdsall, A. C. Kelley and S. W. Sinding (Eds.), *Population Matters: Demographic Change, Economic Growth, and Poverty in the Developing World* (pp. 165-200). Oxford: Oxford University Press.

Bloom, D. E., Canning, D., et al. (2002). *The Demographic Dividend: A New Perspective on the Economic Consequences of Population Change*. Santa Monica, CA: RAND.

Bloom, D. E. & Williamson, J. G. (1998). Demographic transitions and economic miracles in emerging Asia. *World Bank Economic Review*, *12*(3), 419-456.

Card, D. (1999). The causal effect of education on earnings. *Handbook of Labor Economics*. O. C. Ashenfelter and D. Card. **3**.

Deardorff, A. V. (1976). The optimum growth rate for population: Comment. *International Economic Review*, *17*(2), 510-514.

Fogel, R. W. (1997). New findings on secular trends in nutrition and mortality: Some implications for population theory. In M. R. Rosenzweig and O. Stark (Eds.), *Handbook of Population and Family Economics* (pp. 433-481). Amsterdam: Elsevier.

Hall, Robert E. & Jones, C. I. (1999) Why do some countries produce so much more output per worker than others? *Quarterly Journal of Economics*, *114*, 83-116.

Heckman, J. J., Ochner, L. J., et al. (2008). *Earnings functions and rates of return*. NBER Working Paper 13780.

Higgins, M. & Williamson, J. G. (1997). Age structure dynamics in Asia and dependence on foreign capital. *Population and Development Review*, *23*(2), 261-293.

Jones, C. I. (2002). Sources of U.S. economic growth in a world of ideas. *American Economic Review*, *92*(1), 220-239.

Kelley, A. C. & Schmidt, R. M. (1995). Aggregate population and economic growth correlations: The role of the components of demographic change. *Demography*, *32*(4), 543-555.

Kelley, A. C. & Schmidt, R. M. (2001). Economic and demographic change: A synthesis of models, findings, and perspectives. In N. Birdsall, A. C. Kelley and S. W. Sinding (Eds.), *Population Matters: Demographic Change, Economic Growth, and Poverty in the Developing World* (pp. 67-105). Oxford: Oxford University Press.

Kelley, A. C. & Schmidt, R. M. (2007). Evolution of recent economic-demographic modeling: A synthesis. In A. Mason and M. Yamaguchi (Eds.), *Population*

*Change, Labor Markets and Sustainable Growth: Towards a New Economic Paradigm* (pp. 5-38). Amsterdam: Elsevier.

Kinugasa, T. & Mason, A. (2007). Why nations become wealthy: The effects of adult longevity on saving. *World Development*, *35*(1), 1-23.

Klenow, Peter J. & Rodriguez-Clare, A. (1997) The neoclassical revival in growth economics: Has it gone too far? In B. Bernanke and J. Rotemberg (Eds.), *NBER Macroeconomics Annual 1997* (pp. 73-102). Cambridge, MA: MIT Press.

Lee, R., Mason, A., et al. (2003). From transfers to individual responsibility: Implications for savings and capital accumulation in Taiwan and the United States. *Scandinavian Journal of Economics*, *105*(3), 339-357.

Lee, R. D., Lee, S.-H., et al. (2008). Charting the economic lifecycle. In A. Prskawetz, D. E. Bloom and W. Lutz (Eds.), *Population Aging, Human Capital Accumulation, and Productivity Growth, a supplement to Population and Development Review 33* (pp. 208-237). New York: Population Council.

Lee, R. D., Mason, A., et al. (2001). Saving, wealth, and population. In N. Birdsall, A. C. Kelley and S. W. Sinding (Eds.), *Population Matters: Demographic Change, Economic Growth, and Poverty in the Developing World* (pp. 137-164). Oxford: Oxford University Press.

Lee, R. D., Mason, A., et al. (2001). Saving, wealth, and the demographic transition in East Asia. In A. Mason (Ed.), *Population Change and Economic Development in East Asia: Challenges Met, Opportunities Seized* (pp. 155-184). Stanford: Stanford University Press.

Mankiw, G., Romer, D., et al. (1992). A contribution to the empirics of economic growth. *Quarterly Journal of Economics*, *107*(2), 407-437.

Mason, A. (1987). National saving rates and population growth: A new model and new evidence. In D. G. Johnson and R. D. Lee (Eds.), *Population Growth and Economic Development: Issues and Evidence* (pp. 523-560). Social Demography Series. Madison, Wis.: University of Wisconsin Press.

Mason, A. (2006). Reform and support systems for the elderly in developing countries: Capturing the second demographic dividend. *GENUS, LXII*(2), 11-35.

Mason, A. & Lee, R. (2006). Reform and support systems for the elderly in developing countries: capturing the second demographic dividend. *GENUS*, *LXII*(2), 11-35.

Mason, A. & Lee, R. (2007). Transfers, capital, and consumption over the demographic transition. In R. Clark, N. Ogawa and A. Mason (Eds.), *Population Aging, Intergenerational Transfers and the Macroeconomy*. Elgar Press.

Mason, A., Lee, R., et al. (forthcoming). Population aging and intergenerational transfers: Introducing age into national accounts. In D. Wise (Ed.), *Developments in the Economics of Aging*. Chicago: NBER and University of Chicago Press.

Modigliani, F. & Brumberg, R. (1954). Utility analysis and the consumption function: An interpretation of cross-section data. In K. K. Kurihara (Ed.), *Post-Keynesian Economics*. New Brunswick, N.J.: Rutgers University Press.

Montgomery, M. R., Arends-Kuenning, M., et al. (2000). Human capital and the quantity-quality tradeoff. In C. Y. C. Chu and R. Lee (Eds.), *Population and Economic Change in East Asia, A supplement to vol. 26, Population and Development Review* (pp. 223-256).

Nelson, R. & Phelps, E. (1966). Investment in humans, technological diffusion, and economic growth. *American Economic Review*, *56*, 69-75.

Razin, A., Sadka, E., et al. (2002). The aging population and the size of the welfare state. *Journal of Political Economy*, *110*(4), 900-918.

Samuelson, P. (1975). The optimum growth rate for population. *International Economic Review*, *16*(3), 531-538.

Samuelson, P. (1976). The optimum growth rate for population: Agreement and evaluations. *International Economic Review*, *17*(3), 516-525.

Solow, R. M. (1956). A contribution to the theory of economic growth. *Quarterly Journal of Economics*, *70*(1), 65-94.

Tobin, J. (1967). Life cycle saving and balanced economic growth. In W. Fellner (Ed.), *Ten Economic Studies in the Tradition of Irving Fisher* (pp. 231-256). New York: Wiley.

Willis, R. (1973). A new approach to the economic theory of fertility behavior. *Journal of Political Economy*, *81*(2 pt. 2), S14-64.

World Health Organization, C. o. M. a. H. (2001). *Macroeconomics and Health: Investing in Health for Economic Development*. Geneva: World Health Organization.

## Appendix. Citations Pertaining to the Data Used for Figure 1 and the Empirical Estimates

**Austria:** Sambt, Joze and Alexia Prskawetz (2009) "National transfer accounts for Austria: Low levels of education and the generosity of the social security system", Sixth National Transfer Account Workshop, January 9-10, Berkeley, CA.

**Brazil:** Turra, Cassio M., Bernardo L. Queiroz, and Eduardo L.G. Rios-Neto, 2007 "Idiosyncrasies of Intergenerational Public Transfers in Brazil, Fifth National Transfer Account Workshop, November 5-6, Seoul, Korea.

**Chile:** Bravo, Jorge and Mauricio Holz (2007) "Inter-age transfers in Chile 1997: economic significance". Paper presented at the Conference on "Asia's Dependency Transition: Intergenerational Transfers, Economic Growth, and Public Policy", Tokyo, Japan, 1-3 November, 2007.

**Costa Rica:** Rosero-Bixby, L. & Robles, A. (2008). Los dividendos demográficos y la economía del ciclo vital en Costa Rica". Papeles de Población 55: 9-34.

**Finland:** Vaittinen Risto and Reijo Vanne (2008) Intergenerational Transfers and Life-Cycle Consumption in Finland, Finnish Centre for Pensions Working Papers 2008:6.

**France:** Zuber, Stephan (2005) "Public National Transfer Accounts for France," 35th East-West Center Summer Seminar, June 1-30.

**Hungary:** Gal, Robert (2009) "NTA age profiles in Hungary", Sixth National Transfer Account Workshop, January 9-10, Berkeley, CA.

**India:** Narayana, M.R., and Ladusingh, L. (2008) "Public sector resource allocation and inter-generational equity: Evidence for India based on National Transfer Accounts", 83rd Annual Conference of the Western Economic Association International_, June 29 – 3 July 2008, Sheraton Waikiki, Honolulu, Hawaii, USA.

Narayana, M.R., and Ladusingh, L. (2008) "Construction of National Transfer Accounts for India, 1999-00", _Working Paper#08-01, National Transfer Accounts Database, University of Hawaii (Honolulu, USA)_: March 2008, pp.57. //www.schemearts.com/proj/nta/doc/repository/NS2008.pdf

**Indonesia:** Maliki (2007), "Indonesia Social Security and Support System of the Indonesian Elderly," NTA Working Paper.

**Japan:** Naohiro Ogawa, Andrew Mason, Amonthep Chawla, and Rikiya Matsukura (2008) "Japan's Unprecedented Aging and Changing Intergenerational Transfers". NTA Working Paper.

**Mexico:** Mejía-Guevara, I. (2008), "Economic Life Cycle and Intergenerational Redistribution: Mexico 2004", IDRC/ECLAC Project.

**Philippines**: Racelis, Rachel H. and J.M. Ian S. Salas. "Measuring Economic Lifecycle and Flows Across Population Age Groups: Data and Methods in the Application of the National Transfer Accounts (NTA) in the Philippines." Makati City: Philippine Institute for Development Studies, Discussion Paper Series No. 2007-12, October 2007.

Salas, J.M. Ian S. and Rachel H. Racelis. "Consumption, Income and Intergenerational Reallocation of Resources: Application of National Transfer Accounts in the Philippines, 1999." Makati City: Philippine Institute for Development Studies, Discussion Paper Series No. 2008-12, March 2008.

**Slovenia:** Sambt, Joze and Janez Malacic, (2009) "Slovenia: Independence and the Return to the Family of European Market Economies," Sixth National Transfer Account Workshop, January 9-10, Berkeley, CA.

**South Korea:** Chong-Bum An, Young-Jun Chun, Eul-Sik Gim, Sang-Hyop Lee (2009) "Intergenerational Reallocation of Resources in Korea", Sixth National Transfer Account Workshop, Berkeley, CA.

**Sweden:** Forsell, Charlotte, Hallberg, Daniel, Lindh, Thomas & Gustav Öberg & Intergenerational public and private sector redistribution in Sweden 2003. Arbetsrapport 2008 nr 4 (Working Paper), Institute for futures studies. http://www.framtidsstudier.se/filebank/files/20080516$125822$fil$nj09JKk75GmJX4vbXVcT.pdf

**Taiwan**: Mason, Andrew, Ronald Lee, An-Chi Tung, Mun Sim Lai, and Tim Miller (forthcoming) "Population Aging and Intergenerational Transfers: Introducing Age into National Income Accounts," Developments in the Economics of Aging edited by David Wise (National Bureau of Economic Research: University of Chicago Press).

**Thailand:** Chawla, Amonthep (2008) "Macroeconomic Aspects of Demographic Changes and Intergenerational Transfers in Thailand." Ph.D. dissertation submitted to the University of Hawaii at Manoa.

**US:** Lee, Ronald, Sang-Hyop Lee, and Andrew Mason (2007) "Charting the Economic Life Cycle," in Population Aging, Human Capital Accumulation, and Productivity Growth, Alexia Prskawetz, David E. Bloom, and Wolfgang Lutz, eds., a supplement to Population and Development Review vol. 33. (New York: Population Council).

**Uruguay**: Bucheli, Marisa, Ceni, Rodrigo and González Cecilia (2007). "Transerencias intergeneracionales en Uruguay", Revista de Economía 14(2): 37-68, Uruguay.

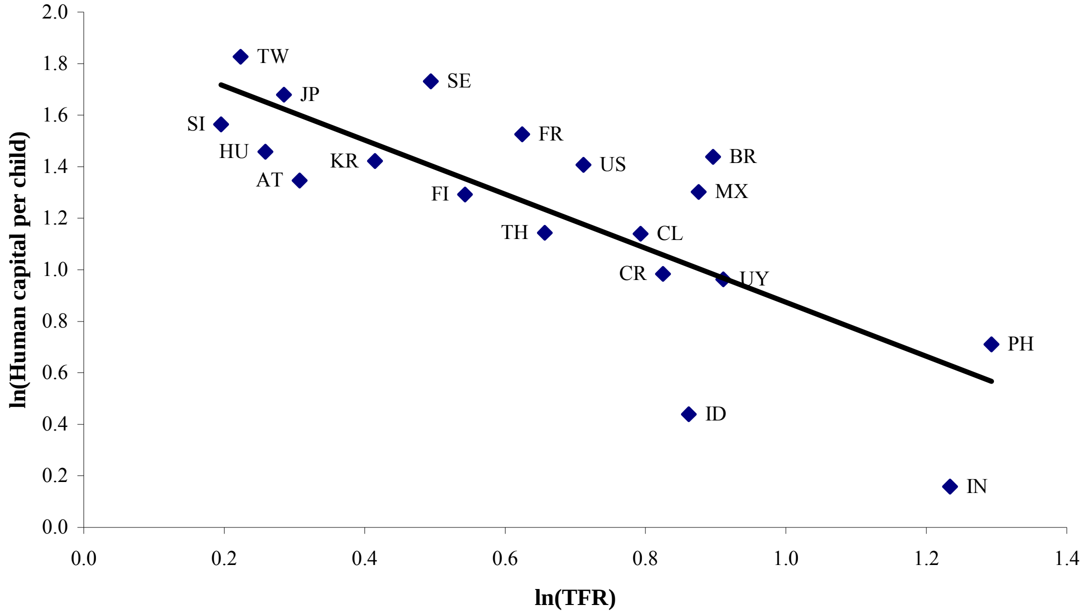


**Fig. 1** Per child human capital spending (public and private) versus the total fertility rate. *Note*: Human capital spending is normalized by dividing by the average labor income of adults 30 to 49 years of age. *Source of data*: See Appendix

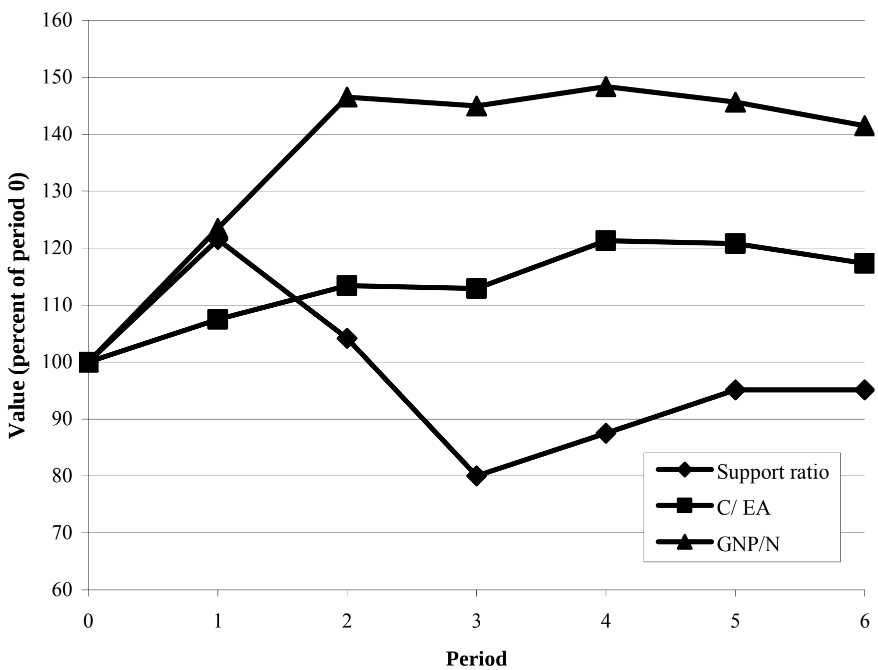


**Fig. 2** Macroeconomic indicators: baseline results

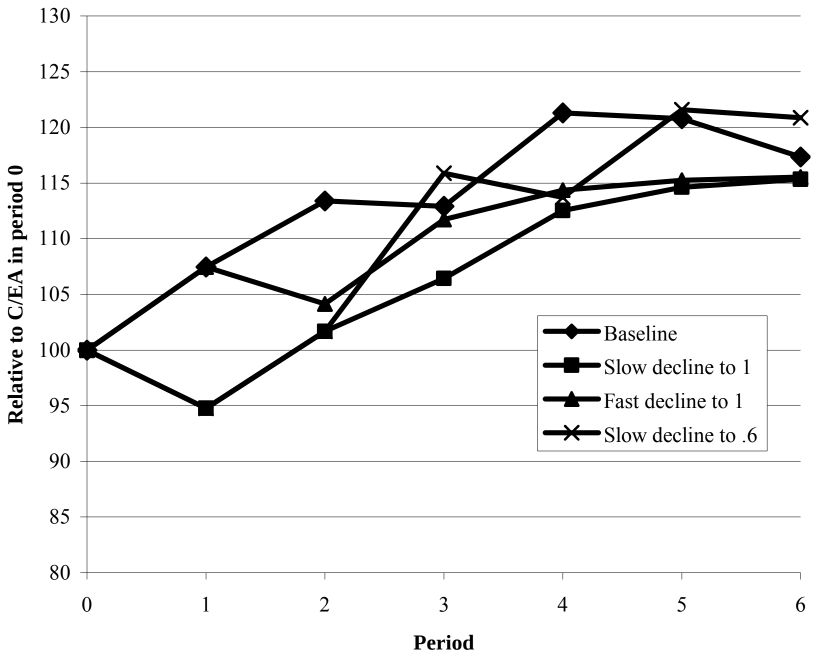


**Fig. 3** Consumption per equivalent adult, alternative fertility scenarios

**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 |
|---|---|---|
| $\alpha$ | 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. |
| $\beta$ | -1.1 | Regression from NTA estimates. See text. |
| $\gamma$ | 1 | Arbitrary (doesn't matter) |
| $\delta$ | 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 | | | Support ratio |
|---|---|---|---|---|---|---|---|
| | | | | Children | Workers | Elderly | |
| 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 |