COMMISSION ON MACROECONOMICS AND HEALTH
A WHO commission examining the interrelations among investments in health, economic growth and poverty reduction

CMH Working Paper Series

Paper No. WG1: 9

Health, Longevity, and Life-Cycle Savings

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Date: March 2001

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September 2000

Abstract: We add health and longevity to a standard model of life cycle saving and show that, under plausible assumptions, increases in longevity lead to higher savings rates at every age, even when retirement is endogenous. In a stable population, these higher savings rates are offset by increased old age dependency but during the disequilibrium phase the effect on savings rates can be substantial. We investigate the effect of longevity on savings empirically and find that, holding the age structure constant, savings do rise sugnificantly with longevity. Our results explain the boom in savings in East Asian as a combination of rising life expectancy and falling youth dependency, though they predict that savings in the region will return to more normal levels as the populations age. We also find that falling life expectancies in Afria are associated wit hdeclining savings rates.

** We would like to thank Angus Deaton and Alan Kelley and Andrew Mason for hepful discussions while this paper was being written.

1. Introduction

The rate of savings is among the most studied macroeconomic aggregates, reflecting its importance for understanding a wide range of economic phenomena. How much society chooses to save today for consumption tomorrow has important implications for the welfare of the elderly, economic growth and consumption levels. Savings rates differ across countries and across time within countries, often dramatically. The benchmark model for explaining these differences has been the life cycle model of savings.

According to the life cycle model of saving people save when young in order to finance consumption during retirement. In theory (in the absence of a bequest motive), the dissaving of the old should offset the saving of the young, such that in a stable population there is no aggregate saving. However, if the age structure of the population is unbalanced, as occurs over demographic transition for example, the saving behaviors of different cohorts need not cancel out, and aggregate savings may occur. In addition, Fray and Mason (1982) and Mason (1981, 1987, 1998) point out that in growing economies, where the wage incomes of the young increase relative to the retirement income of the old (which were saved out of past, lower, wages), the age-savings profile should tilt. These age structure and growth tilting effects have been studied extensively (e.g., Leff (1969), Kelley and Schmidt (1996), Higgins and Williamson (1997), Higgins (1998), Masson, Bayoumi, and Samiei (1998)), with the finding that in general national savings rates are higher when dependency rates are low and there is rapid economic growth.

While the empirical evidence tends to support the main predictions of the life cycle theory, a number of puzzles remain. Most importantly is the extraordinary increase in national savings rates observed in East Asia between 1950 and 1990. Such large swings in savings are difficult to explain in the context of the standard life cycle model. Changes in population age structure and the distribution of income between cohorts, the "tilting effect," made only small contributions to this upswing in saving. The East Asian data indicates that the major factor driving the surge was an increase in the rate of savings at every age (see Deaton (1992) for Thailand and Deaton and Paxton (1993, 1997, 1998) for the case of Taiwan). Such across the board savings "surges" cannot be reconciled with the standard life cycle theory. Recently Lee, Mason and Miller (1998) have suggested the reason for this surge in savings was rapidly increasing health and life expectancy in the region. By calibrating a simulation model with a fixed retirement age, they argue that the need to finance a longer period of retirement can account for the surge in savings.

The aim of this paper is to investigate if changes in longevity really play such an important role in determining national savings. While the focus of this paper is on savings, it can be viewed as part of a larger literature that is reevaluating the role of health and life expectancy on economic behavior (Strauss and Thomas (1998) and Bloom and Canning (2000a, 2000b)). In particular, there is an emerging literature arguing that life expectacny may increase the rutens to, and investment in, education (Bils and Klenow (2000), Kalemli-Ozcan, Ryder and Weil (1998), Meltzer (1995)).

We begin by investigating the role of longevity in a dynamic optimization model of life cycle savings. We take labor market participation decisions to be endogenous, allowing agents to choose their age of retirement. Under the assumption that consumption and lesiure and normal goods and rise with wealth, we show that a rise in life expectancy increases the optimal fraction of life spent working, but not by enough to offset the increased need for retirement income. Therefore savings rates rise at every age as longevity rises in order to meet the increased need for assets to finance consumption during retirement. However, increased longevity is likely to go hand in hand with all round health improvements that may increase the productivity, and wages, of the elderly while reducing their disutility of work. For example, Fogel (1994, 1997) argues that, as well as an increase in life expectancy, there has been a remarkable decline in the disability of the aged in the U.S. over the last 100 years. Health improvements that both increase longevity and reduce morbidity may allow a sufficient increase in the length of working life to allow savings rates to fall.

Ideally, we would like to separate out the effects of increased longevity from those of reduced morbidity. However, in the absence of comprehensive data on ill health we use life expectancy as a measure for health in general that proxies both for longevity and lack of disability. It follows that while the pure effect of improved longevity on savings is positive, in practice it will be a proxy for general improvements in health and its overall effect on optimal savings is ambiguous.

We construct an empirical model of aggregate savings that includes longevity as a determinant and estimate it using cross-country panel data. While the inclusion of life expectancy in models of aggregate savings is rare, it has sometimes been used and found to have a positive effect (e.g. Doshi (1994), Asian Development Bank (1997)). We aim to improve upon these empirical studies in a number of ways.

First, there is the question of which measure of aggregate savings to use. We replicate our work on four different measures; gross national savings and gross domestic savings, each measured using local relative prices and then international relative prices. While none of these measures is perfect, each has some advantages as a measure of savings and we wish to demonstrate that our result do not depend on a particular measure of aggregate savings. We find that in almost all specifications increases in longevity are associated with a statistically significant increase in the savings rate.

Second, there is the issue of how to incorporate age structure effects. While Leff (1969) and Kelley and Schmidt (1996) use young and old age dependency rates to model age structure, Higgins (1998) allows the size of each 5-year age cohort to have an effect, though he constrains these effects to lie on a cubic function for estimation purposes. We find that using dependency rates fits the data better than a cubic in age and has the advantage of being much easier to interpret.

Third, while we might expect savings rates to rise with longevity, they may be important nonlinearities in the relationship. We investigate these by allowing for a nonlinear functional form and by a separating life expectancy into discreet (5-year) bands and estimating the effect on savings of moving between bands. We find that savings increases sharply with life expectancy up to about age 65 but then the effect levels off.

Fourth, the savings decision is affected by a number of additional factors that we have not yet discussed. Savings rates may depend on the level of income as well as the rate of income growth. Mandatory pay-as-you-go pension schemes mean that consumption in retirement may be financed by transfers from the young, reducing the need for life-cycle savings. As incomes rise and family size declines there may be less dependency on family support for old age and more use of savings. To account for these factors we include a range of additional variables and use fixed effects to control for institutional and cultural differences across countries. One important finding is that life cycle savings behavior is more pronounced in richer countries, suggesting that in low income countries family support mechanisms do indeed seem to significantly reduce the need for savings.

Finally, we address the issue of reverse causality. In particular, when we include the level of income, or the growth rate of income, in a saving equation there is an obvious potential for a feedback effect. We therefore use an instrumental variables approach to control for this feedback. In addition, while it is less clear that that there is a feedback from savings to longevity, we also provide instrumental variable estimates in this case. Our results are robust to controlling for reverse causality in this way.

Our results agree with the ideas in Lee, Mason and Miller (1998); increases in life expectancy play a large role in savings behavior and in particular they explain the observed surge in savings in East Asia. While increases in longevity may increase the savings rate at every age, the effect on aggregate savings is transitory. Increases in longevity imply that the stable age structure has a more aged population and in the long run higher age specific saving rates are offset by greater numbers of the elderly who are dissaving. The effects of increases in life expectancy in East Asia on saving may be very great, but our theory suggests that they will dissipate as the population ages.

The life cycle theory of saving predicts that in a stable population, with no economic growth, net saving will be zero. This suggests that models that include age structure effects, but not longevity, are misspecified. High rates of old age "dependency" need not reduce saving if they are associated with increasing life expectancy and are matched by the saving of the young for their retirement. According to our theory, only age structures that are in disequilibrium, given current life expectancy, will affect aggregate savings, but standard models of age structure effects do not distinguish between stable populations and disequilibrium age structures. The fact that many countries have close to stable populations tends to drive the age structure effects in these models towards zero. Adding longevity to the relationship allows us to uncover the large effects on savings rates that occur when the age structures change at a given life expectancy (e.g. due to changes in fertility) and when health improves and life expectancy rises for a given population age structure.

To sum up, an extension of the life cycle model to incorporate the effects of changes in longevity on savings behavior can generate the type of across the board increases in savings rates observed in East Asia in the 1960s and 1970s (and may suggest the effects of HIV/AID induced falls in longevity on savings in Sub-Saharan Africa). Our empirical results, which control for simultaneity and country specific effects, broadly support our theory that longevity is important for savings.

2. Theory

We assume agents maximize their utility over their lifetime, choosing how much to work and how much to consume and investigate how changing life expectancy affects their choice. We follow Meltzer (1995) and Bils and Klenow (2000), who study investments in education, and assume that agents have a known lifetime, T. For simplicity we assume that longevity is fixed exogenously, ignoring the possibility that it is linked to consumption and spending on health care (e.g. see Phillipson and Becker (1998) for an analysis that allows health status and longevity to be endogenous). We also ignore any effects of uncertainty about the timing of death, effects that may be important (e.g. see Leung (1994)). Agents seek to maximize lifetime utility given by

$$\int_0^T e^{-dt} U(c_t, l_t, h_t) dt \qquad (2.1)$$

where c is consumption, l is leisure, h is health, and d is their discount rate and the index t is age. We assume that the time path of health is exogenously fixed. Agents choice their leisure and consumption paths subject to the constraints

$$c_t \geq 0, \quad 1 \geq l_t \geq 0, \quad W_T \geq 0 \quad (2.2)$$

where the stock of wealth, W_t, evolves according to

$$\frac{dW_t}{dt} = rW_t + (1 - l_t) w_t - c_t \quad (2.3)$$

We assume that the time path of wages, w_t, the interest rate, r, and the initial stock of wealth, W_0, are fixed exogenously. Equation (2.3) gives the savings (the addition to wealth) of the agent.

Assuming that the instantaneous utility function U is increasing and concave in each argument, it is straightforward to show (by forming the Hamiltonian and applying the maximum principle, e.g. see Berck and Sydaeter (1992)) that the optimal path of consumption and leisure satisfies

$$\frac{dc_t / dt}{c_t} = r - d \qquad (2.4)$$

and

$$\frac{dU}{dl_t} = w_t \frac{dU}{dc_t} \ \textit{if}\ 1 < l < 0, \quad \frac{dU}{dl_t} \geq w_t \frac{dU}{dc_t} \ \textit{if}\ l = 1, \quad \frac{dU}{dl_t} \leq w_t \frac{dU}{dc_t} \ \textit{if}\ l = 0 \quad (2.5)$$

Consumption grows at the rate $r - d$ while agents work up to the point where they are marginal utility of extra leisure equals the marginal utility of the consumption goods they could purchase if they worked. Retirement occurs ($l = 1$) when the marginal utility of leisure, even with no work, exceeds the marginal utility of the consumption times the wage rate. Let us denote the optimal plan by $(c_t^*,\ l_t^*)$ which produces the time path of net wealth holdings W_t^*.

As it stands, the model does not imply that people ever retire. For retirement to take place we need the wage rate to decline over time, or the utility of leisure to rise. For example if health declines over time, it may lower productivity and wages and, in addition, if health and leisure are complements (so that lowering health raises the disutility of working) it may increase the marginal utility of leisure.

The key idea of the life cycle model is that people save for retirement.

Assumption 1: Given $W_o = 0$ the optimal path (for any T) has $W_t^* \geq 0$, for all $0 \leq t \leq T$.

This implies that people never go into debt to finance consumption. Sufficient conditions to ensure this are quite easy to find. For example, if the wage rate falls over time, while the marginal utility of leisure increases, the work and earnings will be concentrated in the early part of life. Provided r is large enough, so that consumption is level or skewed towards the end of life, this concentration of earnings when young, and the need for consumption when old, will ensure positive wealth holdings at all times. Rather than impose conditions on the utility function and wage profile that ensure people save for retirement, it seems easier to assume 1 directly.

We also assume

Assumption 2: Both consumption and leisure are normal goods, that is

$$\frac{dc_t^*}{dW_0} \geq 0, \frac{dl_t^*}{dW_0} \geq 0, \text{ for all } 0 \leq t \leq T.$$

We assume that an increase in initial wealth increases consumption and leisure at all times. The alternative would be that an increase in wealth causes people to decrease their hours of work to such an extent that their optimal consumption falls, or they increase consumption to such an extent that their leisure time falls. While these outcomes are possible they seem unlikely. Note that we define normal good with respect to initial wealth, which is exogenous; income depends on labor supply and is endogenous. Now consider what happens to the agents optimal plan when we increase longevity, keeping everything else the same. We are particularly interested in the savings rate defined as

$$s_t = \frac{y_t - c_t}{y_t}, \; where \; y_t = rW_t + (1 - l_t)w_t \qquad (2.7)$$

Proposition 1: Let $W_0 = 0$. Under assumptions 1 and 2 an increase in longevity increases the savings rate at every age.

proof: Let $(c_t^*, \; l_t^*)$ be the original optimal plan for life expectancy T and let $(c_t^{**}, \; l_t^{**})$ be the new optimal plan when life expectancy rises. By assumption 1, wealth at time T in the new optimal plan is non-negative, that is $W_T^{**} \geq 0$. Now let us keep behavior after T fixed and restrict out attention to the time interval [0, T]. Since the new optimal plan cannot be improved upon it maximizes

$$\int_0^T e^{-dt} U(c_t, l_t, h_t) dt$$

subject to

$$c_t \geq 0, \quad 1 \geq l_t \geq 0, \quad W_T \geq W_T^{**}$$

where we allow for free disposal of wealth. But this is the same problem, and has the same solution, as maximizing over [0, T] subject to

$$c_t \geq 0, \quad 1 \geq l_t \geq 0, \quad W_T \geq 0$$

but with $W_0 = -W_T^{**} e^{-rT}$. This is the original problem of maximizing over [0, T] but with lower initial wealth. By assumption 2, it follows that on [0, T] we have $c_t^{**} \leq c_t^{*}, l_t^{**} \leq l_t^{*}$. Using equation (2.7) it is easy to show that he savings rate is increasing in y and decreasing in c; it follows immediately that $s_0^{**} \geq s_0^{*}$. At each point in time, wage income under the new plan is higher and consumption is lower than before. By equation (2.3) wealth accumulates more quickly under the new plan, and as time passes this effect is compounded by interest payments on the rising stock of wealth. It follows that at every point in time income under the new plan is higher, and consumption is lower, giving a higher savings rate.

The rise in savings rates at every age is consistent with the evidecne on hosuehold consumption in Thailand and Taiwan where the boom in savings was caused by an upward shift of the whole age specific saving rate schedule.

Proposition 1 deals with a pure increase in longevity, with no increase in health status as people age. In practice, increases in longevity will be associated with better overall health and empirical regressions will pick up both effects if we do not control for morbidity separately.

Suppose that longevity increases from T to $T' = \lambda T$ but at the same time health status improves by delaying the onset of the effects of aging proportionately. This implies productivity and health status stay higher longer and we have $w'_{\lambda t} = w_t, h'_{\lambda t} = h_t$. with these health improvements agents maximize

$$\int_0^{T'} e^{-\delta t} U(c_t, l_t, h'_t) dt \quad (2.8)$$

subject to

$$c_t \geq 0, \quad 1 \geq l_t \geq 0, \quad W_{T'} \geq 0, \quad \frac{dW_t}{dt} = rW_t + (1 - l_t)w'_t - c_t \qquad (2.9)$$

By a simple change of variable ($z = t / \lambda, K_z = W_z / \lambda$) we can show that this is equivalent to choosing the time paths c and l so as to maximize

$$\lambda \int_0^{T} e^{-\lambda \delta z} U(c_z, l_z, h_z) dz \qquad (2.10)$$

subject to

$$c_z \geq 0, \quad 1 \geq l_z \geq 0, \quad K_T \geq 0, \quad \frac{dK_z}{dz} = \lambda r K_z + (1 - l_z) w_z - c_z \qquad (2.11)$$

It is easy to see that if $r = \delta = 0$ the new maximization problem is identical to the original problem except that the objective function is multiplied by λ ; this has the same solution as the original problem. This means that the optimal decisions at time λt in the new problem are the same as those at time t originally. For example, if agents save at a constant rate until retirement, the effect of increasing longevity and health together is that they extend their working life proportionately and save at exactly the same rate as before. Note however, that this proportionality result in (2.10) and (2.11) depends on the interest rate and the rate of time preference being zero; if these are positive the longer time horizon in itself can have real effects on saving, though the direction of these effects is ambiguous.

Our simple theory suggests that the pure effect of greater longevity is to increase savings rates but that if the increased longevity is associated with better health when old, and in particular higher productivity and lower disutility of work than before, the effect is ambiguous.

3. Data

There are several conceptually different measures of aggregate savings.
We start with the following identity:

$$Y = C + I + G + (X-M) \qquad (3.1)$$

Where Y is GDP, C is private consumption, I is gross investment (private plus public), G is government consumption, and (X-M) is net exports (the trade balance). Gross domestic savings is the sum of public and private savings. Letting T be tax revenues, T-G is public savings while Y-C-T is private savings. Thus,

$$GDS = Y - C - G = I + (X-M) \qquad (3.2)$$

so that GDS equals gross investment plus net acquisition of foreign assets. The gross domestic savings rate is GDS/Y.

One source for GDS is the World Bank's *World Development Indicators 1999*, which includes annual data from 1960 to 1997. Alternatively, GDS, can be calculated via the first identity in (3.2) using data on GDP, private consumption, and government consumption contained in the Penn World Tables (version 5.6) which includes annual data from 1950 to 1992. A major difference between these two sources is that the World Bank national income accounts are in local prices, while the Penn World Tables gives volume figures for each component of national income at international prices. If all countries had the same relative prices, this would not matter. However, in poorer countries the relative price of consumption goods is lower than the world average while investment goods are more expensive. This means that in real terms, in constant international dollars, poorer countries have relatively more consumption, and less investment and hence a lower saving rate (often only half as much) than at local prices.

In an international study it is often appropriate to measure all quantities in real terms using world prices; in this case income and savings would be measured in similar units across countries. However, it is not clear that this procedure is appropriate for the savings rate. Since the savings rate is a ratio, comparing this across countries raises no fundamental problem. The advantage of using international prices is that if the actual goods consumed and physical investments made are identical in two countries, they will have the same savings rate; calculated at local prices the two savings rates can be quite different despite actual behavior being identical. The advantage of using local prices is that then savings actually measure consumption forgone; using "real" savings we measure how much extra consumption could have been purchased as world prices, but this may not be the relevant at the national level. Since both measures have advantages we use both in turn as our dependent variable and compare the results.

Gross domestic income only measures the value of income generated by economic activity within a country. People living within a country will also receive income from their ownership of foreign assets and may receive transfer payments from abroad. Gross national product is given by GNP = Y + NFI, where NFI is net factor income from abroad, plus international transfers (e.g., net foreign aid inflows and net remittance inflows from overseas workers). This yields gross national savings:

$$GNS = Y + NFI - C - G = GDS + NFI \qquad (3.3)$$

The gross national savings rate is GNS/GNP. Conceptually, gross national savings is a superior measure to gross domestic savings because it reflects total income, independent of its source. Data on gross national savings are available from *World Development Indicators 1999*, but only from 1970 onwards. In addition to the World Bank's reported gross national savings rates, we can calculate gross national savings from 1960 to 1997 using income, savings, and data on net factor income from abroad contained in the WDI. The drawback of this method is that it excludes international transfer payments.

This gives us four measures of the savings rate that we employ; GDS at local and international prices, GNS properly measured from 1970 and a GNS measure that excludes international transfer payments, from 1960. Savings are quite volatile year to year and we average over successive five-year intervals to smooth out business cycle effects.

These measures of GDS and GNP are gross measures. Conceptually, a net measure, subtracting from both income and gross investment an allowance for the depreciation of capital is superior. In addition, income from the depletion of natural resources actually involves a running down of capital stocks and represents dissaving. Finally, income should include capital gains on a country's stock of physical capital, overseas assets, and natural resources. However the lack of suitable data means we are limited to our imperfect gross savings measures.

When we measure aggregate savings we have not only household saving but also government savings as well as he profit retention by the corporate sector. However, these additional forms of saving will not affect total saving if households, who are their ultimate owners, count these forms of saving as part of their own.

In our analysis we exclude socialist countries since there is no reason their behavior should fit the optimizing life cycle model. We also exclude countries with population less than 1 million because their data tend to be unreliable and major oil producers because we don't take account of capital gains caused by changes in oil prices.

Table 1 lays out the definitions and sources and coverage of the savings rate data used in this study. Table 2 provides simple descriptive statistics on the different savings rate variables. The means, standard deviations, and maxima are reasonably comparable across measures. In table 3 we report the correlation between the different savings rate measures. In some cases, these correlations are significantly less than unity, suggesting that the choice of savings rate may be consequential with respect to empirical results.

Table 4 gives some simple descriptive statistics on the explanatory variables we use. Demographic data on life expectancy and age structure comes from the United Nations (1998). Real income per capita, the GDP deflator and are taken from *the Penn World Tables (5.6)*, which are described in Summers and Heston (1991). Data on the geographical variables we use as instruments are from Gallup, Mellinger and Sachs (1998).

4. Explaining Aggregate Savings

The average savings rate can be written as the sum of the savings rate of the different age groups in a population weighted by their income shares. That is, the average savings rate is

$$\bar{s} = \sum_{i=0}^{T} s_i \frac{Y_i}{Y} = \sum_{i=0}^{T} s_i \frac{P_i}{P} \frac{y_i}{\bar{y}} \qquad (4.1)$$

where s_i is the savings rate of age group i and Y_i/Y is its share of total income. A groups share of income can be further decomposed into its share of total population , P_i/P, and the average income of its members as a proportion on the average income of the population, $y_i / \bar{y}$. This implies that the age structure of the population matters. In addition, to the extent that growth changes the distribution of income between cohorts it will affect the saving rate. This effect is likely to go in different directions for different cohorts, implying that the growth rate effect enters interactively with the age structure. On the other hand, by proposition 1, the effect on increased longevity is to raise the savings rate of every age group, which suggests that we can simply add some function of life expectancy to the relationship.

In table 5 we report of simple regressions where we explain the gross domestic savings rate (at local prices) averaged over a five year period, using economic growth over the previous ten years, and life expectancy and some age structure variables, measured at the beginning of the period. That is, we measure the age structure effects in (4.1) directly, while the distribution of average income between cohorts depends on the growth rate and the age specific savings rate depends on life expectancy (which proxies both for longevity and overall health status). Our theoretical model in section 2 also suggests that the real interest rate should play a role. However, empirical work seldom finds any effect of interest rates on savings (e.g. Higgins (1998)), and for simplicity we exclude it.

Column (1) of table 5 reports a regression including life expectancy the growth rate on income, and 17 population age groups (by 5-year intervals from zero to 84). Both life expectancy and economic growth appear to have positive, and statistically significant effects on the average saving rate. While we do not report the individual cohort effects, we can reject the hypothesis that they are all zero (the F test at the bottom of column (1)). While the age structure matters, for tractability we want to compress the age structure effects into a smaller number of parameters. In column (3) we estimate a restricted model, where the coefficients on age structure are constrained to lie on a cubic equation (i.e. the coefficient on the population share of cohort i, f_i say, can be written as $f_i = a_0 + a_1 i + a_2 i^2 + a_3 i^3$) with the addition of a step function, with steps at ages 20 and 60. This encompasses the dependency approach used, for example, by Kelley and Schmidt (1996) and the flexible function approach used by Higgins (1998).

Experimentation showed that splits at 20 and 60 performed better than the conventional dependency rate taken as 0-14 and 65+. In addition, adding a further step at 40 did not significantly improve the fit of the step function approach.

The only age structure effect that is statistically significant in regression (2) is the youth dependency rate. However, a test of the restrictions implied on the age structure effects when use the cubic functional form, plus the dependency rate approach, does not reject these restrictions (the F test at the bottom of column (2)). It follows that the data accept these restrictions and we can reduce the number of age effect parameters to be estimated.

We can go further and test if both the cubic functional form and the dependency rate step function are required. Column (3) report a model where the age structure effects are modeled as lying on a cubic function alone. Now both the linear and squared term become statistically significant. The age effects are close to an inverse U, with young and old cohorts depressing savings and the middle age groups increasing the savings rate. However an F test that we can set the dependency rate parameters to zero (bottom of column (3)) is rejected. It appears therefore that the combined model fits the data better than the cubic function alone.

In column (4) we estimate the relationship allowing only dependency rate effects of age structure. We find that the presence of large proportions of elderly or young people in the population depresses the savings rate, with effect of the old being particularly large. Now, however, we cannot reject the exclusion of the cubic age effects (F test at the bottom of column (4)). It follows that the age structure effects can be modeled adequately by the effects of the dependency rates, and we do not require come complex age structure effects.

In table 6 we repeat the analysis carried out in table 5 but add fixed effects to capture any country specific effects that may effect savings rates. Despite the addition of fixed effect, the results in table 6 are remarkably similar to those found in table 5. Again life expectancy has a positive and significant effect, with a ten-year increase in longevity being associated with a rise in savings rates of about 4.5 percentage points. In addition, our tests on how to model the age structure effects follow a similar pattern to those in table 5. The data accepts the simplification of the age structure effects to the encompassing model and then to the dependency rate model, but not to the cubic functional form. We take the model with dependency rate effects as our base model and our starting point for further investigations.

So far we have assumed that the age structure effect is linear, but there is no reason for this to be so. For example if retirement is mandatory, or conventional, at 65 we might expect life expectancy in excess of 65 to have a greater impact on savings than life expectancy increases before 65. In column (1) of table 7 we add two life expectancy variables, life expectancy itself and life expectancy when it is greater or equal to 65. We find that the coefficient on life expectancy in excess of 65 is negative, though not significant. This suggest that, if anything, increasing life expectancy past 65 has less impact on the saving rate than increases when below 65. In column (2) of table 7 we repeat the estimation with fixed effects. In this case the post 65 variable has a coefficient close to zero. We also tried using a life expectancy squared term and found a similar pattern of falling impact of increasing in life expectancy as life expectancy rises.

In column (3) of table 7 we report the result of grouping life expectancy into five year intervals and estimating separately the impact of each life expectancy grouping on the savings rate. The estimated coefficients are graphed as a function of life expectancy in figure 1. We can see a pattern of savings rising rapidly with life expectancy up to about 65, but then being fairly flat. The result remains very similar when we add fixed effects in regression (4).

While these result does not contradict our theory, it is a little surprising. This result suggests that the response of savings to life expectancy may be quite complex. Life expectancy may be having an effect on savings rate, in addition to the longevity effect, though changes in uncertainty, or associated changes in morbidity. For example, if people are uncertain s to when they will die, life span, and the longest life actually achievable (rather then average lifetimes) may be more important. The results also suggest that the largest impact of increases in longevity on savings rates may occur early in the development process when life expectancy is low.

In table 8 we test the robustness of the model by adding a number of additional control variables. First of all, in regression (1), we add the interactive terms between economic growth and the dependency rates that are implies by "growth tilting." Both interactive terms are negative and significant, implying that the impact of economic growth on the savings rate is highest when there is a large working age share in the population. In column (2) of table 8 we add the log of income per capita (in purchasing power parity terms). An increase in income per capita will usually be associated with an increase in the wage rate. This will have both an income and substitution effect on the demand for leisure and the retirement age. For example, if the income effect dominates, people will want more leisure and will retire earlier and have to save more for retirement. On the other hand, if the substitution effect dominates higher wages may induce people to work for longer, reducing the need for retirement income and savings. We find that savings rise with the level of income per capita, and the estimate of the effect of life expectancy on savings, though still statistically significant, is somewhat reduced.

In column (3) we add liquid liabilities as a percentage of GDP and the rate of inflation as explanatory variables. The ratio of liquid liabilities to GDP is a measure of the relative size of the financial system and may indicate opportunities for saving. While we have not included the real interest rate, periods of high inflation may be associated with a very negative real rate of interest, and a flight from financial assets (and a reduction in the opportunity to save). However, in practice neither of these variables seems to play a significant role in determining savings behavior.

In column (2) of table 8 we added log income per capita. In column (4) we add income per capita interactively with the life cycle model. Life cycle saving is multiplied by

$$1+ b \log \frac{y}{y_{\max}} \qquad (4.2)$$

Where y is income per capita and $y_{\max}$ is the highest income per capita in the sample. The positive estimate of b suggests that life cycle saving is more important in richer country, perhaps because in poorer countries there is greater reliance of family support structures.

A serious problem with the results in table (8) is the potent for reverse causation from savings rate to the level of income and the growth rate of income. For example, in many growth studies, the savings rate is key variable that affects the pace of economic growth and the steady state level of income. Despite the fact that we measure income at the start of the five year period over which we average the savings rate, and income growth is measured over the previous ten years, there is still the problem that the savings rate may be correlated over time so that it can be correlated with lagged income, and lagged growth, purely though a reverse feedback effect. In addition, if there is a feedback from savings to income, there is also, potentially at least, a feedback from income to health, implying that higher savings may be giving rise to higher life expectancy.

To deal with this issue we use an instrumental variable approach. The results are reported in table (9). The instruments we use are latitude, percentage of land area within 100km of the coast or a major waterway, and percentage of land area in the tropics. Gallup, Sachs and Mellinger (1999) have argued that these geographical factors are major forces in determining both the level of income and the rate of growth. In addition, Bloom and Sachs (1998) argue that tropical location is a measure contributory factor in ill health and premature death. These variables are good instruments in the sense that they predict both income level and life expectancy quite well, and it is difficult to see how they could affect savings directly, rather than through their effect on income and health[1].

In column (1) of table 9 we report our simple regression but instrument the growth rate of income per capita. When we instrument the growth rate of income it changes sign, from a positive effect to a negative effect. In column (2) we instrument both the growth rate of income and the level of life expectancy. While the coefficient on growth is still negative the coefficient on life expectancy stays positive and significant. In column (3) we again instrument income growth but allow for interactive effects and "growth tilting." The results are now more in line with theory; economic growth increases the savings rate particularly when we have a large working age share in the population. In column (4) we add the level of income per capita to the regression, but instrument it (and the growth rate of income). Income per capita no longer has a significant impact on the savings rate when we instrument it. The same holds true in column (5) of table 9 where we interact the level of income with the life-cycle savings model, using the multiplier given in (4.2). Again the effect of the level of income on the savings rate is not significant when it is instrumented. These results suggest that while the effect of life expectancy on the savings rate and the growth tilting effect are robust to using instruments the effects of the level of income on saving are not robust.

Throughout the analysis we have used gross domestic savings (at local prices) as our savings measure. In table 10 we report the coefficients on life expectancy we obtain be replicating our analysis using different measures of the savings rate. In each case the regressions include income growth and the youth and old age dependency rates as well as a set of time dummies. Column (1) of table 10 reports OLS results while column (2) includes fixed effect and column (3) instruments the growth rate of income. For all for savings measures , both the OLS and instrumental variable regressions give coefficients on life expectancy that are positive and statistically significant. However, the fixed

[1] Geography might affect the marginal product of capital, and the equilibrium interest rate, and so have an effect on the savings rate. However, it seems much more likely that the stock of capital will adjust to equalize its marginal productivity across geographical zones.

effects regressions only find statistically significant results for life expectancy when we use the gross domestic saving rate at local prices and our constructed measure of gross national savings. Using gross domestic savings at world prices or the World Bank's measure of gross national savings, life expectancy losses its significance with fixed effects.

We interpret this as evidence that general favors the idea that increases in longevity raises savings rates. The failure of life expectancy when we include fixed effects could be due to the fact that while there are large differences is life expectancy across countries, all countries have experienced substantial improvements in longevity over the last 40 years. It follows that once we include fixed effects and time dummies, most of the variation in life expectancy is already accounted for.

Our model predicts a boost to saving when life expectancy increases, but this boost is temporary and is off set by a rising old age dependency rate as people age. Figure 2 shows the relationship between life expectancy and the youth and old age dependency rates in 1990. As we would expect, higher life expectancy is associated with higher old age dependency. However, it is also associated with a much lower youth dependency rate. To some extent this is the result of greater survival into older age groups, but it is also a reflection of the low fertility rates that are prevent when life expectancy is high. The model predicts a boom in savigns during the demographic transition when life expectacny rises but old age

In figure 3 we plot actual and predicted savings rates for our cross section of countries in 1990, based on the results in regression (3) of table 9. This allows for life expectancy, age structure, and growth tilting effects as well as worldwide time dummies. It does not include fixed effects, so the model has to predict the average level of the savings rate as well as how it changes over time. The model seems to perform fairly well, even without fixed effects, and picks up the outlying savings rates.

We now investigate how good the model is at picking up the time path of savings. In figure 4 we plot the actual and predicted savings rates for a number of countries, again based on regression (3) of table 9. The model seems do perform fairly well in picking up both the level and time trends of the savings rate in the high savings rate East Asia economies: Hong Kong, Japan, Thailand, South Korea, and Singapore. Rising life expectancy and falling youth dependency rates combine to give a rising predicted savings rate in Singapore and South Korea and to a lesser extent in Thailand. On the other hand, both Hong Kong and Japan saw subtantial increases in the old age dependncy rate after 1980, which stabalized predicted savings in Hong Kong and actually leads to a fall in predicted savings in Japan.

We also look at Uganda, which is interesting contrast because its life expectancy, after rising slowly, fell sharly after1980, and by 1990 was only 41. Over the same period its youth dependency rate was stable at around 50% while the number of old age dependents was negligable. As we can see our predicted savings rate also falls sharply after 1980. While actual savings follow the predicted pattern, they fall somewhat before we predict the decline to take place. For the USA, as for many developed countries, a slow rise in life expectacny and decline in youth dependency over the period is offset by rising old age dependncy, giving a fairly stable level of predicted savings. While the actual savings rate in the USA was stable over the period it was about 5 percentage points lowerthan our prediction.

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Table 1

Definitions and Sources of Savings Rate Data

Savings Rate Variable	Definition	Years Covered	Source
GDS_N	Gross domestic savings rate (in constant local currency units)	1960-97 annual	World Bank, *World Development Indicators 1999*
GDS_R	Gross domestic savings rate (in 1985 constant international dollars)	1950-92 annual	Penn World Tables, Version 5.6
GNS_I	Gross national savings rate (in constant local currency units)	1970-97 annual	World Bank, *World Development Indicators 1999*
GNS_{II}	Gross national savings rate excluding international transfer payments (in constant local currency units)	1960-97 annual	World Bank, *World Development Indicators 1999*

Table 2

Descriptive Statistics on Savings Rate Data

Savings Rate Variable (No. of countries)	Mean	Standard Deviation	Maximum	Minimum
GDS_N 68 countries 410 observations	17.6	9.45	46.8	-14.4
GDS_R 76 countries 480 observations	14.9	10.1	49.7	-14.9
GNS_I 68 countries 300 observations	18.7	8.3	60.3	-18.7
GNS_{II} 69 countries 413 observations	15.9	10.1	47.1	-15.8

Table 3

Correlation Matrix of Savings Rates

	GDS_N	GDS_R	GNS_I	GNS_{II}
GDS_N	1.0			
GDS_R	0.82	1.0		
GNS_I	0.74	0.60	1.0	
GNS_{II}	0.97	0.82	0.79	1.0

Notes:

1. Table 1 lays out the definitions and sources and coverage of the savings rate data used in this study.

2. Table 2 provides simple descriptive statistics on the different savings rate variables. The means, standard deviations, and maxima are reasonably comparable across measures.

Table 3 reports correlations between the different savings rate measures. In some cases, these correlations are significantly less than unity, suggesting that the choice of savings rate may be consequential with respect to empirical results.

Table 4

Descriptive Statistics on Selected Regressors

Variable	Mean	Standard Deviation	Maximum	Minimum
Life expectancy (in years)	62.7	11.1	79.5	22.6
Youth share (population aged 0-19 as share of total population)	0.46	0.11	0.61	0.23
Elderly share (population aged 60+ as share of total population)	0.09	0.05	0.24	0.04
Log income per capita (PPP)	7.90	1.01	9.78	5.96
Liquid liabilities as percentage of GDP	39.9	24.1	171.4	9.35
Rate of inflation (five-year average based on GDP deflator; in percent)	15.7	26.2	215.1	-2.79
Annual average growth rate of income per capita (PPP) over previous decade (in percent)	1.97	2.30	9.45	-4.16

Table 5

Effects of Longevity on Savings, OLS Estimates
(Dependent variable: gross domestic savings rate)

	Specification			
Variable	(1)	(2)	(3)	(4)
Life expectancy	0.339* (0.081)	0.348* (0.076)	0.282* (0.073)	0.365* (0.057)
Growth rate of income per capita during preceding decade	0.913* (0.198)	0.932* (0.197)	0.928* (0.199)	0.948* (0.202)
Youth share of population		-159.6* (53.63)		-80.40* (11.22)
Elderly share of population		-129.1 (124.2)		-155.1* (18.66)
Age effect: linear term		13.61 (27.56)	62.22* (21.35)	
Age effect: square term		-4.637 (3.363)	-6.489* (3.168)	
Age effect: cubic term		0.228 (0.148)	0.173 (0.129)	
Intercept	-14.09 (7.452)	58.86 (39.37)	-13.60* (6.758)	42.63* (8.743)
Country fixed effects	No	No	No	No
Time dummies	Yes	Yes	Yes	Yes
Age dummies	Yes	No	No	No
R-squared	0.539	0.534	0.521	0.526

Null hypothesis	age effects jointly zero	age effects captured by polynomial and dependency variables	dependency variables can be excluded from (2)	polynomial can be excluded from (2)
F statistic (df)	4.37* F(17,385)	0.34 F(12,385)	5.66* F(2,396)	2.17 F(3,396)

Notes: All of the estimates in this table are based on an unbalanced panel of quinquennial data for 68 countries during the years 1960 to 1994 (410 observations). Heteroskedasticity-consistent standard errors are reported in parentheses below coefficient estimates. * denotes significance at the 5 percent level for a two tail test.

Table 6

Effects of Longevity on Savings, OLS Estimates with Country Fixed Effects
(Dependent variable: gross domestic savings rate)

	Specification			
Variable	(1)	(2)	(3)	(4)
Life expectancy	0.462* (0.088)	0.455* (0.087)	0.410* (0.093)	0.459* (0.094)
Growth rate of income per capita during preceding decade	0.713* (0.130)	0.717* (0.126)	0.716* (0.125)	0.735* (0.141)
Youth share of population		-80.41* (28.38)		-89.48* (11.07)
Elderly share of population		-48.58 (59.16)		-153.0* (22.44)
Age effect: linear term		13.28 (16.45)	33.72* (14.25)	
Age effect: square term		-1.234 (2.223)	-1.409 (2.260)	
Age effect: cubic term		0.006 (0.096)	-0.049 (0.097)	
Country fixed effects	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes
Age dummies	Yes	No	No	No
R-squared	0.886	0.883	0.880	0.882

Null hypothesis	age effects are jointly zero	age effects captured by polynomial and dependency variables	dependency variables can be excluded from (2)	polynomial can be excluded from (2)
F statistic (df)	5.39* F(17,316)	0.70 F(12,316)	3.34* F(2,327)	0.80 F(3,327)

Notes: All of the estimates in this table are based on an unbalanced panel of quinquennial data for 68 countries during the years 1960 to 1994 (410 observations). Heteroskedasticity-consistent standard errors are reported in parentheses below coefficient estimates. * denotes significance at the 5 percent level for a two tail test.

Table 7

OLS Estimates of Longevity on Savings: Nonlinear Specifications
(Dependent variable: gross domestic savings rate)

	Specification			
Variable	(1)	(2)	(3)	(4)
Life expectancy	0.437* (0.073)	0.447* (0.092)		
Life expectancy, if greater than or equal to 65	-0.035 (0.020)	0.007 (0.016)		
Life expectancy 35-40			3.732 (2.579)	4.180 (4.204)
Life expectancy 40-45			10.06* (1.582)	8.217* (2.023)
Life expectancy 45-50			16.44* (1.552)	11.72* (1.274)
Life expectancy 50-55			19.38* (1.211)	11.59* (1.632)
Life expectancy 55-60			20.84* (1.176)	13.76* (1.764)
Life expectancy 60-65			19.77* (1.308)	14.17* (1.994)
Life expectancy 65-70			21.58* (1.313)	15.98* (2.317)
Life expectancy 70-75			21.52* (1.772)	16.66* (2.590)
Life expectancy 75-80			21.74* (1.958)	15.92* (2.919)
Growth rate of income per capita during preceding decade	0.942* (0.204)	0.733* (0.140)	0.946* (0.204)	0.651* (0.148)
Youth share of population	-84.76* (11.59)	-87.58* (12.52)	-95.08* (11.51)	-97.66* (13.38)
Elderly share of population	-156.6* (18.68)	-149.6* (12.52)	-155.1* (19.08)	-148.5* (27.20)
Intercept	41.62* (8.776)	--	52.97* (7.362)	--

Country fixed effects	No	Yes	No	Yes
Time dummies	Yes	Yes	Yes	Yes
R-squared	0.530	0.882	0.554	0.884

Notes: All of the estimates in this table are based on an unbalanced panel of quinquennial data for 68 countries during the years 1960 to 1994 (410 observations). Heteroskedasticity-consistent standard errors are reported in parentheses below coefficient estimates. * denotes significance at the 5 percent level for a two tail test.

Table 8

Growth Tilting, Income Effects, and Robustness Checks
(Dependent variable: gross domestic savings rate)

	Specification			
Variable	(1)	(2)	(3)	(4)
Life expectancy	0.369* (0.059)	0.192* (0.083)	0.183* (0.188)	0.349* (0.075)
Growth rate of income per capita during preceding decade	6.735* (2.027)	0.889* (0.201)	0.879* (0.229)	1.091* (0.249)
Youth share of population	-52.08* (14.19)	-71.32* (11.73)	-69.85* (13.88)	-84.47* (12.71)
Elderly share of population	-90.14* (25.99)	-159.5* (18.69)	-159.9* (21.74)	-178.3* (21.11)
Youth share x Income growth	-8.768* (3.320)			
Elderly share x Income growth	-20.79* (7.050)			
Log GDP per capita (PPP)		3.158* (0.955)	3.354* (1.025)	
Liquid liabilities as a percent of GDP			0.008 (0.030)	
Rate of inflation			0.971 (1.183)	
Beta (effect of income on the strength of the life cycle model)				0.085* (0.034)
Intercept	23.49* (10.69)	24.98* (10.13)	22.97* (11.29)	50.03* (10.51)
R-squared	0.534	0.541	0.527	0.530

Notes: All of the estimates in this table are based on an unbalanced panel of quinquennial data for 68 countries during the years 1960 to 1994 (410 observations), exept for column (3) which is based on 66 countries during 1965-94 (365 observations). Heteroskedasticity-consistent standard errors are reported in parentheses below coefficient estimates. * denotes significance at the 5 percent level for a two tail test. Beta is the coefficient in the interaction term (1 + Beta log(GDP/max(GDP)) that is multiplied by the rest of the reported model.

Table 9

The Effect of Longevity on Savings: Instrumental Variables Estimates
(Dependent variable: gross domestic savings rate)

	Specification (Variables Instrumented)				
Variables	(1) (Income growth)	(2) (Income growth, life expectancy)	(3) (Income growth)	(4) (Income growth, income level)	(5) (Income growth, income level)
Life expectancy	0.598* (0.076)	0.460* (0.126)	0.637* (0.091)	1.058* (0.426)	0.631* (0.175)
Growth rate of income per capita during preceding decade	-1.405* (0.563)	-1.283* (0.544)	12.49* (3.752)	-1.594* (0.692)	-1.458* (0.630)
Youth share of population	-111.6* (15.83)	-119.5* (16.43)	-38.43 (23.97)	-138.5* (32.74)	-114.8* (20.91)
Elderly share of population	-223.9* (29.03)	-219.5* (28.51)	-82.89 (44.99)	-222.8* (33.57)	-237.7* (73.15)
Youth share x Income growth			-22.32* (6.57)		
Elderly share x Income growth			-42.75* (13.34)		
Log GDP per capita (PPP)				-7.804 (7.065)	
Beta (effect of income on the strength of the life cycle model)					0.039 (0.194)
Intercept	49.26* (10.76)	61.23* (13.80)	-0.106 (18.18)	93.80* (44.04)	50.76* (13.43)
R-squared	0.349	0.349	0.338	0.229	0.360

Notes: All of the estimates in this table are based on an unbalanced panel of quinquennial data for 68 countries during the years 1960 to 1994 (410 observations), exept for column (3) which is based on 66 countries during 1965-94 (365 observations). Heteroskedasticity-consistent standard errors are reported in parentheses below coefficient estimates. * denotes significance at the 5 percent level for a two tail test. Beta is the coefficient in the interaction term (1 + Beta log(GDP/max(GDP)) that is multiplied by the rest of the reported model.

Instruments: Latitude, land area within 100km of the coast or major waterway, percent of land area in the tropics.

Table 10

Effects of Longevity on Alternative Savings Rate Measures,
OLS Estimates With and Without Country Fixed Effects, and IV Estimates

	Coefficient of Life Expectancy		
Savings Rate	OLS	Fixed Effects	IV (income growth instrumented)
GDS_N (68 countries, 410 observations)	0.365* (0.057)	0.459* (0.094)	0.631* (0.175)
GDS_R (75 countries, 430 observations)	0.284* (0.052)	0.098 (0.086)	0.317* (0.064)
GNS_I (68 countries, 300 observations)	0.176* (0.065)	0.077 (0.111)	0.159* (0.070)
GNS_{II} (68 countries, 408 observations)	0.354* (0.056)	0.441* (0.106)	0.554* (0.077)

Notes: All of the estimates are based on unbalanced panels of quinquennial data, as described in the notes to Table 1. The specifications include income growth, youth and elderly age shares, and time dummies. Heteroskedasticity-consistent standard errors are reported in parentheses below coefficient estimates. * denotes significance at the 5 percent level for a two tail test.