Scand. J. of Economics 105(3), 319–338, 2003

Longevity and Life-cycle Savings*

David E. Bloom

Harvard School of Public Health, Boston, MA 02115, USA
dbloom@hsph.harvard.edu

David Canning

Harvard School of Public Health, Boston, MA 02115, USA
dcanning@hsph.harvard.edu

Bryan Graham

Harvard University, Cambridge, MA 02138, USA
bgraham@fas.harvard.edu

Abstract

We add health and longevity to a standard model of life-cycle saving and show that, under plausible assumptions, increases in life expectancy lead to higher savings rates at every age, even when retirement is endogenous. In a stationary population these higher savings rates are offset by increased old age dependency, but during the disequilibrium phase, when longevity is rising, the effect on aggregate savings rates can be substantial. We find empirical support for this effect using a cross-country panel of national savings rates.

Keywords: Life expectancy; health; national savings

JEL classification: *E*21; *I*12

I. Introduction

The savings rate 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 over time within countries, often dramatically. The benchmark model for explaining these differences has been the life-cycle model of savings.

*We would like to thank Angus Deaton, Allen Kelley, Andrew Mason and Larry Rosenberg for helpful discussions and comments. An early version of this paper was presented at meetings of the World Health Organization's Commission on Macroeconomics and Health (Working Group One) and at a conference on demography and economic performance held at the Harvard University Center for Population and Development Studies. Financial support was provided from the Economic Advisory Service of the World Health Organization.

According to the life-cycle model of savings, people save when young 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, so that in a stationary population (with a stable age distribution and no population growth) there is no aggregate saving. However, if the age structure of the population is unbalanced, as occurs under population growth, or if the economy is undergoing rapid economic growth and the wage incomes of the young are high relative to the retirement incomes of the old, the savings of different cohorts may not cancel out, and aggregate savings, or dissavings, may occur; see e.g. Ando and Modigliani (1963). In addition, Fry and Mason (1982) and Mason (1981, 1987, 1988) point out that the presence of children increases the consumption requirements of young families, so that high rates of youth dependency can depress saving and lower the impact of economic growth on savings rates. Investigators have studied these age-structure and growth effects extensively and have found that, in general, national savings rates are higher when dependency rates are low and economic growth is rapid; see e.g. Higgins (1998), Higgins and Williamson (1997), Kelley and Schmidt (1996), Leff (1969) and Masson, Bayoumi and Samiei (1998).

While the empirical evidence tends to support the main predictions of the life-cycle theory, a number of puzzles remain, in particular 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 the age structure of the population, and in the distribution of income between cohorts, account for only a small part of this upswing in saving. Household data from East Asia indicate that the major factor driving the surge was an increase in the rate of saving at every age; see Deaton (1992) for Thailand and Deaton and Paxson (1994, 1997, 2000) for the case of Taiwan. Such across-the-board savings surges cannot be reconciled with standard life-cycle theory.

Recently Lee, Mason and Miller (1998, 2000) have suggested that the reason for this surge in savings was the rapidly improving 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 both theoretically and empirically whether changes in longevity play an important role in determining national savings. We begin by examining the role of longevity in a dynamic optimization model of life-cycle savings. We take decisions to participate in the labor market to be endogenous, allowing agents to choose their retirement age. Under the assumption that consumption and leisure are normal goods, so that the demand for both rises when wealth increases, we show that a rise in life expectancy increases the optimal length 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 general health improvements that may increase the productivity and wages of the elderly, giving an incentive to postpone retirement. For example, Fogel (1994, 1997) argues that not only has life expectancy increased, but disability among the aged has also declined dramatically in the United States 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 of health in general that proxies for both 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 life expectancy 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 been used on occasion and found to have a positive effect; see, for example, Asian Development Bank (1997) and Doshi (1994). Skinner (1985), however, argues that increasing longevity may have depressed the savings rate in the United States.

Our results agree with the ideas put forward by Lee *et al.* (2000), namely that increases in life expectancy play a large role in savings behavior and, in particular, explain the observed surge in savings in East Asia. They also complement the results of Tsai, Chu and Chung (2000) and Hurd, McFadden and Gan (1998) who find evidence in household data that increased prospective longevity leads to higher saving rates.

While increases in longevity may increase the savings rate at every age, the effect on aggregate savings is transitory. Increases in longevity imply that a stationary population has an age structure with a higher proportion of elderly, so that in the long run higher age-specific saving rates are offset by greater numbers of elderly who are dissaving (note that this balancing effect may take 50 years, or more, to come about). The effects of increases in life expectancy in East Asia on saving may be great, but our theory suggests that they will dissipate as the population ages.

II. Theory

We assume that agents maximize their utility over their lifetimes, choosing how much to work and how much to consume, and investigate how changing life expectancy affects their choice. Bils and Klenow (2000), Kalemli-Ozcan, Ryder and Weil (2000), and Meltzer (1995) model how life expectancy affects investments in education. We use a similar approach to model how life expectancy affects saving and, following Bils and Klenow (2000) and Meltzer (1995), 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 to spending on health care; see, for instance, Ehrlich and Chuma (1990) and Philipson and Becker (1998). We also ignore any effects of uncertainty about the timing of death, effects that may be important for saving behavior; see, for example, Leung (1994) and Kalemli-Ozcan and Weil (2002). In addition, we assume that each agent maximizes his individual utility over his lifetime, ignoring the effects of family structure on consumption and saving, effects that can be important since changes to longevity can change fertility behavior, child survival rates and the pattern of household living arrangements. Mason (1981, 1987, 1988), for example, analyses a model of household consumption where the number of children in the household affects the consumption decision. We also ignore the possibility of a bequest motive in saving, a motive that may have important effects on how saving varies with longevity saving; see Skinner (1985).

We assume that agents seek to maximize lifetime utility given by

$$\int_0^T e^{-\delta t} U(c_t, l_t, h_t) dt, \tag{1}$$

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

$$c_t \geqslant 0, \quad 1 \geqslant l_t \geqslant 0, \quad W_T \geqslant 0, \tag{2}$$

where the stock of wealth, W_t, evolves according to

$$\frac{dW_t}{dt} = rW_t + (1 - l_t)w_t - c_t. \tag{3}$$

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 (3) gives the savings (the addition to wealth) of the agent.

Assuming that the instantaneous utility function U is increasing and strictly concave in each argument, it is straightforward to show, by forming the Hamiltonian and applying the maximum principle as in for example, Berck and Sydæter (1992), that the optimal path of consumption and leisure satisfies

$$\frac{dc}{dt} = \frac{(r-\delta)\frac{dU}{dc} + \frac{d^2U}{dcdl}\frac{dl}{dt} + \frac{d^2U}{dcdh}\frac{dh}{dt}}{-\frac{d^2U}{dc^2}} \tag{4}$$

and

$$\frac{dU}{dl_t} = w_t\frac{dU}{dc_t}\text{if} 1 < l < 0, \quad \frac{dU}{dl_t} \geqslant w_t\frac{dU}{dc_t}\text{if} l = 1, \quad \frac{dU}{dl_t} \leqslant w_t\frac{dU}{dc_t}\text{if} l = 0. \tag{5}$$

Agents work up to the point where their 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 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^*.

The declining marginal utility of consumption means that the bottom line of equation (4) is positive. The time path of consumption depends on the rate of time preference and the complementarity of consumption with leisure and health. Consumption will tend to rise over time if the interest rate exceeds the rate of time preference.

We make two assumptions. The first (assumption 1) is that, given initial wealth holdings of zero at the start of life, the optimal path (for any T) has $W_t^* \geqslant 0$ for all $0 \leqslant t \leqslant T$. This implies that people never go into debt to finance consumption; they save initially to build up wealth and then run this wealth down. 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, work and earnings will be concentrated in the early part of life. Provided r is large enough, so that consumption is level or skewed toward the end of life, the 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) that both consumption and leisure are normal goods, that is,

$$\frac{dc_t^*}{dW_0} \geqslant 0, \frac{dl_t^*}{dW_0} \geqslant 0, \quad \text{for all } 0 \leqslant t \leqslant T. \tag{6}$$

We assume that an increase in initial wealth increases consumption and leisure at all times. 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

$$s_t = \frac{y_t - c_t}{y_t}, \quad \text{where } y_t = rW_t + (1 - l_t)w_t. \tag{7}$$

Our proposition is: let $W_0 = 0$. Under assumptions 1 and 2, an increase in longevity increases the savings rate at every age.

Our proof goes as follows. 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, $W_T^{**} \geqslant 0$. Now let us keep behavior after T fixed and restrict our attention to the time interval [0, T]. As the new optimal plan cannot be improved upon, it maximizes

$$\int_0^T e^{-\delta t} U(c_t, l_t, h_t) dt \tag{8}$$

subject to

$$c_t \geqslant 0, \quad 1 \geqslant l_t \geqslant 0, \quad W_T \geqslant W_T^{**}. \tag{9}$$

However, this is the same problem, and has the same solution, as maximizing over [0, T] subject to

$$c_t \geqslant 0, \quad 1 \geqslant l_t \geqslant 0, \quad W_T \geqslant 0, \tag{10}$$

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 $c_t^{**} \leqslant c_t^*, l_t^{**} \leqslant l_t^*$. Using equation (7) it is easy to show that the savings rate is increasing in y and decreasing in c, and it follows immediately that $s_0^{**} \geqslant s_0^*$. At each point in time, wage income under the new plan is higher than before and consumption is lower. By equation (3), wealth accumulates more quickly under the new plan and, as time passes, interest payments on the rising stock of wealth compound this effect. It follows that at every point in time income under the new plan is higher, and consumption is lower, giving a higher savings rate.[1]

[1]It is clear that our assumption that agents have positive net asset holdings at every age is stricter than necessary. All we actually require is that when life expectancy rises from T to T' the wealth holdings at time T are positive. This allows for the possibility that agents may borrow to finance consumption when young.

The rise in savings rates at every age is consistent with the evidence on household consumption in Taiwan and Thailand, where the boom in savings was caused by an upward shift of the entire age-specific savings rate schedule.

The proposition deals with a pure increase in longevity, with no improvement 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 that productivity and health status stay higher longer, and we have $w'_{\lambda t} = w_t, h'_{\lambda t} = h_t$. With these proportional health and longevity improvements, agents maximize

$$\int_0^{T'} e^{-\delta t} U(c_t, l_t, h'_t) dt \tag{11}$$

subject to

$$c_t \geqslant 0, \quad 1 \geqslant l_t \geqslant 0, \quad W_{T'} \geqslant 0, \quad \frac{dW_t}{dt} = rW_t + (1 - l_t)w'_t - c_t. \tag{12}$$

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

$$\lambda \int_0^{T} e^{-\lambda\delta z} U(c_z, l_z, h_z) dz \tag{13}$$

subject to

$$c_z \geqslant 0, \quad 1 \geqslant l_z \geq 0, \quad K_T \geqslant 0, \quad \frac{dK_z}{dz} = \lambda r K_z + (1 - l_z)w_z - c_z. \tag{14}$$

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, and 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 combined effect of increasing longevity and improving health is that agents extend their working lives proportionately and save at exactly the same rate as before. Note, however, that in equations (13) and (14) this proportionality result 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.

The longer horizon provides more time for the benefits of compound interest to become apparent, and is formally equivalent to an equal increase in the rate of interest and rate of time preference in the original model. This will tend to increase the planned growth rate of consumption (and increase the savings of the young) if the interest rate exceeds the rate of time preference (which is the case if an individual's optimal consumption increases over time). More generally, an improvement in longevity may be associated with a greater or less than proportional improvement in health status at each age. Our simple theory suggests that the pure effect of greater longevity is to increase savings rates, but that if increased longevity is associated with much better health when old and, in particular, with higher productivity and lower disutility of work than before, the effect is ambiguous.

In practice, our simple life-cycle theory of saving faces many challenges. In addition to the need to smooth consumption over the life cycle, many other factors also affect the savings decision. Credit constraints may mean that borrowing and aggregate savings rates depend on the level of income. Habit formation in relation to consumption may boost savings during periods of rapid income growth. Institutional arrangements in many countries mandate retirement between the ages of 60 and 65. These may mean that increases in longevity lead to increases in savings rates, even if health also improves; see Lee and Tuljapurkar (1997). Mandatory pay-as-you-go pension schemes imply that consumption during retirement may be financed by transfers from the young, reducing the need for life-cycle savings. Savings rates may also depend on the availability of financial markets and may be influenced by the likelihood of inflation, which could erode the value of financial assets. To attempt 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. Zhang, Zhang and Lee (2003) examine a more complex theoretical model of how longevity can affect savings and growth, allowing for unplanned bequests and the effect of changing age structure on the median voter and public policies on education, which emphasizes just how partial a view our model represents.

Perhaps the greatest worry is that actual savings decisions are made by households, not individuals, and that longevity and demographic effects operate through changes to family structure rather than individual consumption smoothing. In developing countries with large families the elderly may rely more on intra-household transfers and less on savings as a method of old age support, while the presence of large numbers of children in the household can increase current consumption needs and reduce saving. Reductions in mortality can affect the number of surviving children in the household, and the incentives to bear children, as well as the burden of taking care of elderly relatives. In our theoretical model we ignore these effects, though in practice our estimation of the longevity effect cannot identify which mechanism is operating.

Our theory so far refers only to the individual. There are enormous difficulties in aggregating over individuals to find aggregate savings. Kelley and Schmidt (1996) discuss aggregation issues and the variables that different theories of life-cycle savings suggest should be important, along with their predicted signs. These are the age structure of the population and the expected rate of income growth, along with interactions between the two. In our empirical work we include these variables along with life expectancy, as well as with a number of other variables to try to capture alternative, non-life-cycle, effects.

III. Data

We measure the savings rate using the gross domestic savings rate (measured as total savings divided by gross domestic income) from the *World Development Indicators 1999* of the (World Bank (1999), which includes annual data from 1960 to 1997 for a large cross-section of countries. This measure is not ideal. We take it as an approximation to the true savings rate, which would adjust for foreign income and transfer payments, depreciation of capital and depletion of natural resources, and capital gains, and would allow for the separation of household saving from the savings of government and corporations.[2] Savings are quite volatile from year to year; we follow Higgins (1998) and average over successive five-year intervals to smooth out business-cycle effects.

In our analysis we excluded socialist countries because their savings and investment are controlled almost entirely by the public sector; we have no reason to expect their savings behavior to fit the optimizing life-cycle model. We also excluded countries with populations of less than 1 million, and major oil producers (with a value of oil production in excess of 2.5 percent of GDP) because we do not take account of the extremely large capital gains and losses caused by changes in oil prices that dominate the economies of these countries. We selected countries that have complete data for at least the period 1975–1994, so that we have at least 20 years (and at most 35 years) of data for each country. A list of the 68 countries in the sample and the data set we used is available on request.

[2]Bloom, Canning and Graham (2002) report similar results to those found here using gross national savings rates, but using national savings reduces the size of the data set quite considerably.

We take demographic data on life expectancy and age structure from the United Nations (1998). Real income per capita and the GDP deflator are from *Penn World Tables (5.6)*; see Summers and Heston (1991) for a description of this data set. The ratio of liquid liabilities to GDP is from International Economic Data Base (1997).

IV. Explaining Aggregate Savings

Table 1 reports simple regressions where we explain the gross domestic savings rate averaged over a five-year period, using economic growth for the previous 10 years, and life expectancy and some age structure variables measured at the beginning of the period. Our theoretical model in Section II also suggests that the real interest rate should play a role. However, in common with most empirical work, we find little effect of interest rates on savings; see, for example, Higgins (1998). So for the sake of simplicity we exclude it.

Column (1) of Table 1 reports a regression that includes life expectancy, the growth rate of income and 17 population age groups (by five-year intervals from zero to 84). Note that in column (1) we do not report the individual cohort effects. Both life expectancy and economic growth appear to have positive and statistically significant effects on the average savings rate. While we do not report the individual cohort effects, we can reject the hypothesis that they are all zero (F-statistic 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. Kelley and Schmidt (1996) and Leff (1969) use young and old age dependency rates to model age structure, while Higgins (1998) allows the size of each five-year age cohort to have an effect, although he constrains these effects to lie on a low-order polynomial for estimation purposes.

In column (2) we estimate a restricted model, where the coefficients on age structure are constrained to lie on a cubic equation (that is, the coefficient on the population share of cohort i, ϕ_i say, can be written as $\phi_i = \alpha_0 + \alpha_1 i + \alpha_2 i^2 + \alpha_3 i^3$) 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.

A test of the restrictions implied on the age structure effects when using the cubic functional form plus the dependency rate approach does not reject these restrictions (the F-statistic is reported at the bottom of column (2)). It

Table 1. *Effects of longevity on savings, OLS estimates (dependent variable: gross domestic savings rate)*

Variable	Specification (1) Dummies for each age group	(2) Polynomial age and dependency rate effects	(3) Polynomial age effects	(4) Dependency rate effects
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 $F(3, 396)$

*Denotes significance at the 5 percent level for a two-tail test.

Note: All the estimates in this table are based on an unbalanced panel of quinquennial data for 68 countries during 1960–1994 (410 observations). Heteroskedasticity-consistent standard errors are reported in parentheses below coefficient estimates.

follows that we can reduce the number of age-effect parameters to be estimated.

We can go further and test whether both the cubic functional form and the dependency rate step function are required. Column (3) reports a model where the age-structure effects are modeled as lying on a cubic function alone. Now both the linear and squared terms 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 of the hypothesis that the dependency rate parameters are jointly zero (bottom of column (3)) is rejected. Thus the combined model appears to fit the data better than the cubic function alone.

In column (4) we estimate the relationship allowing only the dependency-rate effects of age structure. The presence of large proportions of elderly or young people in the population is found to depress the savings rate. Now, however, we cannot reject the exclusion of the cubic-age effects (F-statistic at the bottom of column (4)). Thus the age-structure effects can be modeled adequately by the effects of dependency rates, and we do not require polynomial age-structure effects.

Table 2 repeats the analysis carried out in Table 1, but adds fixed effects to capture any country-specific effects that may affect savings rates. Despite the addition of fixed effects, the results in Table 2 are remarkably similar to those in Table 1. Life expectancy again has a positive and significant effect, with a 10-year increase in longevity 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 1. The data accept 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.

In Table 3 we test the robustness of the model by adding a number of additional control variables. One possible complication is that the effect of economic growth and age structure on savings behavior may be interactive. Economic growth increases the relative incomes of the young, thereby increasing not only average savings but also the effect of a large young cohort. This leads to "growth-tilting" (a tilt in the relationship between population age shares and overall savings rates) so that the impact of a large working-age cohort on savings is larger in a fast-growing economy. Mason (1981, 1987, 1988) suggests that, in addition, a large cohort of children increases the propensity to consume of their parents, reducing the impact of economic growth on savings. In regression (1) we added the interactive terms between economic growth and the dependency rates to test for growth tilting. Both interactive terms are negative and significant, implying that, as predicted, the impact of economic growth on the savings

Table 2. *Effects of longevity on savings, OLS estimates with country-fixed affects (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 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)

*Denotes significance at the 5 percent level for a two-tail test.

Note: All the estimates in this table are based on an unbalanced panel of quinquennial data for 68 countries during 1960–1994 (410 observations). Heteroskedasticity-consistent standard errors are reported in parentheses below coefficient estimates.

Table 3. *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 × income growth	−8.768* (3.320)			
Elderly share × income growth	−20.79* (7.050)			
Log GDP per capita (PPP)		3.158* (0.955)	3.354* (1.025)	
Liquid liabilities as a percentage 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

*Denotes significance at the 5 percent level for a two-tail test.

Note: All the estimates in this table are based on an unbalanced panel of quinquennial data for 68 countries during 1960–1994 (410 observations) except for column (3), which is based on 66 countries during 1965–1994 (365 observations). Heteroskedasticity-consistent standard errors are reported in parentheses below coefficient estimates. Beta is the coefficient in the interaction term (1 + Beta log(GDP/max(GDP))) that is multiplied by the rest of the reported model. PPP: Purchasing power parity.

rate is highest when a large share of the population is of working age. In column (2) of Table 3 we added the log of income per capita (in purchasing power parity terms). Countries with high income per capita will usually have high wage rates. High wages have both an income and a substitution effect on labor supply decisions and the retirement age. For example, if the income effect dominates, people will want more leisure, will retire earlier and have to save more for retirement. By contrast, if the substitution effect dominates, higher wages may induce people to work longer, thereby 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 added 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 tend to be associated with a highly negative real rate of interest and a flight from financial assets. However, in practice neither of these variables seems to play a significant role in determining savings behavior.

Whereas in column (2) of Table 3 we added log income per capita, in column (4) we added income per capita interactively with the life-cycle model. This allows for the idea that the importance of life-cycle savings depends on the level of development, proxied by a country's income level. Life-cycle saving is multiplied by

$$1 + \beta \log \frac{y}{y_{\max}}, \tag{15}$$

where y is income per capita and $y_{\max}$ is the highest income per capita in the sample. The positive estimate of β suggests that life-cycle saving is more important in richer countries, likely because in poorer countries people rely more heavily on family support structures.

A serious problem with the results in Table 3 is the potential for reverse causation from the savings rate to the level of income and the growth rate of income. For example, in many growth studies, the savings rate is the key variable that affects the pace of economic growth and the steady-state level of income. Even though we measure income at the start of the five-year period over which we average the savings rate and measure income growth over the previous 10 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 through a feedback effect. In addition to a feedback from savings to income, there is potentially a feedback from income to health, implying that higher savings may give rise to higher life expectancy.

To deal with this issue we used an instrumental variable approach, treating income levels and growth rates, as well as life expectancy, as potentially endogenous. The results are reported in Table 4. The instruments we use are latitude, percentage of land area within 100 kilometers of the coast or a major waterway, and percentage of land area in the tropics. Gallup, Sachs and Mellinger (1999) argue 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 major 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 effects on income and health.

In column (1) of Table 4 we report our simple regression, but instrument the growth rate of income per capita. When we instrument the growth rate of income, its coefficient 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 a large share of the population is of working age. In column (4) we added 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 4 where we interact the level of income with the life-cycle savings model, using the formula given in equation (15). Once 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 effects 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.

The model predicts the pattern of savings rates across countries, and the time series of savings rates within countries, quite well. For example, it tracks the Japanese savings rate, predicting both the rise to peak savings in 1970–1974 as life expectancy increased and youth dependency fell and the decline in savings after 1974 as the effect of growing old-age dependency came to dominate; see Bloom *et al.* (2002) for further details of the predictions of the model.

V. Conclusion

Improvements in health and longevity are likely to have large impacts on life-cycle behavior as people look forward to longer, healthier lives. In relation to savings behavior, a key issue is how improvements in health and longevity affect the length of working life. Increases in longevity alone

Table 4. *Effect of longevity on savings: instrumental variables estimates (dependent variable: gross domestic savings rate)*

Variable	Specification (Variables instrumented)				
	(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 × income growth			−22.32* (6.57)		
Elderly share × 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

*Denotes significance at the 5 percent level for a two-tail test.

Note: All the estimates in this table are based on an unbalanced panel of quinquennial data for 68 countries during 1960–1994 (410 observations) except for column (3), which is based on 66 countries during 1965–1994 (365 observations). Heteroskedasticity-consistent standard errors are reported in parentheses below coefficient estimates. Beta is the coefficient in the interaction term (1 + Beta log(GDP/max(GDP))) in equation (15) that is multiplied by the rest of the reported model. Instrumental variables: Latitude, land area within 100 km of the coast or major waterway, percent of land area in the tropics. PPP: Purchasing power parity.

tend to increase the relative length of retirement, thereby raising the need for retirement income and generating higher savings rates among the young. Improvements in health, however, lead to a more ambiguous effect on savings, because they can give rise to longer working lives and postponed retirement.

Empirically, the dominant effect of increased life expectancy appears to be higher savings rates. In terms of our model, the savings effect occurs because the effect of increased longevity on retirement income outweighs the effect of improved health on the length of desired working life, thereby increasing the need for retirement income. Our model predicts a boost to savings when life expectancy increases, but this boost is temporary and is subsequently offset by a rising old-age dependency rate as people age. The life-cycle model predicts that when the age structure reaches equilibrium, net savings should be zero.

In practice, savings are likely to be strongly influenced by institutional arrangements, such as legislation on retirement age and social security provisions. A more complete model would study how these institutional factors affect savings behavior.

References

Ando, A. and Modigliani, F. (1963), The "Life Cycle" Hypothesis of Saving: Aggregate Implications and Tests, *American Economic Review 53*, 55–84.

Asian Development Bank (1997), *Emerging Asia*, Asian Development Bank, Manila.

Berck, P. and Sydæter, K. (1992), Economists' Mathematical Manual, 2nd ed., Springer-Verlag, Berlin.

Bils, M. and Klenow, P. (2000), Does Schooling Cause Growth?, *American Economic Review 90*, 1160–1183.

Bloom, D. E. and Sachs, J. (1998), Geography, Demography, and Economic Growth in Africa, *Brookings Papers on Economic Activity 2*, 207–273.

Bloom, D. E., Canning, D. and Graham B. (2002), Longevity and Life Cycle Savings, NBER Working Paper no. 8808.

Deaton, A. (1992), *Understanding Consumption*, Oxford University Press, Oxford.

Deaton, A. and Paxson, C. H. (1994), Savings, Growth, and Aging in Taiwan, in D. Wise (ed.), *Studies in the Economics of Aging*, NBER and University of Chicago Press, Chicago.

Deaton, A. and Paxson, C. H. (1997), The Effects of Economic and Population Growth on National Savings and Inequality, *Demography 34*, 97–114.

Deaton, A. and Paxson, C. H. (2000), Growth, Demographic Structure, and National Savings in Taiwan, *Population and Development Review 26* (*Supplement*), 141–173.

Doshi, K. (1994), Determinants of the Saving Rate—An International Comparison, *Contemporary Economic Policy 12*, 37–45.

Ehrlich, I. and Chuma, H. (1990), A Model of the Demand for Longevity and the Value of Life Extension, *Journal of Political Economy 98*, 761–782.

Fogel, R. W. (1994), Economic Growth, Population Theory, and Physiology: The Bearing of Long-term Processes on the Making of Economic Policy, *American Economic Review 84*, 369–395.

Fogel, R. W. (1997), New Findings on Secular Trends in Nutrition and Mortality: Some Implications for Population Theory, in M. Rosenzweig and O. Stark (eds.), *Handbook of Population and Family Economics*, Vol. 1A, Elsevier, Amsterdam.

Fry, M. and Mason, A. (1982), The Variable Rate of Growth Effect in the Life-cycle Model, *Economic Inquiry 20*, 426–442.

Gallup, J. L., Sachs, J. D. and Mellinger, A. (1999), Geography and Economic Development, *International Regional Science Review 22*, 179–232.

Higgins, M. (1998), Demography, National Savings, and International Capital Flows, *International Economic Review 39*, 343–369.

Higgins, M. and Williamson, J. (1997), Age Structure Dynamics in Asia and Dependence on Foreign Capital, *Population and Development Review 23*, 261–293.

Hurd, M., McFadden, D. and Gan L. (1998), Subjective Survival Curves and Life-cycle Behavior, in D. Wise (ed.),*Inquiries in the Economics of Aging*, University of Chicago Press, Chicago.

International Economic Data Base (1997), available online at the Australian National University (http://iedb.anu.edu.au/).

Kalemli-Ozcan, S. and Weil, D. N. (2002), Mortality Change, the Uncertainty Effect, and Retirement, NBER Working Paper no. 8742.

Kalemli-Ozcan, S., Ryder, H. and Weil, D. N. (2000), Mortality Decline, Human Capital Investment, and Economic Growth, *Journal of Development Economics 62*, 1–23.

Kelley, A. C. and Schmidt, R. M. (1996), Saving, Dependency, and Development, *Journal of Population Economics 9*, 365–386.

Lee, R. D. and Tuljapurkar, S. (1997), Death and Taxes: Longer Life, Consumption, and Social Security, *Demography 34*, 67–81.

Lee, R. D., Mason, A. and Miller, T. (1998), Saving, Wealth, and Population, Mimeo, University of California, Berkeley.

Lee, R. D., Mason, A. and Miller, T. (2000), Life Cycle Saving and the Demographic Transition: The Case of Taiwan, *Population and Development Review 26* (*Supplement*), 194–219.

Leff, N. H. (1969), Dependency Rates and Savings Rates, *American Economic Review 59*, 886–896.

Leung, S. F. (1994), Uncertain Lifetime, the Theory of the Consumer, and the Life Cycle Hypothesis, *Econometrica 62*, 1233–1239.

Mason, A. (1981), An Extension of the Life-Cycle Model and its Application to Population Growth and Aggregate Saving, Working Paper no. 4, East-West Center, Honolulu, HI.

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*, University of Wisconsin Press, Madison.

Mason, A. (1988), Saving, Economic Growth, and Demographic Change, *Population and Development Review 14*, 113–144.

Masson, P. R., Bayoumi, T. and Samiei, H. (1998), International Evidence on the Determinants of Private Saving, *World Bank Economic Review 12*, 483–501.

Meltzer, D. (1995), Mortality Decline, the Demographic Transition, and Economic Growth, Ph.D. dissertation, University of Chicago.

Philipson, T. J. and Becker, G. S. (1998), Old-age Longevity and Mortality Contingent Claims, *Journal of Political Economy 106*, 551–573.

Skinner, J. (1985), The Effect of Increased Longevity on Capital Accumulation, *American Economic Review 75*, 1143–1150.

Summers, R. and Heston, A. (1991), The Penn World Tables (Mark 5): An Expanded Set of International Comparisons, 1950–1988, *Quarterly Journal of Economics 106*, 327–368.

Tsai, I.-J., Chu, C. Y. C. and Chung, C.-F. (2000), Demographic Transition and Household Saving in Taiwan, *Population and Development Review 26* (*Supplement*), 174–193.

United Nations (1998), *Demographic Indicators 1950–2050*, New York.

World Bank (1999), *World Development Indicators 1999*, Washington, DC.

Zhang, J., Zhang, J. and Lee, R. D. (2003), Rising Longevity, Education, Savings and Growth, *Journal of Development Economics 70*, 83–101.