THE EFFECTS OF ECONOMIC AND POPULATION GROWTH ON NATIONAL SAVING AND INEQUALITY*

ANGUS S. DEATON AND CHRISTINA H. PAXSON

This is a progress report on ongoing research into the effects of economic and population growth on national saving rates and inequality. The theoretical basis for the investigation is the life cycle model of saving and inequality. We report evidence that is conditional on the validity of the model, as well as evidence that casts doubt on it. Using time series of cross-sectional household surveys from Taiwan, Thailand, Britain, and the United States, we show that it is possible to force a life cycle interpretation on the data on consumption, income, and saving, but that the evidence is not consistent with large rate-of-growth effects, whereby economic and population growth enhances rates of national saving. The well-established cross-country link between economic growth and saving cannot be attributed to life cycle saving, nor will changes in economic or population growth exert large effects on saving within individual countries. There is evidence in favor of the life cycle model's prediction that within-cohort inequality of consumption and of total income—though not necessarily inequality of earnings—should increase with the age of the cohort. Decreases in the population growth rate redistribute population toward older, more unequal, cohorts, and can increase national inequality. We provide calculations on the magnitude of these effects.

One of the most celebrated predictions of the life cycle theory of saving is that the ratio of national saving to national income depends positively on the rates of both population growth and per capita real income growth. People save for retirement, so saving is positive for the young and negative for the old. Economic growth redistributes resources in favor of the young and population growth increases their relative numbers; increases in either favor saving over dissaving. Simple versions of this story generate large effects. For example, in the simple "stripped-down" model outlined below, a 1% increase in the rate of growth of total income—through growth in either population or income per head—increases saving rates by about two percentage points, and there is evidence from the cross-section of countries—at least on the relationship between saving and per capita income growth—that is consistent with such magnitudes (Modigliani 1970, 1986, 1990, and for an overview, Deaton 1992: chap. 2). Our recent theoretical and empirical work (Deaton and Paxson 1994a, 1995) posits a related life cycle mechanism linking population growth to consumption and income inequality. The life cycle theory of saving in the presence of uncertainty implies that inequality will increase over time among a fixed group of individuals. Thus inequality among a birth cohort should increase over time as the cohort ages; and our empirical work indicates that this is indeed the case. Population aging redistributes people toward older and more unequal cohorts, and therefore contributes to greater national inequality. Like the effects of population growth on saving, the effects are potentially large: For example, the Gini coefficient for household consumption in Britain rises from 0.210 among households with heads aged 25 to 0.406 among households with heads aged 55 (Deaton and Paxson 1994a).

The effects of population and income growth on saving and inequality are currently matters of considerable concern—particularly in East and Southeast Asia, where there is a group of economies (e.g., Hong Kong, Indonesia, Korea, Malaysia, Singapore, Taiwan, and Thailand), which in recent years has combined rapid growth of income per head with historically high national saving rates. In several cases, these economies also are distinguished by their relatively equal distribution of resources. The populations of these countries are expected to age rapidly in the next two decades as a consequence of the demographic transition, increases in life expectancy, and the aging of postwar baby booms (see U.S. Department of Commerce 1993). If the life cycle models are correct, this redistribution of the population from young to old may lower saving rates. Although the causality between saving and economic growth is unclear, many would see such declines in saving rates as a threat to economic growth and future prosperity. At the same time, population aging is likely to increase inequality. Whereas this largely mechanical effect offers no direct threat to welfare, it is important that it be understood if only to avoid the imposition of unnecessary policies designed to correct it.

The empirical and theoretical investigation of the consequences for saving and inequality of population and economic growth is the subject of our current research program. In this paper, which is designed as an introduction and progress report, we outline the basic theory, discuss the issues that require quantification and testing, and summarize our empirical experience with data from the United States, Britain, Taiwan, and Thailand. The underlying results are taken from Deaton and Paxson (1994a, 1994b, 1995) and Paxson (1996). The theoretical development here, however,

*Angus S. Deaton and Christina H. Paxson, Research Program in Development Studies, Princeton University, 219 Bendheim Hall, Princeton, NJ 08544–1022; e-mail: dcaton@wws.princeton.edu and cpaxson@wws.princeton.edu. This research was supported by Grants P01-AG05842 and R01-AG11957 from the National Institute of Aging. We would like to thank two anonymous referees for useful comments. Christina Paxson also thanks the Russell Sage Foundation for support.

is self-contained and different from that reported elsewhere. Some of the empirical evidence (e.g., evidence on inequality in Thailand) is reported here for the first time.

Life cycle theory provides the framework for our analysis. The theory that follows focuses on the use of saving behavior to reallocate consumption across different stages of the life cycle, and the implications of life cycle saving behavior for the effects of aging and growth on aggregate saving and inequality. Lee (1994) and Lee and Lapkoff (1988) also examine the effects of population aging on economic outcomes, but within a somewhat different framework. As in our work, they examine the effects of population aging in the context of balanced economic and population growth. They assume, however, that the economy is in a "golden rule" equilibrium, with optimal steady-state levels of saving and investment—something that we do not assume. Their work also emphasizes the role of public and private *inter vivos* transfers between generations. In the theory that follows we do not model transfers explicitly, but account for them in our empirical analysis to the extent that our income measures include public and private transfer payments.

THEORY: PREDICTIONS AND CAVEATS

Predictions

The effects of life cycle saving are studied most clearly in an economy that has experienced balanced economic and population growth for an extended period of time, with population growing at an annual rate n and real income per capita at an annual rate g. Suppose that there are n_{at} people of age a alive in year t, that they have average per capita income y_{at}, out of which they save a fraction s_{at}. The fraction of population that survives to age a is given by the life table p_a, so that the fractions of the population in age group a, π_{at}, is given by

$$\pi_{at} = \frac{n_{at}}{\sum_{\alpha=0}^{\infty} n_{\alpha t}} = \frac{(1+n)^{-a} p(a)}{\sum_{\alpha=0}^{\infty}(1+n)^{-\alpha} p(\alpha)}, \tag{1}$$

an expression that does not depend on t. Income is part labor earnings and part the return on past saving, and in the analysis that follows it is important that the distinction between income and earnings be carefully maintained.

Although there appears to be little evidence to support it, the standard assumption in life cycle models is that the profile of the logarithm of earnings with age does not depend on the rate of economic growth; the age-earnings profile of a worker today is assumed to have the same shape as that of his father or grandfather. Economic growth is assumed to increase the level of the age-earnings profile for successive cohorts without changing its shape. Life cycle theory also posits that the *shape* of the age profile of consumption is determined by the interaction of tastes and real interest rates, while the *level* of the profile is set by the expected value of lifetime resources. If the age profiles of both earnings and consumption are invariant over cohorts, so will be the age profile of wealth and returns to wealth, provided different cohorts face the same real interest rate—something that will be the case in balanced growth. Under these conditions, income per capita in year t for those aged a will be:

$$y_{at} = y(a)(1+g)^{t-a}, \tag{2}$$

where $y(a)$ is the age profile of income (and includes both earnings and asset income) and g is the rate of economic growth. As a consequence of Eqs. (1) and (2), the share of income accruing to people aged a is independent of t:

$$\theta_a = \frac{n_{at} y_{at}}{\sum_{\alpha=0}^{\infty} n_{\alpha t} y_{\alpha t}} = \frac{(1+\gamma)^{-a} p(a) y(a)}{\sum_{\alpha=0}^{\infty}(1+\gamma)^{-\alpha} p(\alpha) y(\alpha)}, \tag{3}$$

where $(1+\gamma)=(1+n)(1+g)$, so that γ is approximately the rate of growth of aggregate national income.

National per capita saving is the saving of each age group weighted by its share in the population, but the quantity that most concerns us is the ratio of national saving to national income, which is the saving ratio of each group weighted by its share in aggregate income (i.e., weighted by Eq. (3)). Hence, if the age-specific saving ratios are s_a the national saving rate is

$$(S/Y)_t = \sum_{a=0}^{\infty} \theta_a s_{at} = \frac{\sum_{a=0}^{\infty}(1+\gamma)^{-a} p(a) y(a) s_a}{\sum_{a=0}^{\infty}(1+\gamma)^{-a} p(a) y(a)}. \tag{4}$$

According to Eq. (4), the effects of population and per capita income growth on saving rates are the same, because each appears only through their sum, γ. Differentiation and some manipulation yield the derivative

$$\frac{\partial (S/Y)_t}{\partial \gamma} = -(1+\gamma)^{-1} \sum_{a=0}^{\infty} s_a \theta_a (a - \tilde{a}), \tag{5}$$

where underline $\tilde{a}$ is the "plutocratic" average age, defined as age weighted by income shares:

$$\tilde{a} = \frac{\sum_{a=0}^{\infty} a y(a) p(a)(1+\gamma)^{-a}}{\sum_{a=0}^{\infty} y(a) p(a)(1+\gamma)^{-a}}. \tag{6}$$

Eq. (5) provides the central prediction of the theory, that if saving and age are negatively related, higher growth—of income per capita or of the population—will generate more saving. Eq. (5) also yields quantitative predictions and permits an analysis of potential limitations of those predictions—something to which we shall return below.

Much the same accounting apparatus can be used to analyze the effects of growth on inequality. The microeconomic theory is again the life cycle model of consumption, but it takes explicit note that earnings are uncertain, so even if consumers plan for a constant consumption stream through life, the constant accrual of new information will generate constant replanning and change. Under the simplest form of the life cycle model under uncertainty, the consumption of each individual is a martingale (Hall 1978), so that, provided there is some heterogeneity across consumers, the dispersion of consumption will increase over time for any fixed group of consumers such as a birth cohort. The increasing dispersion of consumption is funded either by an increasing dispersion in earnings with age, or by increasing dispersion of assets and asset income with age, or by both. (See Deaton and Paxson (1994a) for a full theoretical development.) The theory also implies that income inequality will increase with age, at least up until retirement, regardless of whether earnings inequality increases with age. There are good theoretical reasons why earnings inequality should increase with age. For example, Mincer (1974) argues that individual differences in rates of human capital accumulation will result in differences in the slopes of age-earnings profiles, resulting in first decreasing but eventually increasing earnings inequality with age. It is important to note, however, that the prediction of life cycle theory that *consumption and income* inequality increases with age does not require that dispersion in earnings increase.

If inequality increases with age for a given cohort, changes in the age distribution of the population will change inequality, just as changes in the age distribution of the population change the aggregate saving rate when saving rates differ by age. However, aggregate inequality depends not only on inequality within cohorts, but also on inequality between cohorts, and changes in the age distribution of the population will affect the latter. We analyze the net effects for a particular measure—the variance of logarithms—in Deaton and Paxson (1995). We show that given additional but fairly standard assumptions about preferences, life cycle theory predicts that population aging will increase both within-group and between-group inequality. In outline, the argument is as follows.

Suppose that x denotes the quantity whose variance concerns us; for consumption or income inequality, x would be the logarithm of consumption or income. Overall inequality is measured by the variance, which at time t can be written

$$V_t = \sum_{a=0}^{\infty} \pi_{at}\left[v_{at} + \left(x_{at} - \bar{x}_t\right)^2\right], \tag{7}$$

where v_{at} is the variance for age group a, and the average $\bar{x}_t = \sum \pi_{at} x_{at}$. According to the theory, the within age component of the variance increases with age, and because we are interested in growth effects on inequality, we assume that there are no other extraneous factors affecting inequality. Hence, if the variance at birth is v_0 we write

$$v_{at} = v_0 + \eta(a), \tag{8}$$

where $\eta(a)$ is monotone nondecreasing in a. Substituting Eq. (8) into Eq. (7),

$$V = \sum_{a=0}^{\infty} \pi_a\left[v_0 + \eta(a) + \left(x_a - \bar{x}\right)^2\right]. \tag{9}$$

The expression is time invariant in balanced growth because (a) we have assumed that inequality at birth is constant, and (b) inequality between age groups is constant—a consequence of the assumption that age profiles of all cohorts have the same shape. For example, if x were the logarithm of income, then

$$x_{at} = \ln y_{at} = \ln y(a) + (t-a)\ln(1+g), \tag{10}$$

so that the dispersion of x_{at} around its mean is independent of t.

If Eq. (1) is substituted into Eq. (9) and the result is differentiated with respect to the rate of population growth n, we obtain

$$\frac{\partial V}{\partial n} = -(1+n)^{-1}\sum_{a=0}^{\infty}\pi_a(a-\bar{a})\eta(a) - (1+n)^{-1}\sum_{a=0}^{\infty}\pi_a(a-\bar{a})(x_a-\bar{x})^2, \tag{11}$$

where $\bar{a}$ is the (usual, or democratic) mean of age. The first term on the right hand side of Eq. (11), which shows the effect of changes in n on total within-group inequality, is negative because $\eta(a)$ rises with a; an older population will have higher total within-group inequality because there is more inequality among older groups than among younger groups. The second term is the effect of changes in n on inequality across age groups. In general it can be positive or negative depending on the shape of the age profile of x. However, if the age profile of x_a is linear in age, and if the age distribution is positively skewed (as would normally be the case), then the second term in Eq.(11) is also negative, so that a decline in the rate of population growth will unambiguously increase the overall variance V. If we are concerned with the inequality of consumption, so that x_a is the average logarithm of consumption at age a, the condition that x_a is linear in age means that consumption exhibits constant growth (possibly including zero growth) over the life cycle. That the age profile of average consumption should exhibit steady growth is an implication of isoelastic or quadratic utility—two standard assumptions in the life cycle literature. Given one of these assumptions, the life cycle model predicts that population aging will unambiguously result in more consumption inequality.

Caveats

One of the main tasks of our empirical work is to discover whether the data permit a life cycle interpretation—whether it is possible, as the theory requires, to decompose consumption into age and cohort effects, to document the age profiles of saving rates, and to test whether saving is indeed negatively correlated with age. As we shall show in the next section, there are numerous anomalies and findings that challenge the predictions of life cycle theory. In spite of these anomalies, a life cycle interpretation is not ruled out, and it is possible to turn the theoretical magnitudes into actual numbers and to calculate the population and income growth effects. In our view, the major question remains whether saving is indeed primarily motivated by the needs of retirement. If not, the life cycle model is unlikely to be a useful vehicle for the analysis and prediction of saving, and in particular, is unlikely to give reliable predictions about the likely effects of demographic and economic trends. For most of this paper, we temporarily set aside this fundamental question and seek a life cycle interpretation of the evidence—an interpretation that can be used to calibrate the formulas presented above. The attempt to do this does not prevent us from noting a number of difficulties along the way. In the concluding section we shall return to the wider issues of what determines saving and to the usefulness of life cycle theory for this sort of modeling exercise.

Before we turn to the data, there are a number of qualifications to the theory that must be discussed. We start with the effects of economic and population growth on saving (Eq. (5)). In the simplest versions of the theory, Modigliani's "stripped-down" model, income is assumed to be constant through the working life, and consumption to be constant through both the working and the retirement phases of life, so that saving is a fixed fraction of income during the working years providing enough assets immediately prior to retirement to support consumption thereafter. This induces a negative relationship between saving rates and age. Saving is positive until retirement and negative after retirement so that the effect of growth on the aggregate saving rate can be large. For example, in this model the derivative of the aggregate saving rate with respect to the growth rate γ is $R/2$ when $\gamma = 0$, for retirement span R. Although the saving rate is concave in γ, the derivative is 2 when γ is 3.5%, the work span is 40 years, and the retirement span is 10 years (see Deaton (1992: chap. 2) for the calculations). Making this model more realistic can affect its predictions in a number of ways.

People not only work and retire. They also spend time as children, supported by their parents who are then usually in the early part of their working cycle. Because children have to be fed, clothed, and educated, they raise consumption in the early working years and their parents may start saving only between middle-age and retirement. This reduces the length of the accumulation phase and the total amount of assets at retirement. Although saving will still take place at younger ages than will dissaving during retirement, so that growth will still increase the aggregate saving rate, the effect will be attenuated. In extreme cases, children may be a substitute for assets. There is evidence from Taiwan and Thailand that elderly individuals receive considerable financial support from their children (see, for example, Deaton and Paxson 1992; Hermalin, Ofstedal, and Chang 1991). Where traditions of filial support for the aged are strong, there may be relatively little need for life cycle accumulation of financial assets, with transfers between family members substituting for saving. Much the same effect may occur in most of the advanced industrialized countries where there are unfunded, state-run social security systems that may reduce or even eliminate the need to save for retirement. Indeed, as incomes rise with economic development, the responsibility for retirement provision may pass from the family to the state, leaving at most a limited role for life cycle saving.

That the age structure of families affects saving behavior breaks the equivalence between per capita income growth on the one hand and population growth on the other. When the rate of population growth declines, for example, population is indeed redistributed toward the older groups; but the structure of families must also change, so that households headed by workers and potential savers will contain fewer children and (perhaps) more elderly parents. Because people consume in households, not as individuals, population growth rates affect not only the weights that are used to aggregate the age profile of consumption, but also the shape of the age profile itself. The lack of equivalence between population and economic growth also shows up in the data, where the effects of economic growth on national saving rates are detected much more easily and robustly than are those of population growth (see Gersovitz 1988 for a survey of this literature.) Of course these negative findings, although consistent with the theory, can hardly be taken as evidence in its favor.

The recognition that household size and age structure affect consumption and income patterns can also compromise the implications of population growth for inequality. There are two effects that parallel those in the discussion of the effects on saving. First, the presence of children affects the age profiles of consumption or income, and therefore has a direct effect on the variance Eq. (9) and its derivative with respect to the rate of population growth Eq. (11). If we define inequality as inequality at the individual level, then we will presumably assign to children very low incomes and (relatively) low consumption. The squares of the deviation of income and consumption from their means will be largest, therefore, among the youngest groups, so that the last term in Eq. (11) can be positive, and declines in the population growth rate will diminish inequality. Even on a household basis, per capita consumption and income may be lowest among the households with the largest number of children, and the same effect may occur. The second effect of children on the analysis of inequality is the same as that discussed for saving—that it is impossible to hold the age pattern of consumption constant when the rate of population growth changes. As a result, there will be additional terms in Eq. (11) about which it is hard to say anything. There are plausible specifications, however, that once again induce a positive relationship between the rate of population growth and inequality—especially at high rates of economic growth.

The effects of economic growth on saving are also likely to be less straightforward than in the theory so far. First, growth in per capita income may occur within generations as well as between them. If people anticipate this growth over their lifetimes, there are incentives when they are young, not to save, but to borrow. If this takes place, it is possible for dissaving among the young to dominate and for increases in economic growth to decrease saving. Modigliani (1986) argues that the ability of this effect to alter the qualitative result is limited by the fact that most young people would find it hard to borrow large sums to finance consumption early in their careers. However, anticipated growth in earnings over the life cycle is another reason why the young may save relatively little, and it will diminish the quantitative importance of the effects of growth on saving. Second, a similar effect comes from the presence of children in young adult households. If such households save little, the redistribution of income in their favor that comes from higher growth will not increase the national saving rate. Third, there is no reason to suppose that the age profiles of consumption and earnings are identical across countries, especially when we are comparing populations with different patterns of fertility, of household formation, and of real interest rates. Yet it is only when these things are held constant that the theory has *any* implications for international patterns of saving and growth. Our empirical evidence shows that age profiles are different in different countries, and earlier work by Carroll and Summers (1991) establishes that the positive relationship between saving and economic growth across different countries is inconsistent with international comparisons of age-consumption profiles. Of course this does not mean that the life cycle model of saving and inequality may not hold within each country separately. It is on this basis that we conduct our investigations. We look at consumption and income profiles for each country, and use these to calculate the implications of changes in growth rates for each country separately.

EVIDENCE

Data

In this section, we present evidence on whether life cycle patterns in consumption and saving are consistent with life cycle theory, and whether population aging and economic growth are likely to have large or small effects on aggregate saving and inequality. The data are taken from surveys in four countries: the United States, Britain, Taiwan, and Thailand. Although these countries were chosen largely because their governments have collected data that can be used to examine the issues at hand, they represent an interesting cross section. The two Western economies have had slow income and population growth over the past several decades. The two Asian economies have had higher rates of per capita income growth, and although they have experienced declines in fertility rates they still have faster-growing and younger populations than the Western economies. The personal saving rate differs sharply across the countries. National Accounts figures indicate that Taiwan, the fastest growing country, had a personal saving rate of 20% in 1990, in contrast to saving rates of 13.2% for Thailand, 6% for the United States, and 3.2% for the United Kingdom in the same year (see Paxson 1996). Thus the experience of these countries is consistent with the well-documented positive cross-country correlation between growth and saving rates.

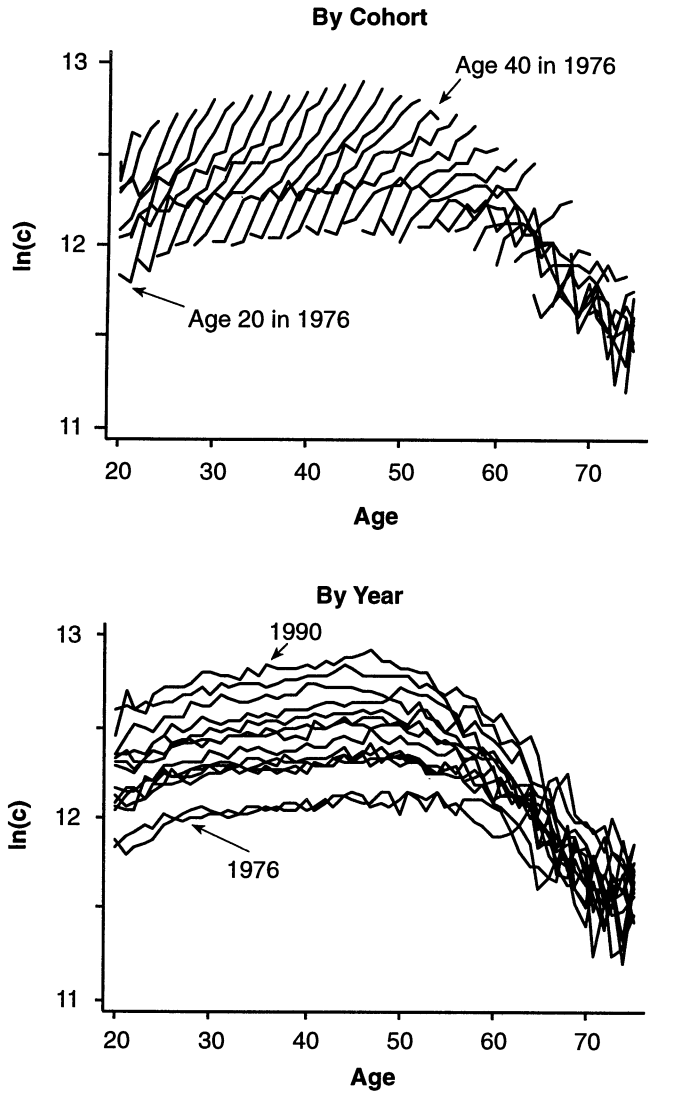
For each country we use time-series of cross-sectional household surveys that provide consumption, income, and saving information for a large number of households. In all cases, we work with household income and expenditure surveys in which saving is defined as a residual. As with most such surveys, there are difficulties in reconciling estimates of saving from these microeconomic data with estimates of aggregates from national accounts. (See Paxson (1996) for a comparison of survey-based and national accounts measures of saving in the four countries discussed in this paper.) Among these difficulties are mismeasurement of income in the surveys and the difficulty of estimating the mean of a variable whose distribution is as skewed as is that of saving. All indications are that a large fraction of saving is done by a relatively small fraction of households. We also should note a conceptual difference. The survey measures of saving do not include contributions to occupational pension schemes, which account for a substantial amount of saving in the United States and the United Kingdom.

The U.S. data are drawn from the *Consumer Expenditure Surveys* (CEX) from 1980 to 1992. These surveys contain information on approximately 4,500 households surveyed in each quarter of each year. For Britain we use data from the 1969 to 1992 rounds of the *Family Expenditure Surveys* (FES). Like the U.S. survey, the British survey is conducted quarterly, and about 1,750 households are surveyed each quarter. The Taiwanese data are taken from the 1976 to 1990 rounds of the *Survey of Personal Income Distribution*, a survey of approximately 13,000 households per year. The Thai data are from the *Socioeconomic Surveys* conducted in 1976, 1981, 1986, 1988, 1990, and 1992. The number of households per year in the Thai surveys ranges from 11,000 to 13,500. The data are discussed in more detail in Deaton and Paxson (1994a) and Paxson (1996).

Although all of these surveys are cross-sectional (i.e., individual households are not reinterviewed in successive years of the survey) they are useful for examining how consumption, saving, and inequality change over the life cycle. Our approach is to examine the experience not of individuals but of birth-year cohorts. For example, we can link together measures of average consumption among 20-year-olds surveyed in 1980, 21-year-olds surveyed in 1981, 22-year-olds surveyed in 1982, and so on, to see how average consumption evolves over time as the cohort ages. Averages of other variables, as well as higher-order moments that measure inequality, can also be tracked over time for each cohort.

Figure 1 illustrates the cohort-level data we use. The figure shows cohort averages of the logarithm of household consumption for Taiwan, graphed against age. In the upper panel each line connects the data points for a single cohort. The left-most line traces the experience of the cohort aged 20 in 1976, the next traces the experience of the cohort aged 21 in

FIGURE 1. CONSUMPTION AND AGE IN TAIWAN, BY COHORT AND BY YEAR



1976, and so on. Consumption rises with age for the youngest groups, and then levels off at the very oldest ages. The effects of rapid economic growth (around 5% per year during the sample period) appear as vertical downward shifts in the lines for each successively older cohort: Households with heads born more recently consume more at each age than did those from older generations. The lower panel shows the same data, displayed to highlight how cross-sectional age-consumption profiles have changed over time. Each line connects the data points for a specific year, so the lowest line shows the cross-sectional age-consumption profile for 1976, and the highest shows the same profile for 1990. This figure illustrates not only how misleading cross-sectional age profiles of consumption are as measures of the experience of individual cohorts, but also how rapid growth combined with rising consumption with age can result in nearly flat age-consumption profiles within any one year (or cross-section) of data. The shape of cross-sectional age-consumption profiles determines the between-cohort contribution to inequality. In the case of Taiwan the fact that these profiles are flat implies that the contribution of across-cohort inequality to total inequality is small. We shall return to this topic in the section on aging, growth, and inequality below.

The use of cohort data is not problem free. In principle, the sample of observations used to construct information on a specific cohort should be drawn from a population of individuals that remains fixed over time. However, because the data contain information on the consumption of *households* rather than of *individuals*, cohorts must be defined according to the age of the household head, and the population of household heads is not fixed over time. New household formation, marriage, divorce, and death will change the underlying population from which the observations for a specific cohort are drawn. Selection into and out of headship is likely to be important in the Asian countries, where older people often reside with their adult children. Furthermore, selection into and out of headship is influenced by survey design, which may differ across countries. In Taiwan, for example, the household head is defined by the survey as the primary earner, so that a person, typically a man, will cease to be a head when the earnings of one of his coresident children exceeds his own. Cohort averages at the oldest ages are based on the selected sample of people who choose to live independently of their children (if they have children), or who out-earn the children with whom they reside. In Thailand, the definition of headship is not set by the survey, and the typical pattern is to designate the oldest male to be the head, so that the effects of selection are likely to be different but no less serious than in Taiwan. In either case the potential selection problems must be kept in mind when interpreting the results that follow. How family structure is determined and changes with economic and population growth is an important topic for future research.

Aging, Growth, and Saving

The first set of questions we address is whether the data are consistent with the life cycle model and whether the effects of population aging and economic growth are likely to have large or small effects on the aggregate saving rate. The main objective is to estimate age profiles of income and saving rates, which can be used with Eq. (5) to quantify the effects of aging and growth on aggregate saving. Many of the results that follow are drawn from Paxson (1996).

Our starting point is a simple version of the life cycle model with no uncertainty. Consumption for an individual i at age a born in year b is denoted as:

$$c_{iab} = G_i(a,r)W_{ib}, \tag{12}$$

where W_{ib} is the lifetime wealth of the individual (equal to initial assets plus the present value of earnings, transfers, and bequests), and r is the interest rate. According to Eq. (12), W_{ib} sets the *position* of the age profile of consumption, whereas the function $G_i(a,r)$ sets the *shape* of the profile by determining how lifetime resources are allocated to consumption in each period. According to simple life cycle theory, this shape depends only on age-specific tastes and the interest rate, not on the timing of receipts over the life cycle. Taking the logarithm of Eq. (12) and averaging across all people of the same age and born in the same year yields:

$$\overline{\ln(c_{ab})} = \overline{\ln(W_b)} + \overline{\ln(G(a,r))}. \tag{13}$$

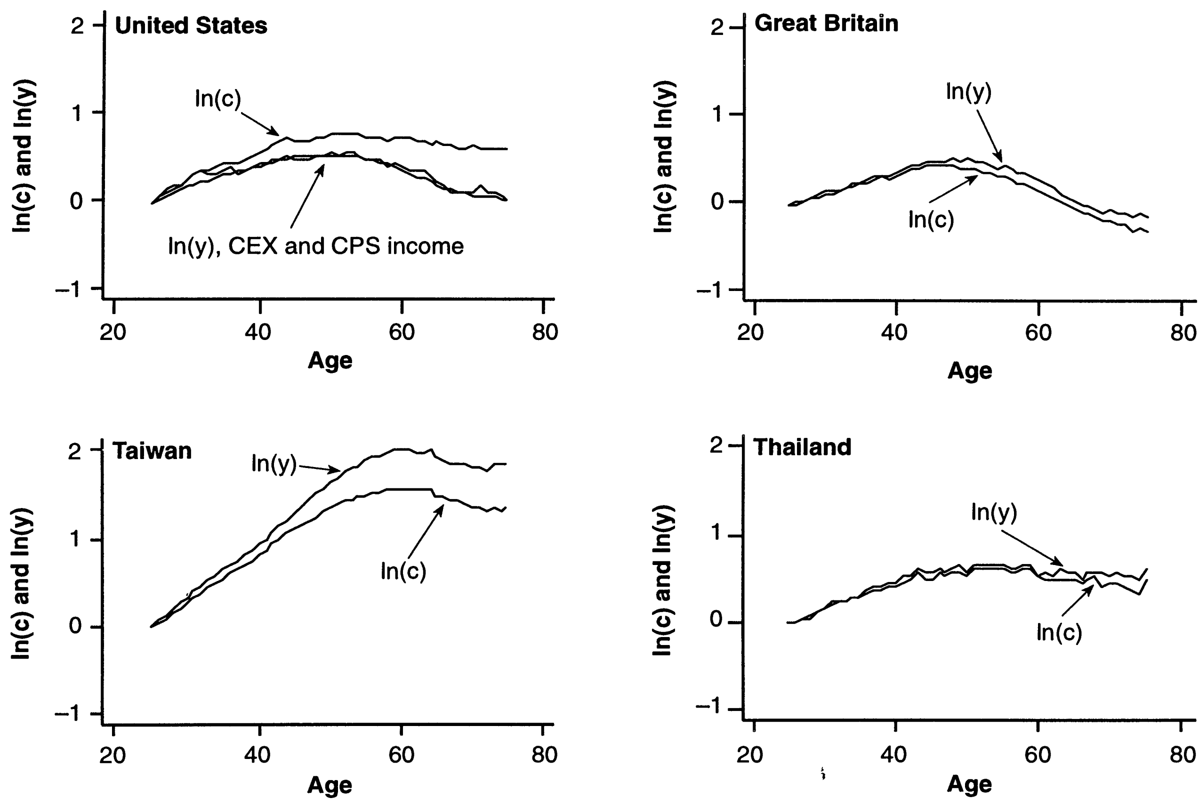
According to Eq. (13), the cohort average of the logarithm of consumption can be decomposed additively into two terms. The first represents the effects of lifetime wealth on consumption regardless of age, and the second represents the effects of age-specific tastes and the interest rate on consumption. Eq. (13) is estimated by regressing the average of the logarithm of consumption for each age-cohort cell on a set of cohort (i.e., birth year) and age dummy variables. Provided that the life cycle model is correct, the estimated age effects provide information on age-specific tastes for consumption as modified by the real interest rate, and the cohort effects provide information on the effects of economic growth on consumption. Under the assumptions of the previous section—that economic growth shifts age-earnings and age-consumption profiles up without changing their shapes, and that all cohorts face the same interest rate—the average of the logarithm of income can also be decomposed into age and cohort effects using the same methodology.

The theory discussed above and its empirical implementation take no account of the possibility that consumption or income might be affected by macro shocks that affect all cohorts regardless of age. For example, Taiwan experienced a recession in the early 1980s, which is reflected in Figure 1 as slow consumption growth for all cohorts during this period. The age-cohort decomposition discussed above will not capture these pure year effects. To account for year effects we include a set of year dummies in each regression, even though this simple modification has both theoretical and practical difficulties. In theory, the life cycle model under uncertainty indicates that the effect on consumption of an unanticipated shock to lifetime wealth will vary with age, because, compared to older people, younger people have a longer time horizon over which to consume unanticipated increases in wealth. The additive year effects will not capture these interactions between macro shocks and age. In practice, the full set of age, cohort, and year effects cannot be estimated without imposing additional parameter restrictions. The problem is that age, birth year, and calendar year are linearly dependent; a person's age must equal the current year minus his year of birth. Because of this collinearity, there is no unique way to identify a trend in the variable of interest. To see the problem, consider an example in which all cohorts have identical consumption in a given year and consumption grows for all cohorts by 5% per year. One possible interpretation of these data is that there are no cohort or age effects, but that there are year effects in consumption that increase by 5% per year. Another equivalent interpretation is that there are no year effects in consumption, and that consumption increases by 5% per year of age and decreases 5% per year for each successively older cohort. For example, the consumption of the cohort born in 1960 will increase by 5% per year, and the consumption at age 30 of the cohort born in 1960 will be 5% less than was the consumption at age 30 of the cohort born in 1961. Because the year effects are included to account for macroeconomic shocks and not trends, we restrict the year effects so that they sum to 0 and are orthogonal to a time trend. The effect of this normalization is that trends in consumption and income are attributed to age and cohort, not to time.

Figure 2 shows estimates of age-consumption and age-income profiles. The points graphed are simply the age effects from regressions of the logarithm of consumption and income on age, cohort, and restricted year effects for each of the four countries. We show two age-income profiles for the United States. One is based on income data from the CEX, and the second uses data from the Current Population Survey (CPS), which is thought to provide more reliable income figures. Each set of age effects is normalized to equal 0 at the youngest age of 25, so the figure provides information on changes in each variable with age rather than their levels; it does *not* indicate that saving rates are negative at all ages in the United States. One important feature of the figure is that the age-consumption profiles have different shapes in different countries. As Paxson (1996) shows, these cross-country differences cannot be explained by differences across countries in the size and age structures of households. For example, Taiwan's high consumption at the oldest ages is not explained by larger household size among households with older heads. Even so, the fact that age-consumption profiles differ across the four countries is not necessarily at odds with life cycle theory; the theory imposes no restrictions on the shape of age-consumption profiles, and if age-specific tastes and or interest rates differ across economies then the age profiles of consumption will also differ. However, the differences in the figures certainly call into question the predictions of life cycle theory for the *cross-country* relationship between growth and saving, because these predictions are based on the effects of variations in growth rates conditional on identical age profiles of consumption and income.

Another important feature of Figure 2 is that the age profiles of consumption and income within each country are quite similar to one another—especially in Britain and Thailand. Even within the United States and Taiwan increases and decreases in the consumption and income profiles coincide. This result is consistent with other research (e.g., Carroll and Summers 1991), which finds that consumption "tracks" income over the life cycle. The presence of tracking is difficult to reconcile with the simple life cycle model, but it may be explained by more complicated versions of the model such as those that include precautionary motives for saving

FIGURE 2. AGE EFFECTS IN LN(Y) AND LN(C), NORMALIZED TO 0 AT AGE 25



and borrowing constraints (see, for example, Carroll forthcoming; Hubbard, Skinner, and Zeldes 1995). Whatever its source, the effect of tracking will be to weaken any relationship between economic and population growth and the aggregate saving rate because the young must save substantially more than the old for large effects to exist.

Quantifying the effects of population and economic growth on aggregate saving requires estimates of the age profile of saving rates, represented by the terms $s(a)$ in Eq. (5). Because the saving rate is approximately equal to the difference between the logarithms of income and consumption, one way to proceed is to decompose this measure of the saving rate into age, cohort, and restricted time effects, just as was done for the logarithms of income and consumption. The age effects reveal the life cycle patterns in saving rates and can be used to calculate the effects of growth on the aggregate saving rate using Eq. (5). The cohort effects will measure fixed differences across cohorts that raise or lower the saving rate at all ages, and will reflect differences across cohorts in the fraction of lifetime wealth that is consumed or not bequeathed to future generations. In the absence of bequests and *inter-vivos* transfers, the present value of consumption is equal to lifetime wealth, and the cohort effects should be 0. The year effects will capture the effects of macroeconomic shocks on the saving rates of all groups in a particular year.

As has been frequently noted, there was a downward trend in the U.S. aggregate saving rate during the 1980s and, although none of the other three countries show similarly sustained trends over the periods of analysis, there are several cases where there are trends for a period of years. Such phenomena are, in principle, consistent with the life cycle interpretation of saving; indeed Modigliani (1990) has argued for a life cycle interpretation of declining national saving rates in developed countries through the 1960s, 1970s, and early 1980s. The slowdown in rates of economic growth has redistributed lifetime resources (relatively) toward older consumers, who supposedly save less, thereby lowering aggregate saving. Of course, this interpretation may or may not be correct. An obvious alternative is that there have been declines in age-specific saving rates. Suppose, for example, that all individuals save the same fraction of their income in any year, regardless of age, but that for some unknown reason (e.g., saving "fads" or the spread of a belief that saving is unlikely to help much in retirement), the saving rate declines over time—say, from 10% to

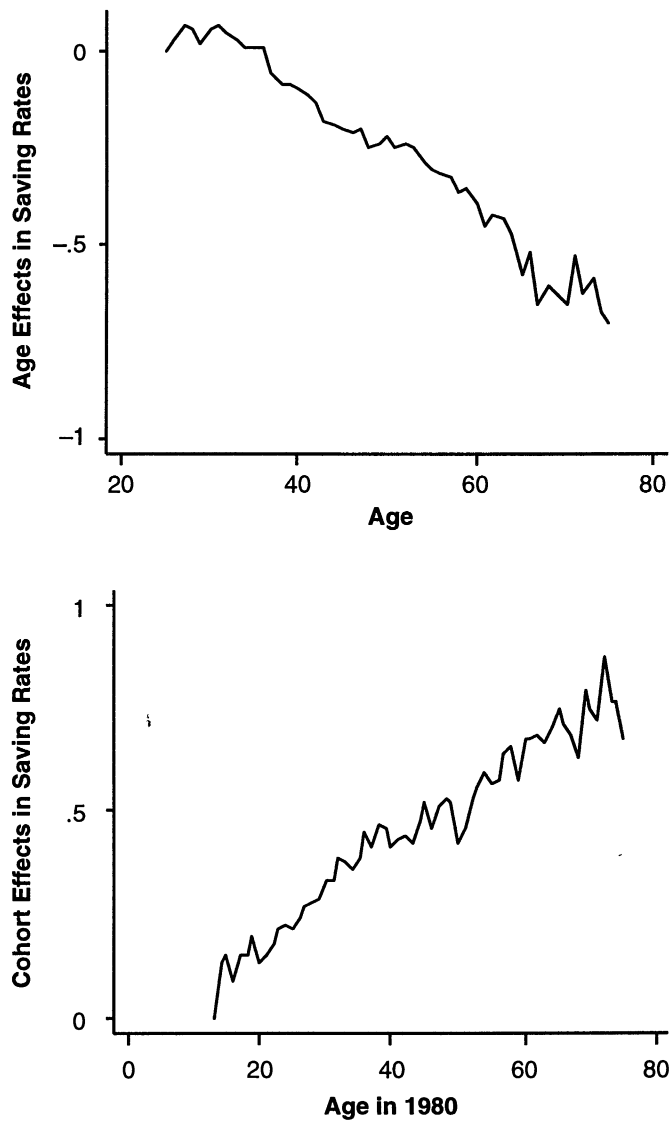
5% from one year to the next. If we apply our econometric procedures to this case, the estimated age effects will show a 5% decline with age because each cohort saves 5% less as it ages by one year. The cohort effects, on the other hand, will show that a 5% increase per year as we move from younger to older cohorts: Cohorts born more recently save less at any age than did older cohorts when they were the same age. The "fad-driven" time trend in the saving rate will appear as offsetting age and cohort effects. The attempt to impose a life cycle interpretation on these non-life-cycle data has "succeeded" in the sense of fitting the data, but has done so at the price of absurd age and cohort profiles. More realistic examples in which the saving rate for a cohort in a given year is the sum of an age-specific component $s(a)$ plus a time-trend common to all individuals will also generate offsetting age and cohort effects.

This is exactly what happens when we estimate saving rate equations for the United States. Figure 3 shows estimates of age effects and cohort effects in the saving rate for the United States. The estimates indicate that the saving rate declines approximately 1% for each year of age and increases 1% per year across cohorts, which is roughly consistent with the average decline over the sample period in the aggregate saving rate. If these results are accepted at face value, they imply that saving rates decline dramatically with age. For example, the estimated age effects imply that, all else equal, 25-year-olds have saving rates that exceed those of 40-year-olds by about 25 percentage points, so if 40-year-olds save on average 5% of their incomes, 25-year-olds will save 30%. Likewise, the estimates of cohort effects imply that each cohort intends to bequeath 1% less of its lifetime wealth than does the cohort of people born a year earlier.

This "life cycle" interpretation of American saving patterns is clearly absurd. It attributes the decline in U.S. saving rates over the 1980s to unexplained declines in bequest motives combined with rapid and consistent declines in saving rates with age throughout the life span. Although we do not have an alternative well worked-out explanation of the trend in the U.S. saving rate, it is clear that the life cycle interpretation in Figure 3 is not a promising candidate. One possibility is that what appear to be trends are actually consequences of changes in the surveys used to measure saving. Bosworth, Burtless, and Sabelhaus (1991) argue that the quality of the income data collected by the U.S. Consumer Expenditure Survey has deteriorated over time, resulting in a spurious decline in the measured saving rate. The British Family Expenditure Survey may also have measurement problems, but with different effects. The data show a sharp *increase* in measured saving rates between 1986 and 1991 that is not reflected in the National Accounts data, and which may be partly due to changes in the survey's sampling frame. Attributing these spurious changes in measured saving rates to age and cohort effects will clearly give misleading results.

That the age and cohort estimates in Figure 3 are not credible does not mean that a life cycle interpretation is impossible. In particular, the figure does not tell us about the *importance* of the offsetting trends in age and cohort effects

FIGURE 3. AGE AND COHORT EFFECTS IN SAVING RATES IN THE U.S.



or whether they can be eliminated without significant loss of fit. One way of doing so is to impose linear homogeneity on the lifetime utility function so that bequests are a constant fraction of lifetime resources. This is a plausible restriction, but it is not necessarily true, and many commentators have argued that the bequest motive becomes more important with the level of development. If it is imposed, cohort effects in consumption must match cohort effects in income so there are no cohort effects in saving and we can reestimate the saving models with only age and unrestricted year effects. Of course, using this procedure means that observed trends in saving rates are attributed to year effects and are left unexplained by life cycle theory. This is only satisfactory if we could be sure that the trends are indeed a consequence of measurement error. Yet the procedure has the advantage of yielding age effects in saving rates that can be used to calculate how changes in economic and population growth will affect the aggregate saving rate in the absence of any future trends or year effects. We adopt this procedure in deriving the remainder of the results in the paper; but note that it is different from Deaton and Paxson (1994a) so that the results from Taiwan reported in that paper are different from those reported here.

If we allow unrestricted year effects in savings together with the age effects, but with no cohort effects, we do not lose a great deal of fit compared with the model with a full set of age, cohort, and year effects. For the United States, the F-statistic is 1.76, which given 61 and 600 degrees of freedom, is significant at conventional levels, but is nevertheless not large enough to suggest serious misspecification. The corresponding F-test statistics for the other countries are 1.42 for Britain, 2.60 for Taiwan, and 1.10 for Thailand. For Britain and Thailand these are not significant at conventional levels. However, these statistics are hardly adequate tests of the life cycle model, if only because they do not penalize trends in the year effects. If these trends were all attributable to progressive measurement error, the procedure would be reasonable, but if the trends are real, the procedure allows the model too much flexibility. A more stringent test of the life cycle hypothesis is therefore not only to remove the cohort effects, but also to require that the year effects be trendless. The test for this restriction generates much larger F-statistics, 4.70 for the United States, 5.04 for Britain, 28.34 for Taiwan, and 1.86 for Thailand. These numbers show that we pay a heavy price for our insistence on a life cycle interpretation of the data, particularly if we rule out (lifetime) wealth elastic bequests.

The age effects from regressions of saving rates on age and year dummies are shown as the heavier lines in Figure 4. For the United States and Taiwan, the age effects are consistent with the simple life cycle theory prediction. Saving rates generally rise until retirement age, and then drop sharply. The pattern in Britain is similar, although the differences in saving rates across age groups are much less pronounced and there is a peculiar increase in the saving rate among the oldest age groups. This could perhaps be due to selection out of headship among older people who save the least. Only the Thai data indicate no life cycle patterns in saving rates, and the F-statistic for joint significance of the age effects is only 1.37. The lighter lines in the figure represent the age effects when average numbers of children and adults in each household are included as additional controls. In all countries except Thailand, more children depress the saving rate, and including the demographic controls shifts the age-saving profiles up among those households in the childrearing years.

Although the estimates in Figure 4 show evidence of life cycle patterns in saving rates, there is actually too little life cycle saving for population or economic growth to have large effects on the aggregate saving rate. Paxson (1996) uses these estimates of age-saving profiles to tabulate the implied effects on the aggregate saving rate of changes in the rate of economic growth g, maintaining the assumption that growth does not change the shape of age-earnings profiles. Because none of these countries are in demographic equilibrium, these calculations make use of the actual distribution of people across age groups in each country rather than the theoretical distributions that would be obtained in steady state. Specifically, the aggregate saving rate is expressed as:

$$\left(S/Y\right)=\frac{\sum_{a=0}^{\infty} s_a y(a)\left(1+g\right)^{-a}\pi_a}{\sum_{a=0}^{\infty} y(a)\left(1+g\right)^{-a}\pi_a}, \tag{14}$$

where s_a and y_a are defined in Eq. (4), and π_a is the fraction of household heads aged a in the most recent survey year. The change in the aggregate saving rate with respect to g can be expressed as:

$$\frac{\partial\left(S/Y\right)}{\partial g}=\frac{1}{(1+g)}\frac{\sum_{a=1}^{A} a\left(S/Y-s_a\right)y(a)(1+g)^{-a}\pi_a}{\sum_{a=1}^{A} y(a)(1+g)^{-a}\pi_a}. \tag{15}$$

Eq. (15) is tabulated by setting the terms s_a equal to the age effects from the saving rate equations graphed in Figure 4, and the logarithm of the terms $y(a)$ equal to the age effects from the income equations graphed in Figure 2.

Tabulations of Eq. (15) indicate that the effects of growth on saving are small. For example, the results for the United States indicate that at a growth rate of 2% per annum, a one percentage point increase in the growth rate (from 2% to 3%) would increase the aggregate saving rate by only 0.27 of a percentage point (e.g., from 5% to 5.27%). The effects of growth on aggregate saving are even smaller for the other countries, and are actually slightly negative for Thailand. Furthermore, the effects are much smaller than those observed in the cross-country data, which indicate that an increase of one percentage point in the growth rate is associated with an increase of one and a half to two percentage points in the aggregate saving rate.

That the age effects in saving are small implies that changes in the rate of population growth should also have small effects on the aggregate saving rate. To illustrate how changes in the rate of population growth affect the aggregate saving rate, we use data from Taiwan and Eq. (5), which is reproduced here for convenience:

$$\frac{\partial\left(S/Y\right)}{\partial\gamma}= -(1+\gamma)^{-1}\sum_{a=0}^{\infty} s_a\theta_a(a-\tilde{a}). \tag{5}$$

As before, $\tilde{a}$ is the average of age weighted by income shares, and θ_a is the share of income that accrues to those aged a. Both $\tilde{a}$ and θ_a are functions of the rate of economic growth g, the rate of population growth n, and the life table $p(a)$. Given information on the life table $p(a)$, age-specific

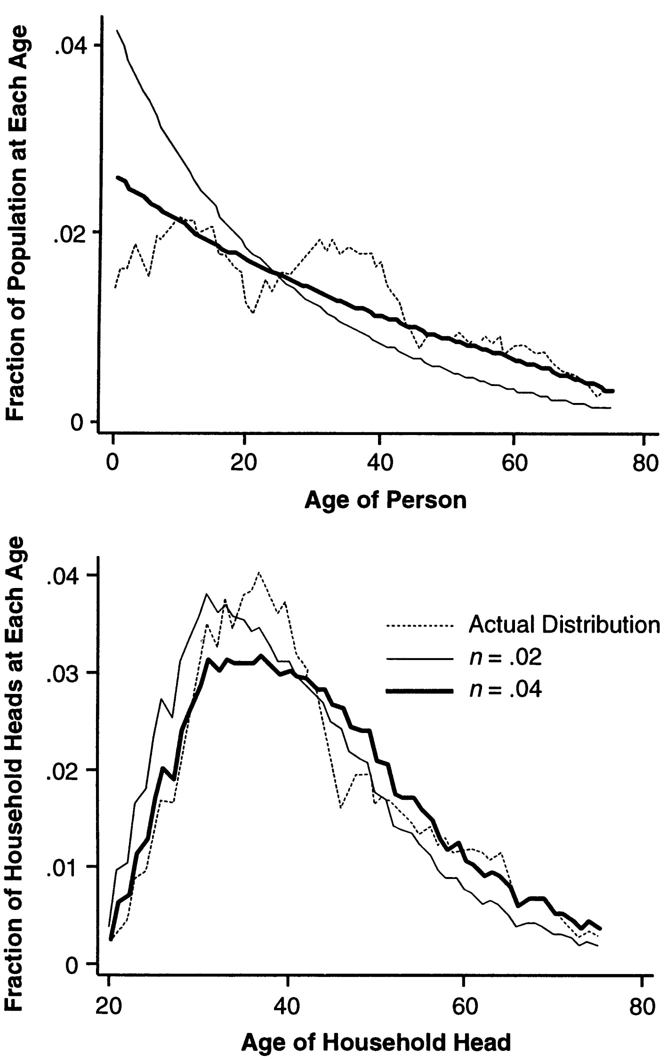
FIGURE 4. AGE EFFECTS IN SAVING RATES, NO COHORT EFFECTS AND UNRESTRICTED YEAR EFFECTS

saving rates s_a from Figure 4, and the age profile of income $y(a)$ from Figure 2, Eq. (5) can be filled in for different values of n and g.

Although calculating Eq. (5) appears to be straightforward, matters are complicated because individuals live in families, and income and saving are measured at the household level rather than at the individual level. There are two major issues. The first and more difficult issue is that changes in the rate of population growth will change the size and age structure of households, which in turn may affect the age profiles of consumption, income, and saving. For example, higher rates of population growth will result in more children per household, and households with more children may consume more and earn less than others. Because children are concentrated among households with younger heads, saving rates would decrease among households with younger heads. In terms of Eq. (5), the problem is that both s_a and $y(a)$ (the latter of which is used to construct θ_a) may change with changes in the rate of population growth in ways that are difficult to predict without much more information on how family structure is determined. We do not attempt to deal with this problem in this paper, and proceed as if the age profiles of saving and income are invariant to changes in the rate of population growth.

The second issue is related to the first, but is less difficult to handle. The results in Figures 2 and 4 show how income and saving rates vary with the age of the *household head*, and how the age distribution of household heads is not the same as the age distribution of the entire population. Thus the terms $p(a)$ implicit in Eq. (5) must be replaced by the probabilities that someone survives to age a and is a household head at that age. Without a theory of how headship is determined and perhaps influenced by changes in the rate of population growth, the best we can do is make ad hoc assumptions about age-specific headship probabilities. In the calculations that follow we assume that the probability of

FIGURE 5. AGE DISTRIBUTIONS OF THE POPULATION AND HOUSEHOLD HEADS IN TAIWAN, ACTUAL AND IN DEMOGRAPHIC EQUILIBRIUM



being a head at any age will not change with changes in the rate of population growth. Specifically, we calculate the probability that someone survives to age a and is a household head at that age as:

$$p_a^h = p_a^m h_a^m P_M + p_a^f h_a^f \left(1 - P_M\right), \qquad (16)$$

where p_a^m is the probability that a male survives to age a, h_a^m is the probability that a male aged a is a household head, and P_M is the probability at birth that a person is male. The terms with "f" superscripts are defined in the same way, but for females.

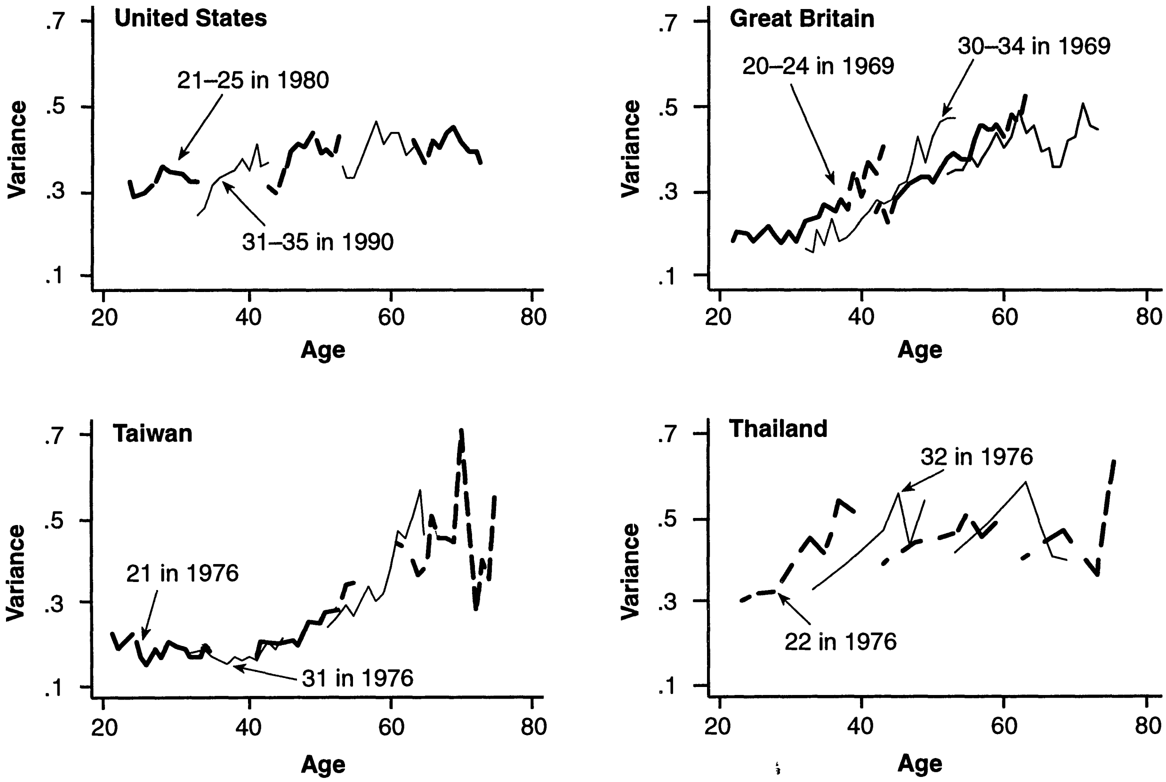
Figure 5 illustrates the implications of our assumption of constant age-specific headship probabilities. The upper panel shows the actual distribution of the Taiwanese population based on the 1991 Personal Income Distribution Survey and the steady-state age distributions at 2% and 4% population growth rates. Several aspects of the upper panel deserve mention. First, the "actual" age distribution of the population shows too few people in their late teens and early 20s. This is not a genuine feature of the population, but reflects the fact that for a variety of reasons (including mandatory military service and college attendance) many young people are not covered by the survey. Second, the figure shows evidence of the immigration of mainland Chinese in the early 1950s, the postwar baby boom, and the rapid fertility decline of the 1960s, all of which produce an age distribution that is quite different from the steady-state distributions. The lower panel shows the actual age distribution of household heads and the calculated age distributions of household heads at 2% and 4% population growth. As expected, at a lower rate of population growth the fraction of household heads who are relatively old increases, because a greater fraction of the population is concentrated among older ages. However, the fractions of heads who are very old is quite low not only because there are few people alive at old ages, but also because headship probabilities among the old are low. In Taiwan, older parents often move in with their adult children and cease to be household heads. Low headship rates among the elderly will tend to attenuate the calculated effects of population aging on saving: Even if the oldest household heads have saving rates that are much lower than those of other groups, these saving rates are given very little weight because there are few household heads at the oldest ages.

As expected, calculations of Eq. (5) indicate that changes in the rate of population growth will have small effects on the saving rate. For example, at a 2% rate of population growth and a 4% rate of economic growth, an increase of one percentage point in the rate of population growth is predicted to increase the saving rate by 0.19 percentage point. At low values of n and g, the effect is somewhat smaller, and at high values it is somewhat larger; but even with population and economic growth rates of 6%, the effect on the saving rate of a one-percentage-point rise in n is only 0.26 percentage point. Of course, these calculations rely on the assumption that changes in population growth will have no effect on the income and saving profiles of households.

Aging, Growth, and Inequality

The results presented in the last section indicate that even if the life cycle model is correct, economic and population growth will have small effects on aggregate saving rates. However, the results we present in this section indicate that changes in population aging may have large effects on consumption inequality. The size of these effects depends on the rate of economic growth, and on the responses of consumption to the changes in family size and age structure that accompany fertility change. We show that although there are

FIGURE 6. VARIANCE OF LN(CONSUMPTION) FOR SELECTED COHORTS



some conditions under which the effect of population aging on inequality will be small, there are plausible circumstances under which population aging will yield substantial increases in consumption inequality.

The results of this section hinge on the finding that in each of the four countries we examine, within-cohort inequality increases with age. This result is shown in Figure 6. The graphs show one inequality measure (the variance of the logarithm of consumption) graphed against age for selected cohorts born 10 years apart in each of the four countries. To eliminate seasonal effects in the variances in the quarterly data from the United States and Britain, we averaged across all quarters within each year. Two features of the graphs deserve mention. First, in all four countries inequality increases with age within cohorts. Second, in all countries except Taiwan there is evidence of cohort effects: At any specific age, inequality is higher among more recently born cohorts. In Taiwan there is no evidence of cohort effects. For example, inequality is essentially the same for those aged 41 in 1976 as for those aged 41 in 1986.

The age effects in inequality can be seen more clearly in Figure 7, which shows the estimates of age effects from regressions of the inequality measure on age, cohort, and (for the United States and Britain) quarter effects for each country. The vertical positions of the lines are chosen so that at a specific age (38 in Taiwan and Thailand, 36–40 in the United States, and 35–39 in Britain) they pass through actual inequality for that age group averaged over all of the survey years.

The results for all four countries indicate that inequality increases with age. Furthermore, these increases are quite large. For example, the results for the United States show that age effects increase from 0.251 for 25-year-olds to 0.469 for 55-year-olds. If consumption is lognormally distributed, the results imply that, as a cohort ages from age 25 to age 55, its Gini coefficient will increase from .282 to .378—an increase that is much larger than that observed in aggregate inequality over the sample period in the United States. The increases in inequality with age in Taiwan and Britain, which are of the same scale as for the United States, are also large relative to observed aggregate changes in each country. Those for Thailand are even larger; note that the vertical scale of the graph for Thailand differs from the other countries. The age effects increase from 0.35 at age 25 to 0.72 at age 55. Although there has been a large increase in aggregate inequality in Thailand over the sample period—the variance of the logarithm of consumption over all households has increased from 0.372 in 1976 to 0.539 in 1992—the increases in inequality with age are even larger.

FIGURE 7. AGE EFFECTS IN THE VARIANCE OF LN(CONSUMPTION)

Note: The graphs for the United States, Britain, and Taiwan are reproduced from Deaton and Paxson (1994a).

Because inequality increases with age in each of these countries, population aging through reductions in the rate of population growth will increase the contribution of within-cohort inequality to total inequality as it shifts the balance of the population toward older and more unequal age groups. In Deaton and Paxson (1995), we use the Taiwanese results from Figure 7 with Taiwanese age-specific survival probabilities $p(a)$ and headship probabilities at each age to assess the effect of changes in the rate of population growth on within-cohort inequality. These tabulations indicate that a decline in the rate of population growth from 4% to 0% yields an increase in within-cohort inequality (measured as the variance of the logarithm of consumption) from .240 to .289, which implies a nonnegligible increase in the Gini coefficient of about .025 assuming consumption is lognormally distributed.

Total inequality depends on both within- and between-cohort inequality, and the effect of changes in the rate of population growth on between-cohort inequality depends on the shape of the cross-sectional age-consumption profile. As discussed in our theoretical section, if consumption for individuals (and thus for cohorts) grows at a constant rate with age, then population aging will necessarily increase between-cohort inequality. However, if lifetime age-consumption profiles are not linear, or if changes in the age structure of the population that come with declines in fertility change the shape of the age-consumption profile, then the result can be overturned. The age effects shown in Figure 2 indicate that the age-consumption profiles are not linear in any of the countries; consumption first rises and then declines with age. Furthermore, consumption varies with the size and age structure of households. Results reported in Paxson (1996) indicate that in all four countries, more adults are associated with higher consumption, and more children are associated with either declines in consumption or increases in consumption that are smaller than those produced by more adults. Declines in fertility, which reduce the numbers of children relative to adults, are likely to increase consumption among age groups in their childrearing years relative to those in older age groups, thereby either increasing or decreasing between-cohort inequality.

The effects on between-cohort inequality of growth, family size, and composition are illustrated using information on the age-consumption profiles from Taiwan. The first issue is how changes in the rate of economic growth affect between-cohort inequality. As shown by the right-hand terms in Eq. (9), the amount of between-cohort inequality is determined by the shape of the *cross-sectional* age-profile of consumption, which is influenced both by age-specific tastes for consumption and by the rate of economic growth. For example, if individuals have flat age-consumption profiles and the rate of economic growth is high, the consumption of the younger, wealthier cohorts will exceed that of older, less wealthy cohorts, resulting in high between-group inequality. Conversely, steep age-consumption profiles coupled with high economic growth can result in flat cross-sectional age-consumption profiles, which (as shown in Figure 1) is close to the actual case in Taiwan.

To illustrate the effects of economic growth on inequality, we start with the following equation for the average logarithm of consumption of those at age a born in year b:

$$\begin{aligned} x_{ab} &= \overline{\ln(c_{ab})} = \alpha_a + (\omega_0 + gb) \\ &= \alpha_a + \omega_0 + g(t-a). \end{aligned} \tag{17}$$

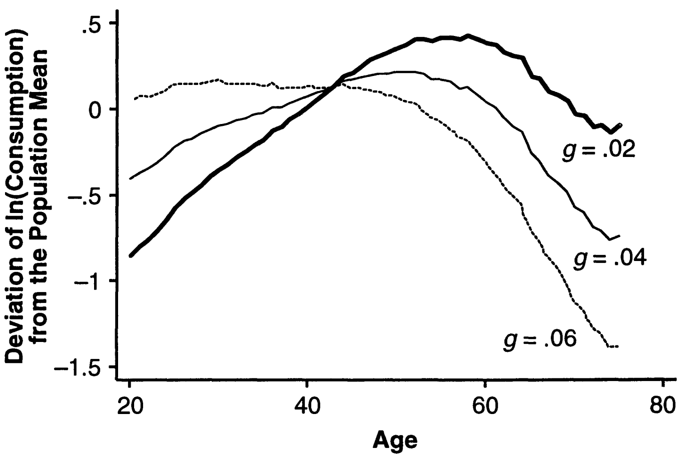
This equation is simply a restatement of the consumption Eq. (12) with the additional assumption that lifetime wealth is growing at rate g, so that more recently-born cohorts consume more at each age than did their parents and grandparents. The term α_a represents the effects of age-specific tastes and the interest rate on consumption. Given Eq. (17), the deviation of the logarithm of consumption of those aged a from the national average depends only on the age effects α_a and the rate of economic growth:

$$x_{ab} - \overline{x_{ab}} = (\alpha_a - \overline{\alpha_a}) - g(a - \bar{a}). \tag{18}$$

Figure 8 shows the cross-sectional age-consumption profiles, expressed as deviations from the mean over the entire population, for three rates of economic growth. We calculated the mean of the logarithm of consumption using population weights consistent with a steady-state population growth rate of 2% per annum, age-specific headship probabilities from the survey data, and the Taiwanese life table from Keyfitz and Flieger (1990). For each profile, the age effects α_a are the same as those graphed in Figure 2 for Taiwan. As expected, higher growth "pivots" the profiles clockwise in favor of the young. At a growth rate of 4% per year, which is close to Taiwan's current situation, the profile is quite flat; but either higher or lower growth results in more between-cohort inequality.

The effects of changes in the rate of population growth n on between-cohort inequality differ with different rates of economic growth. Tabulations presented in Deaton and Paxson (1995) indicate that at high rates of economic growth, declines in the rate of population growth increase between-cohort inequality, so that it is true that population aging increases both within- and between-cohort inequality. However, at low rates of economic growth the opposite is true: Population aging results in less between-cohort inequality, although the increase in across-cohort inequality is large enough to offset this effect even at a growth rate of 0.

FIGURE 8. CROSS-SECTIONAL AGE-CONSUMPTION PROFILES AT DIFFERENT ECONOMIC GROWTH RATES, WITH 2% POPULATION GROWTH, IN TAIWAN



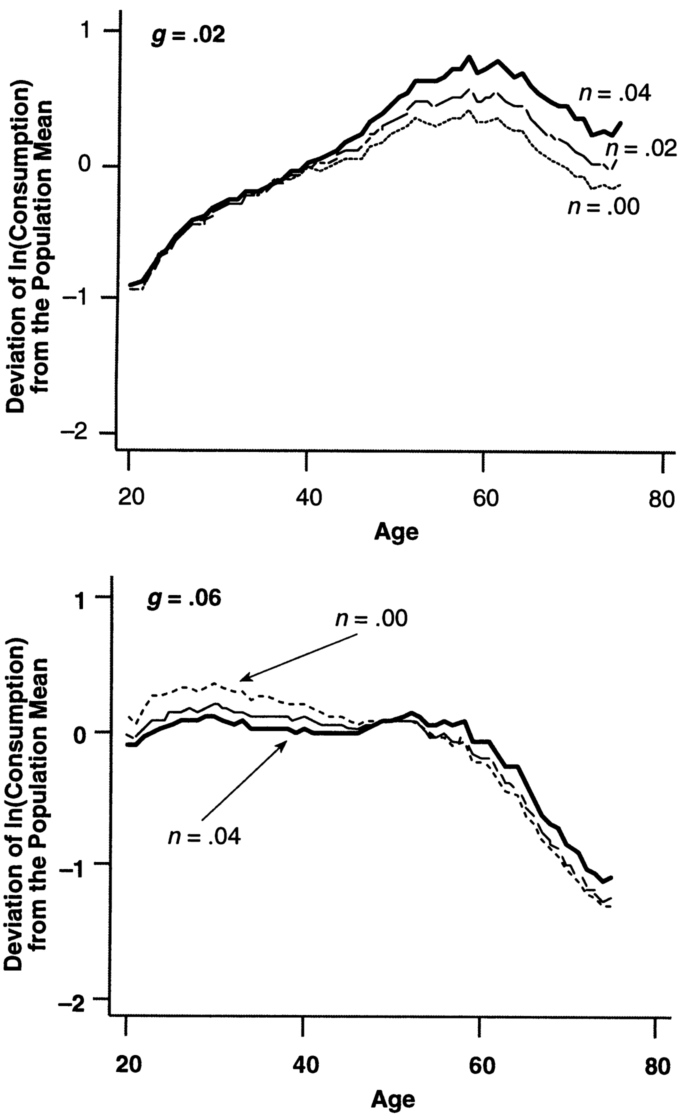
The next issue is how changes in household size and age structure that are caused by changes in the rate of population growth affect cross-sectional age-consumption profiles and between-cohort inequality. To examine this issue, we modify the consumption equation to include controls for the logarithm of family size and the ratio of children to family size:

$$\begin{aligned} x_{ab} - \overline{x_{ab}} = (\alpha_a - \overline{\alpha_a}) &+ \beta_S(\ln S_a - \overline{\ln(S_a)}) \\ &+ \beta_k(k_a - \overline{k_a}) - g(a - \bar{a}), \end{aligned} \tag{19}$$

where S_a is average family size for households with heads aged a and k_a is the average ratio of children to family size. Estimates presented in Deaton and Paxson (1995) indicate that β_S equals 0.24, so that larger families have higher consumption, and that β_k equals 0.21, so that controlling for family size a higher proportion of children in the household results in lower consumption.

Calculating the effects of population growth on the age-consumption profile requires information on how population growth affects the size and age composition of households. As in the last section, we assume that the probability that a person is a household head at each age is invariant to changes in population growth. We also assume that the probability that a person aged α lives in a household headed by someone aged a is also invariant to the rate of population growth. These assumptions enable us to calculate values of S_a and k_a for various rates of population growth (full details are in Deaton and Paxson 1995). The implied effects of population growth on age-consumption profiles are illustrated in Figure 9, which shows cross-sectional age-consumption profiles (again expressed as deviations from means) for values of n ranging from .01 to .03. The upper panel shows results for a

FIGURE 9. CROSS-SECTIONAL AGE-CONSUMPTION PROFILES FOR DIFFERENT RATES OF POPULATION AND ECONOMIC GROWTH, TAIWAN



growth rate of .02, and the lower panel shows results for a growth rate of .06.

Figure 9 illustrates two important points. First, changes in the size and age structure of households that are caused by changes in population growth may have large effects on age-consumption profiles. The results for Taiwan indicate that at higher rates of population growth the age-consumption profile is pivoted counterclockwise, so increasing the consumption of households headed by older people relative to those headed by younger people. Although on average higher population growth increases family size for all households, it increases the proportion of members who are children most in households with younger heads in childrearing years; and a higher proportion of children depresses consumption. Second, the effects of changes in the rate of population growth on between-cohort inequality depends critically on the rate of economic growth. When economic growth is low, as in the left-hand panel, the young consume much less than the old. Increases in the population growth rate depress their consumption relative to the old even further, and cause between-cohort inequality to increase. Conversely, when economic growth is high, as in the right-hand panel, the young consume more than the old. Increases in the rate of population growth depress consumption of the young relative to the old, "flattening" the cross-sectional age-consumption profile and reducing between-cohort inequality.

That these effects can be quantitatively significant is illustrated by the tabulations presented in Deaton and Paxson (1995), which show the effects of population aging on both within- and between-cohort inequality. The results indicate that at low rates of economic growth, population aging will increase total within-cohort inequality but will reduce between-cohort inequality enough that the net effect of aging is to *reduce* total inequality. At the higher rates of economic growth, which are closer to what Taiwan has experienced over the last several decades, population aging increases both within- and between-cohort inequality. For example, the calculations imply that at economic growth of 6% per year, a decline in the rate of population growth from 3% to 1% would yield an increase in the variance of the logarithm of consumption from .313 to .416. This increase is equivalent to a large increase in the Gini coefficient from 0.309 to 0.352, again assuming for the purposes of the calculation that consumption is lognormally distributed.

CONCLUSION

In this paper, we have used data on consumption and income and saving from Great Britain, Taiwan, Thailand, and the United States to estimate life cycle models of saving. We used the results—in particular the estimated age-specific saving rates—to calculate the effects on national saving of changes in the rates of economic and population growth. The important conclusion of this exercise is that these effects are *small.* Although the data are consistent with age-specific saving rates that decline with age, the correlation is not sufficiently strong nor is the amount of saving sufficiently large to provide much of a lever for growth rates to influence aggregate saving.

We think it is likely that higher rates of economic growth engender higher rates of national saving through life cycle effects, but each percentage-point increase in the growth rate will result in only a fraction of a percentage point increase in the saving rate. The life cycle effect of growth on saving is not large enough to explain the cross-country evidence, nor the declines in saving rates that have accompanied the productivity slowdown in advanced industrialized countries. Both of these phenomena require that changes in growth rates change saving rates by twice as much, and must therefore be attributed to other factors.

Much the same is true for the effects of changes in the population growth rate on national saving. Again, it is reasonable to suppose that slower rates of population growth in Asia will reduce Asian saving rates, but the effects are small, and we find nothing to suggest that the "greying" of Asia will bring the Asian miracle to a halt by choking off its (local) supply of capital.

There is stronger evidence for the second topic of the paper, the effect of growth rates on aggregate inequality. Although there are many other factors at work, there is clear evidence from the four countries we examined that within-cohort inequality increases with age. Thus it is both possible and plausible that the redistribution of the population toward the elderly will increase aggregate inequality. This is guaranteed to occur if the intercohort contribution to inequality is sufficiently small, as is the case when the cross-sectional age-profiles of consumption are relatively flat.

There must also be considerable doubt about the validity of the life cycle model itself, or at least about its usefulness for interpreting the evidence on saving. The model does not account for the downward trend in the saving rate in the United States, which seems to come from declines in age-specific saving rates—not from an aggregation effect through the redistribution of population mass or relative purchasing power toward the low-saving elderly. And although consumption and saving patterns can be interpreted in terms of age and cohort effects as required by the theory, the estimated effects are not always plausible and are frequently suggestive of the importance of other, non-life-cycle explanations. The existence of time trends in age-specific saving ratios is one issue. Another issue is that the age, cohort, and year effects in consumption are closely mirrored by the age, cohort, and year effects in income—a complicated way of saying that for each cohort, consumption and income move very closely together. Such "tracking" of income by consumption has been noted widely (see, in particular, Carroll and Summers 1991). Although life cycle theory predicts some tracking because the age profile of earnings is similar to the age profile of household size, not all tracking can be so accounted for, and there is a supposition that other factors (e.g., liquidity constraints or precautionary motives) are tying income and consumption more closely together than is permitted in the standard life cycle models. Another possibility is that transfers between generations, either through gifts between family members or through more formal social security systems, make life cycle saving unnecessary. For our current purposes, it matters relatively little whether savings are small because of the parameters of the life cycle model or because borrowing constraints or precautionary motives mean that the model itself needs serious modification. In either case, the result is the same. There is insufficient saving at any age for it to provide a mechanism for either economic or population growth to contribute much to national saving rates.

The mechanism that links inequality to aging is perhaps more robust because it depends less on the validity of the life cycle model of saving. Although the life cycle model under uncertainty predicts that consumption inequality should increase with age, there are other explanations of the phenomenon. For example, earnings inequality might increase with age for the reasons discussed by Mincer (1974), and borrowing constraints might result in consumption tracking income. The results reported here and in Deaton and Paxson (1994a) show that for whatever reason, within-cohort inequality increases with age not only for consumption, but also for income and earnings. Unless the mechanism that generates this inequality is itself a function of demographic structure, the aging of populations will always exert an effect that increases inequality.

REFERENCES

Bosworth, B.P., G. Burtless, and J. Sabelhaus. 1991. "The Decline in Saving: Evidence from Household Surveys." Pp. 183-241 in *Brookings Papers on Economic Activity*, No. 1. Washington, DC: Brookings Institution.

Carroll, C. Forthcoming. Buffer-stock Saving and the Life Cycle/Permanent Income Hypothesis. *Quarterly Journal of Economics*.

Carroll, C. and L.H. Summers. 1991. "Consumption Growth Parallels Income Growth: Some New Evidence." Pp. 305–43 in *National Saving and Economic Performance*, edited by B.D. Bernheim and J.B. Shoven. Chicago: University of Chicago Press for National Bureau of Economic Research.

Deaton, A.S. 1992. *Understanding Consumption*. Oxford: Clarendon Press.

Deaton, A.S. and C.H. Paxson. 1992. "Patterns of Aging in Thailand and Côte d'Ivoire." Pp. 163–206 in *Topics in the Economics of Aging*, edited by D.A. Wise. Chicago: University of Chicago Press.

———. 1994a. "Intertemporal Choice and Inequality." *Journal of Political Economy* 102:437–67.

———. 1994b. "Saving, Growth, and Aging in Taiwan." Pp. 331–57 in *Studies in the Economics of Aging*, edited by D.A. Wise. Chicago: University of Chicago Press for National Bureau of Economic Research.

———. 1995. "Saving, Inequality, and Aging: An East Asian Perspective." *Asia-Pacific Economic Review* 1:7–19.

Gersovitz, M. 1988. "Saving and development." Pp. in 382–424 *Handbook of Development Economics*, edited by H. Chenery and T.N. Srinivasan. New York: American Elsevier.

Hall, R.E. 1978. "Stochastic Implications of the Life Cycle-Permanent Income Hypothesis: Theory and Evidence." *Journal of Political Economy* 86:971–87.

Hermalin, A.I., M.B. Ofstedal, and M.-C. Chang. 1991. "Types of Support for the Aged and Their Providers in Taiwan." Unpublished manuscript. Population Studies Center, University of Michigan.

Hubbard, R.G., J. Skinner, and S.P. Zeldes. 1995. "Precautionary Saving and Social Insurance." *Journal of Political Economy* 103:360–99.

Keyfitz, N. and W. Flieger. 1990. *World Population Growth and Aging: Demographic Trends in the Late Twentieth Century*. Chicago: University of Chicago Press.

Lee, R.D. 1994. "The Formal Demography of Population Aging, Transfers, and the Economic Life Cycle." Pp. 8–49 in *The*

Demography of Aging, edited by L.G. Martin and S.H. Preston. Washington, DC: National Academy Press.

Lee, R.D. and S. Lapkoff. 1988. "Intergenerational Flows of Time and Goods: Consequences of Slowing Population Growth." *Journal of Political Economy* 96:618–51.

Mincer, J. 1974. *Schooling, Experience, and Earnings*. New York: Columbia University Press for the National Bureau of Economic Research.

Modigliani, F. 1970. "The Life-Cycle Hypothesis of Saving and Intercountry Differences in the Saving Ratio." Pp. 197–225 in *Induction, Trade, and Growth: Essays in Honour of Sir Roy Harrod*, edited by W.A. Eltis, M.F.G. Scott, and J.N. Wolfe. Oxford: Clarendon Press.

———. 1986. "Life-Cycle, Individual Thrift, and the Wealth of Nations." *American Economic Review* 76:297–313.

———. 1990. "Recent Declines in the Savings Rate: A Life Cycle Perspective." *Rivista di Politica Economica* December:5–42.

Paxson, C.H. 1996. "Saving and Growth: Evidence from Micro Data." *European Economic Review* 40:255–88.

U.S. Department of Commerce. 1993. *An Aging World II*. International Population Reports P95/92–3. Washington, DC: U.S. Bureau of the Census.