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Growth, Demographic Structure, and National Saving in Taiwan

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THIS CHAPTER IS concerned with the effects that changes in demographic structure have had on Taiwan's national saving rate, and how coming changes in its age structure—notably population aging—will affect the future saving rate. We examine this topic within the framework of the life cycle hypothesis. Life cycle theory is a natural starting place, because it implies that changes in demographic structure can exert potentially large effects on national saving. According to the theory, increases in the number of people who save (presumably those in middle age) relative to those who save little or dissave (the very young and the elderly) will increase the aggregate saving rate. A related implication of the life cycle hypothesis is that changes in the rate of growth of per capita income affect saving. Higher rates of economic growth increase the lifetime wealth of the young relative to the old, and the effects of higher growth on saving are much the same as the effects of increasing the numbers of young relative to the old. The life cycle hypothesis also delivers a rich set of predictions about interactions between economic growth and the age structure. As is emphasized in the variable-rate-of-growth models of Fry and Mason (1982) and Mason (1987 and 1988), the effects of changes in age structure on the saving rate will depend on the lifetime wealth of individuals in different age groups, something that is determined by economic growth. These interactions are important for understanding how the Taiwanese saving rate has evolved over time and how it may change in the future.

A large empirical literature examines the relationships between demographic structure, economic growth, and saving. Early international comparisons of saving rates by Leff (1969) and Modigliani (1970) provided empirical support both for a positive association between growth and saving rates and for a negative effect of dependency rates—the ratio of young and old to the working ages—on aggregate saving. Subsequent empirical analysis has been less positive. The demographic effects were shown not to be robust to improvements in data and econometric technique (see, e.g., the review in Gersovitz 1988: 415–417). Although the correlation between per capita growth and saving rates remains robust in the aggregate data, there is strong and accumulating evidence from the analysis of microeconomic data in individual countries that life cycle saving is not the cause (Carroll and Summers 1991; Deaton and Paxson 1997; Paxson 1996).

An older literature implicates dependency rates, not only in decreasing saving rates, but also in hindering growth. Under the presumption that saving drives growth, not the other way round, Coale and Hoover (1958) argued that with high population growth the burden of children would decrease workers' ability to save and so limit growth. More recently Higgins and Williamson (1997), using pooled cross-sectional and time-series data from a number of Asian countries, have found strong negative effects of the dependency rate on saving and concluded that "Coale and Hoover were right." Indeed Bloom and Williamson (1998) and the Asian Development Bank (1997) attribute about a third of East Asia's recent growth performance to the increases in saving and labor supply, relative to population, provided by the "demographic gift" of low fractions of children and the elderly associated with the postwar baby boom and the rapid subsequent drops in fertility. Since the "gift" will have to be repaid as the baby boomers age, once again there are concerns for the future, not only for saving rates, but also for growth.

Taiwan's saving, growth, and demographic structure conform to the broad patterns of East Asia. High rates of economic growth have accompanied an increase in private saving rates from 5 percent of disposable income in 1950 to around 25 percent in the early 1990s. A sharp drop in fertility succeeded the postwar baby boom, so that the dependency ratios became low when the baby boomers entered the labor force around 1970; and they will remain low until the boomers leave around 2010. In 1950, 52 percent of the population were under age 20 and 43 percent were between ages 20 and 60; by 1995 the corresponding fractions were 33 percent and 56 percent (Table 1). The results of Bloom and Williamson (1998) as well as Coale and Hoover (1958) imply that Taiwan's future may look quite different from its recent experience. Lee, Mason, and Miller (in this volume) have simulation results for Taiwan that point in the same direction.

Our own recent work has been on the determinants of saving in Taiwan, in Asia, and elsewhere, with a primary focus on the effects of economic growth on saving and a good deal less attention to the effects of demographic structure on saving. Working with repeated cross-sectional surveys, our approach has been to estimate age and cohort effects in income and consumption in order to derive the age profiles of saving that are the fundamental determinants of the relationship between growth and

TABLE 1 Percentage distribution of the population by 10-year age groups: Taiwan, selected years, 1950–95

Age group	1950	1965	1980	1995
0–9	29.08	30.95	21.34	14.94
10–19	23.26	23.42	21.99	18.23
20–29	17.44	13.24	20.49	17.14
30–39	12.36	12.61	11.66	17.87
40–49	8.56	9.13	9.54	13.07
50–59	5.11	6.15	8.16	7.77
60–69	2.99	3.07	4.51	6.46
70+	1.19	1.42	2.31	4.53

NOTE: Before 1969, professional servicemen, conscripts, and prison inmates were not included in the population numbers.
SOURCES: Data for 1950, 1965, and 1980 were obtained on diskette from the Directorate General of Budget, Accounting and Statistics. Data for 1995 are from Ministry of Interior (1996: Table 1).

aggregate saving in the life cycle hypothesis. If saving rates are negatively correlated with age—as in the simplest model of saving for retirement—higher growth redistributes resources toward high savers and increases saving. In Paxson (1996) and Deaton and Paxson (1997 and 2000) we find that age-saving profiles for Taiwan, Thailand, Indonesia, the United States, and Britain show little negative correlation with age, which implies little effect of growth on aggregate household saving. These results also have implications for the relationship between demographic structure and saving. Because our estimated age profiles of saving are uncorrelated with age, changes in the rate of population growth have little or no effect on aggregate saving, at least for comparisons between demographic equilibria. The absence of such equilibrium effects for Taiwan and other countries is documented in Deaton and Paxson (1997). However, the changes in demographic structure that take place during a demographic transition are quite distinct from differences in structure across demographic equilibria with different fertility rates, so that the absence of an effect of population growth rates on aggregate savings does not imply that there will be no effects of demographic structure on saving during a transition. In consequence, our earlier results are not necessarily inconsistent with either those of Higgins and Williamson (from macroeconomic cross-country evidence) or those of Lee, Mason, and Miller (from simulations.)

In this chapter we use improved techniques and updated data from Taiwan to see if, after all, it is possible to tell a story in which demographic change has large effects on saving. We do this not because we have any reason to revise our previous empirical results—indeed they are replicated on the most recent data—but because our previous work paid too little explicit attention to demographic factors, and because our results looked only at demographic structures in equilibrium, rather than at the actual transition. Furthermore, our previous work relied on information about *households*, and on how saving rates vary over the household life cycle, where the latter is defined by the age of the household head. This approach, which is dictated by the data, poses problems when we try to translate demographic change, which makes predictions about people, into predictions about households, whose saving is what we know about from the data. It is far from obvious how changes in the age structure of population translate into changes in the age structure of household heads, and whether the age profiles of saving by heads' ages can be expected to be invariant to changes in demographic structure. In consequence, results about growth and saving are determined as much by assumptions about household structure as by our measurements of the age profiles of saving.

Following our more recent approach (Deaton and Paxson 2000), we construct life cycle saving profiles for *individuals*, not households. This new approach, like the household approach, makes its own assumptions and requires its own suspensions of disbelief. But the assumptions and suspensions are different, and it turns out that the new approach gives different results. Specifically, our estimated life cycle saving profile for Taiwan has a pronounced "hump" that is consistent with the hypothesis that greater old-age and youth dependency rates depress saving. These negative effects of children and the elderly on saving are masked when one is working at the household level, since few elderly and virtually no children live in independent households.

Given the hump-shaped age-saving profile we estimate, the life cycle hypothesis implies that increases in the rate of population growth can either increase or reduce the aggregate saving rate. At higher rates of population growth there will be fewer elderly dissavers relative to middle-aged savers, and this will cause the saving rate to rise. Children, however, will make up a greater fraction of the population, and this will depress the saving rate. Which effect dominates depends on the rate of economic growth. At very high rates of per capita income growth—in excess of 6 percent per annum—the lifetime wealth of the elderly is small relative to that of younger persons, and their dissaving contributes little to the aggregate saving rate. In this case the depressing effect on saving of relatively more children predominates, and increases in the rate of population growth are predicted to reduce the aggregate saving rate. Conversely, at slow rates of economic growth—in the range of 0 to 3 percent per annum—the lifetime wealth of the elderly is relatively large, as is their (negative) contribution to aggregate saving. Increases in the rate of population growth that reduce the elderly fraction of the population increase the aggregate saving rate.

Although these positive or negative effects of population growth on saving are possible at high or low rates of economic growth, the growth rates that have characterized recent Taiwanese history fall between these two extremes. We show that at growth rates in the range of 5 or 6 percent per annum, increases in the rate of population growth produce almost no change in the aggregate saving rate. The effects of having relatively fewer elderly are almost exactly offset by the effects of having relatively more children. The same is true for the Taiwanese demographic transition: given Taiwan's economic performance, actual changes in demographic structure account for a very small fraction of the increase in the private saving ratio since 1950. Likewise, the aging of the baby-boom generation will not adversely affect saving rates provided that growth rates of income are maintained. However, if growth rates were to fall, the aging of Taiwan could indeed drive saving rates back to their levels in 1950.

The following section begins with a summary of the life cycle model and its estimation using the "household" method. We lay out the basic implications of the life cycle hypothesis for the relationship between age structure and saving, then provide an explanation of the general methodology for parsing consumption and income into age and cohort effects, and for estimating the age profiles of saving. The presentation is verbal and brief; mathematical statements are given in the Appendix. The next section moves to an approach in which the family is seen "as a veil concealing purely individualistic behavior" (Gersovitz 1988: 401). This "individual" life cycle model allows a reinterpretation of the household data, permits a much cleaner link between population structure and aggregate saving, and shows much clearer demographic effects on age profiles of saving. We then use the individual results to construct counterfactuals for the past, running Taiwan's demographic transition through the estimated age profiles to assess the contribution of demographic trends to the rise in the saving rate. We also estimate the likely future effects on saving of the aging of Taiwan's baby-boom generation. In the final section we summarize our conclusions and discuss some of the more important and controversial assumptions on which the work is based.

Life cycle and aggregate saving by households

The life cycle hypothesis of consumption asserts that consumption over the life cycle follows an age profile, the shape of which is determined by preferences (or needs, or incentives to postpone consumption), and whose level—but not shape—is set by lifetime resources. The age profile of earnings or of income has no effect on the shape of the age profile of consumption, but serves only to determine its level. The budget must balance over the lifetime; but in any given period, borrowing and lending make up the difference between consumption and income. The life cycle hypothesis rests on the questionable assumption that capital markets are sufficiently developed to allow people to borrow against future earnings. Despite its shortcomings and the mixed empirical evidence on its validity, the model nevertheless provides a coherent framework for the analysis of life cycle saving patterns. (See Deaton 1992 for a thorough discussion and assessment of the life cycle hypothesis.)

In a growing economy like Taiwan's, successive birth cohorts are each richer over their lifetimes than were their predecessors, so that, according to the hypothesis, the age profiles of consumption, earnings, and income are higher for later-born cohorts. Although the levels of these profiles differ across cohorts, their shapes remain the same, provided there are no changes in tastes or in incentives to postpone consumption, and provided also that earnings profiles retain a characteristic age profile that does not change shape across cohorts. Given these assumptions (which are not trivial and will be discussed further below), the ratio of consumption to income or equivalently its complement, the ratio of saving to income, can be described by an age profile that has the same shape for all cohorts. A final assumption, that bequests are either zero or an unchanging fraction of lifetime wealth, implies that the level of the age profile of the saving ratio will be the same for all cohorts.

The shape of the age profile of saving determines how the aggregate saving rate responds to changes in economic growth and demographic structure. In what Modigliani (1970) calls the "stripped-down" model, income is constant until retirement, and consumption is constant throughout life, so that there is positive saving until retirement, and negative saving (dissaving) from retirement until death. This negative association between age and the rate of saving implies that the aggregate saving rate will be larger the larger is the rate of per capita economic growth. That is so because the young, who are saving, have higher lifetime resources than the old, who are dissaving. The aggregate saving rate will also be larger the larger is the ratio of young to old (by exactly the same scale effect.) Faster economic growth drives higher aggregate saving rates, as does faster population growth. According to this argument, saving in Taiwan is threatened by the "graying" of the population, as it would be by a reduction in the rate of per capita income growth.

The stripped-down model needs to be modified to recognize the existence of children and their likely effects on the age profiles of consumption, earnings, and saving. While there is no lack of theoretical models, it is unclear from theory alone how these effects will work. The most popular view is that children act as a substitute for retirement saving. Children are costly to rear and to educate, and they require parental time and attention that lowers family earnings. The saving of families with children will therefore be lower, at least while the children are in the household. But children help care for their elderly parents, and their support reduces the need for parents to save when their children are young and lowers dissaving in retirement. There are other possibilities, however. If bequests are an important motive for saving, the presence of children may raise their parents' saving throughout the life cycle, for example to provide housing or small businesses for their children and grandchildren. Or, if parents have strategic bequest motives, they may accumulate assets so as to ensure their children's attention and good behavior.

Whatever the effects, it is clear that the presence and age structure of children are potentially important "taste and need" factors that shape the age profile of family saving. In the aggregate, changes in the ratio of children to adults in the population will also affect the aggregate saving ratio. Further, as Fry and Mason (1982) emphasize, these effects of demographic structure can be expected to interact with the effects of economic growth in determining national savings. For example, suppose that children lower saving for young families enough to cause dissaving at the beginning of the family life cycle, but that saving occurs in the household's middle age and perhaps some dissaving takes place in its old age. An increase in the number of children relative to middle-aged adults (with the fraction of elderly held fixed) will depress the saving rate. This is the familiar "youth dependency" effect. In addition, at higher rates of economic growth, young families will have greater lifetime resources than middle-aged families, the scale of their dissaving will be larger, and the depressing effects of additional children on the saving rate will be bigger. This is the interaction effect.

A similar story, which is more relevant to Taiwan's future, can be told about the effects of population aging. Shifts in the population from middle-aged savers to older dissavers will depress saving. The slower the rate of economic growth, the greater is the lifetime wealth of the older dissavers relative to middle-aged savers and the larger is the decline in the saving rate.

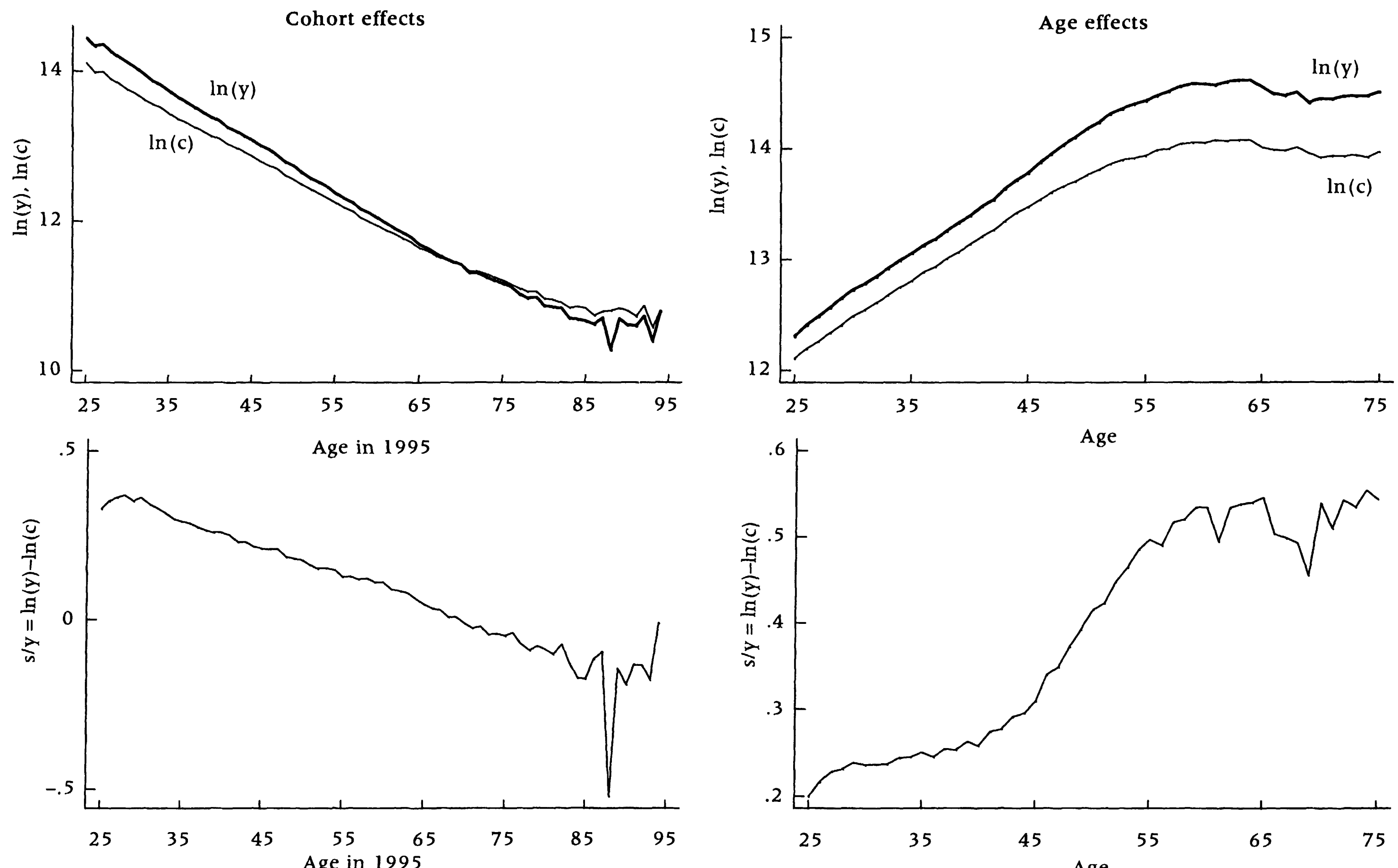
Taiwan is well-endowed with the kind of data required to investigate life cycle saving behavior. The Survey of Family Income and Expenditure (sometimes referred to as the Survey of Personal Income Distribution), collected by the Directorate-General of Budget, Accounting and Statistics, has gathered annual data on income and consumption since 1976 on approximately 14,000 households (fewer in the first two years), and this time series of cross-sectional surveys can be used to track birth cohorts of Taiwanese over time. At the time of writing, we have data through 1995, so that we can track the cohort of individuals born in 1945, for example, through their randomly sampled representatives in 20 surveys, from age 31 to age 50. Although we do not have enough years to track any one cohort through its whole life course, we can take the 20-year segments for many overlapping birth cohorts and infer from them both the cohort effects—the position of the segment for each birth cohort—and the age profiles, which are taken to be common across cohorts.

The techniques, which are straightforward, are described in full detail in our earlier work (Deaton and Paxson 1994a, 1994b, 1997, and 2000; Paxson 1996). The main equations are summarized in the Appendix, equations (A1) through (A6). Since consumption for each household is an age profile scaled by a lifetime wealth effect, the logarithm of consumption is the sum of a logarithmic age profile and a logarithmic wealth effect. For a birth cohort observed in a specific year, say the cohort of 1945 observed at age 40 in 1985, the average of the logarithm of consumption is therefore the sum of an age effect (that for age 40) and a cohort effect (that for persons born in 1945). To estimate these effects, we go through each survey, calculate the average of the logarithm of consumption for each cohort in that year, and then pool the data across the 20 survey years. Because the data are for households rather than individuals, we must define age and cohort in terms of a characteristic of the household. We take the age of the household head as that characteristic, a decision that we discuss at some length in the next section. For each survey we include only observations in which the head is between the ages of 25 and 75; there are too few heads outside this range to allow useful inference. These calculations give us averaged data on 70 cohorts, born between 1901 and 1970, who are observed as household heads for up to 20 years each. These averages of the logarithm of consumption are the observations on our dependent variable, which is regressed on a set of age and cohort dummy variables, thus allowing the shape of the age and cohort profiles to be determined by the data. There is no need to assume any particular parametric form. We then repeat the procedure for the logarithms of income, to obtain age and cohort effects for log income. The difference between the logarithm of income and the logarithm of consumption is approximately the saving ratio, which can also be decomposed into age and cohort effects.

The results are shown in Figure 1, which is an updated version of Figure 9.9 in Deaton and Paxson (1994a). Cohort effects in log consumption, income, and the saving ratio are shown in the two left panels, and the corresponding age effects in the two right panels. Because cohorts are defined here by age in 1995, we move from later-born to earlier-born cohorts as we move from left to right; and because earlier-born cohorts are poorer over their lifetime, the cohort effects decline from left to right. The age profiles of income and consumption do not have the hump shape that is often used to illustrate life cycle models. Instead, both consumption and income appear to increase steadily throughout the life course.

Of greatest interest here are the associated age and cohort profiles of saving, neither of which conforms very well to the standard expectations of life cycle theory. In particular, the estimated income and consumption cohort effects do not cancel out (i.e., they are not proportional in levels), and the lower left panel shows higher *lifetime* saving rates out of *lifetime*

FIGURE 1 Cohort and age effects in log consumption, log income, and the saving ratio: Taiwan, household model



NOTE: ln(y) is the logarithm of income, ln(c) is the logarithm of consumption, and s/y is the (approximate) saving ratio, measured as ln(y)–ln(c). Age refers to the age of the head of the household.

resources for younger Taiwanese households. Taken at face value, this finding implies that bequest motives are becoming more and more important over time, with later-born households leaving larger fractions of their lifetime wealth to their descendants. The age effects are even more contrary to standard theory. Instead of saving rates being negatively correlated with age, with saving characterizing young households and dissaving characterizing the elderly, saving rates simply rise with age. Households with the oldest heads are saving about 30 percentage points more of their incomes than households with the youngest heads.

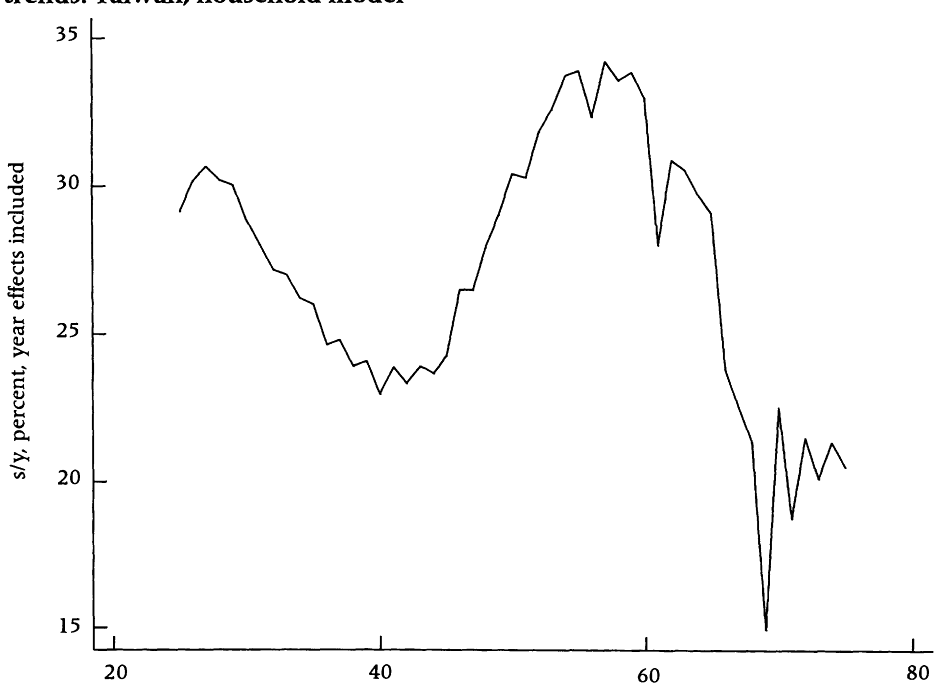
How can we explain these patterns? The life cycle explanation remains possible, but we would have to assign a great deal of importance to bequests, and we must accept quite unconventional age patterns of saving. When we first began this work, that was the explanation we adopted. However, when these methods were applied to the United States and Britain in Paxson (1996), the difficulties of interpretation were even more extreme, and it became necessary to think of other explanations. Suppose that for reasons we do not understand, everyone in Taiwan decides that it is more important to save, so that all cohorts, at all ages, slowly raise their saving ratios over time. (In the United States the supposition runs the other way, with everyone deciding to decrease their saving ratios over time.) We do not know what causes this change, except that, by assumption, it has nothing to do with the life cycle hypothesis. Suppose, then, we look for a life cycle interpretation, and fit cohort and age effects to these data. For any given cohort, we can fit the facts by choosing a rising age profile for saving; as people move through time, they will save more because the age profile is rising with age. But to match the assumption, we also want the 40-year-olds today to be saving more than the 40-year-olds did yesterday; and to make this happen, we need to choose cohort effects that are higher for later-born cohorts or, equivalently, are falling with cohort age in the base year. Offsetting time trends in age and cohort effects are just a complicated way of matching a time trend in the data, and this is what we see in Figure 1. See also Appendix equations (A9) through (A11). When the same calculations are done for the United States, we find the same phenomenon in reverse, with saving showing falling age and rising cohort effects, thus matching the secular fall in the saving ratio. For both Taiwan and the United States the changes in saving ratios have taken place for all households and are synchronized in calendar time.

These results tell us something of great importance: over the periods of our data the rise in the aggregate saving rate in Taiwan (and the decline in the aggregate saving rate in the United States) cannot be explained by the life cycle hypothesis, which attributes the trend to changing relative lifetime incomes and sizes of different age groups, each with a different saving rate. Instead, individual households at all ages and from all birth cohorts have been saving more in Taiwan, just as they have been saving less in the United States.

That the life cycle hypothesis cannot explain the trends does not mean that life cycle motives are not operative, nor that changes in demographic structure and economic growth would not affect aggregate saving rates. We can find out how much they might do so by conceding the time trend to "forces unknown," and then examining the cohort and age effects that remain. One way to do this is to force the cohort effects in the consumption and income regressions to be identical, so that there are no cohort effects in the estimated saving ratios, or, equivalently, to regress the average saving ratios for each cohort at each age on age dummies, without including cohort effects. More generally, this last regression can be estimated by allowing year effects (a dummy variable for each year) in addition to the age effects. Although the year effects are significant, their inclusion or exclusion has little effect on the estimated age effects, which are shown (from the regressions with year effects excluded) in Figure 2.

The age profile of saving in Figure 2 makes a good deal more sense than that in Figure 1, though it is still very far from the hump shape of

FIGURE 2 Age effects in saving with restricted cohort effects and time trends: Taiwan, household model



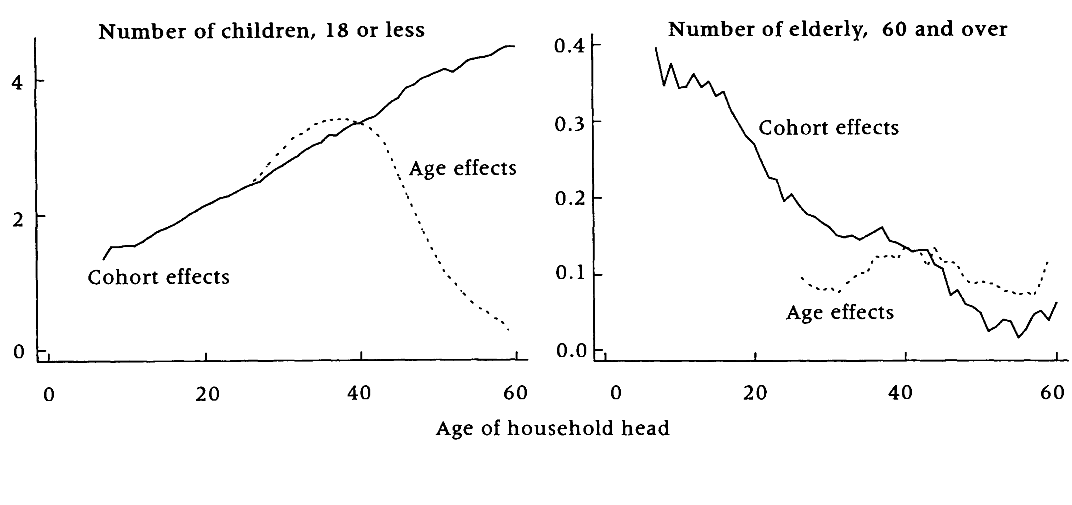
NOTE: s/y is the approximate saving ratio, measured as ln(y)–ln(c), multiplied by 100 to convert to a percent. The age effects that are graphed come from a regression that excluded year effects.

standard life cycle theory. Saving rates are high for young households, when their heads are in their mid-20s. The saving rate then declines with age, until families with heads in their early 40s are saving 7 percentage points less than those in their mid-20s. Saving rates then rise until late middle age, declining once again thereafter. That saving should be lower for heads in their 60s and 70s is consistent with life cycle theory, although their saving positive amounts is not what one would expect from dissaving in retirement. The obvious candidate for explaining the low saving trough earlier in the life cycle is the presence in the household of children, and possibly of elderly adults.

Figure 3 shows age and cohort effects in the average number of children (left panel) and the average number of persons aged 60 and over (right panel), by the age of the head. The cohort effects in the number of children (left panel) show the decline in fertility: households with more recently born heads contain fewer children. Those in the right panel indicate that households with more recently born heads contain more elderly members. This reflects the increasing fraction of the elderly in the population, which more than offsets the increasing tendency of the elderly to live alone. Both sets of age effects peak at around age 40, which coincides with the trough in the age profile of saving in Figure 2, giving some support to the idea that children and dependent elderly depress saving.

The "twin trough" pattern of lifetime saving in Figure 2 implies that, in general, aggregate saving will respond to changes in both demographic structure and the distribution of lifetime income across birth cohorts. Even so, we have shown elsewhere (Deaton and Paxson 2000: Table 1; Paxson 1996: Table 3) that the effects are small. Indeed, at a rate of population

FIGURE 3 Age and cohort effects in number of children and number of elderly in the household: Taiwan



growth of 2 percent, the results in Figure 2 imply a small *negative* effect on aggregate saving of increases in the rate of per capita income growth. With steady-state income growth at 2 percent per annum, the predicted saving rate is 20.3 percent. This falls to 20.1 percent at 4 percent growth and to 20.0 percent at 6 percent growth. These are quite different from the large positive effects predicted by stripped-down models, in which a rise in the growth rate of a percentage point increases the saving rate by about two percentage points. The reason for the small effects is clear from the figure; changes in the rate of growth smoothly redistribute lifetime resources across age groups, so that the effect of growth on saving depends on the correlation over the life cycle of saving and age. Because of the twin troughs in the age profile of saving, this correlation is close to zero, indicating that changes in the equilibrium rate of income growth have little effect on aggregate saving. Of course these conclusions concern changes in the equilibrium rate of growth; patterns of growth that enrich particular cohorts at the expense of others could exert large temporary effects on the aggregate saving rates as those cohorts moved through the relevant age ranges. We shall return to this issue later in the chapter.

The effects of changes in demographic structure on aggregate savings are a good deal harder to deal with than those of income growth. It is straightforward to redistribute population mass across the ages in Figure 2, which would be the effect of changes in the equilibrium rate of population growth, and to calculate the effects on aggregate saving. And for the same reason as before—the low correlation between saving rates and age over the life cycle—the effects are small. However, changes in the rate of population growth not only change the weights of the age profile in aggregate saving, they must also change the age profile itself. Recall that the age profile relates to households, not individuals, and that the ages are the ages of household heads, not of individuals. When fertility falls, there are fewer children per adult and fewer children per household head at each age, so that if the first trough in Figure 2 is associated with children, we might reasonably expect it to flatten out. Similarly, there are now relatively more elderly people, only some of whom live by themselves. Others live with their children, and the higher ratio of elderly to adults in each household is likely to reduce household saving in the age group of the household head.

In our previous work, particularly Deaton and Paxson (1997), we made allowance for these effects as best we could. Two steps are required in making the adjustment. First, the age profiles need to be explicitly linked to the demographic composition of the household, which is done by adding variables for average household composition to the age dummies in the consumption, income, and saving regressions. Second, in making projections with different rates of population growth, it is necessary to "repackage" the numbers of people at different ages into numbers and compositions of households by the age of the head. Neither step is straightforward. The estimation of demographic effects on saving, unlike the age and cohort effects, is done parametrically, and an inappropriate functional form or unfortunate selection of age groups could compromise the results. But the second step is the more difficult. We use headship probabilities by age from recent surveys to turn population predictions into household predictions, but we have little confidence in these essentially mechanical projections. In consequence, when we find that changes in the rate of population growth have little effect on aggregate savings, it is possible that our results are driven as much by our auxiliary assumptions to get from people to households, as by the age profile in Figure 2, about which we are relatively confident.

Figure 2 suggests that different results might be possible under different assumptions. If the first trough in the age profile were to be raised by lower fertility, the negative correlation between saving and age would be increased, so that aggregate saving would become more responsive to changes in the rate of economic growth. This is exactly the sort of effect emphasized by the "variable rate of growth" model.

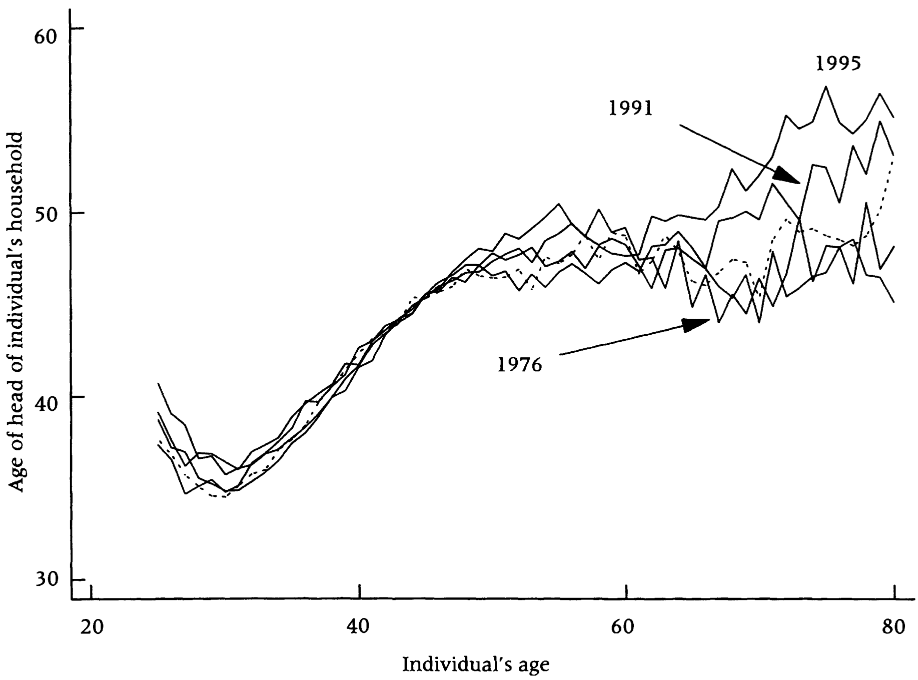
Life cycle and aggregate saving by individuals

It is difficult to move from population projections to their consequences for saving because the projections are about the numbers of *individuals* at different ages, whereas our theory and our data about saving relate to *households* indexed by the age of the household head. In our work to date we have solved this disjunction in favor of the households, transforming population projections into household projections. In this section we discuss the alternative, which is to turn the life cycle theory and its empirical implementation into a theory of individual behavior and to use estimates of age profiles for individuals, not households. The idea is to think of each person as following his or her own life cycle trajectory from birth, each being endowed with an age-specific consumption and income profile, and each satisfying a lifetime budget constraint tying lifetime income to lifetime consumption. Using Gersovitz's (1988) term, we regard households as veils for the individuals within, behind which individual consumption, income, and saving take place unobserved, with only the household totals revealed to the investigator. As Gersovitz emphasizes, such households permit individuals to consume more or less than their income without the household necessarily having to save or dissave, and by removing credit constraints, may allow household members to conform more closely to the theory than would be the case on their own. Young children and many of the elderly have no earnings, and their consumption can be supported from the earnings of other family members without the transfer of assets or liabilities. It would be possible to extend this model to allow household consumption to be different from the aggregate of the consumption of each of its members, thus recognizing joint consumption, public goods in the household, and economies of scale. But in the current analysis, which can be thought of as a first cut, we adopt the simplest version—that household income, consumption, and income are the sums of income, consumption, and saving of each household member.

There are other good reasons for moving away from households, and they have to do with being forced to define a household by the age of its head. When we track cohorts of households from one survey to another, the 40-year-olds in one survey followed by the 41-year-olds in the next, any changes in headship from one year to another will mean that we are not truly observing the same cohort through time. In Taiwan the head is defined as the main earner in the household. For example, in a household consisting of a working couple, children, and the husband's father, the older man will be head as long as he earns more than his son. But if, from one year to the next, the son's earnings overtake those of his father, the "age" of the household head will drop by perhaps 25 years, even though household composition has not changed. Equally problematic is the treatment of the elderly. Because many elderly people in Taiwan live with their children, where they may not be recorded as household heads, households headed by people in their 60s and 70s are a selected sample that is likely to become less and less representative with age. When we look at the saving behavior of those households, and how it changes with age, we have no way of separating out the changes that come from behavior and those that come from selection.

That selection is important can be demonstrated in a number of ways. For example, the education of male heads relative to the education level of all males of the same age increases with age from age 40 (Deaton and Paxson 2000). The heads who survive as such are more highly educated than those who do not. Figure 4 illustrates the selection more directly. It shows for each age (on the horizontal axis) the average age of the heads of households (on the vertical axis) to which individuals of that age belong. (For example, the figure indicates that 30-year-old Taiwanese individuals live in households in which the average age of the household head is approximately 35.) If it were true that once a household head, always a household head, the lines on the graph would coincide with the 45-degree line, at least after the age at which individuals become heads. Instead, the graphed lines fall at first, because many people in their 20s live in their parents' homes. Once we are beyond the age at which people have set up independent households, the head's age rises more or less one for one with age; this is the area of the graph where there is no selection. But after about age 50, the head's age ceases to rise with the individual's age, either be-

FIGURE 4 Age of head of household by individual's age: Taiwan, selected years 1976–95



cause the earnings of a younger person in the household exceed that of the previous head, so that the household becomes "younger," or because a previous head moves in with his or her children or relatives. (The increase in the slope in the last few years indicates that more elderly Taiwanese are living alone.) But the deviation of these lines from the 45-degree line shows that it is dangerous to base a research strategy on the assumption that heads remain heads until they die. If instead of following households, we follow cohorts of individuals, we avoid most of these problems. Emigration, immigration, and death apart, the cohort of 41-year-old individuals is the same as the cohort of 40-year-old individuals a year before.

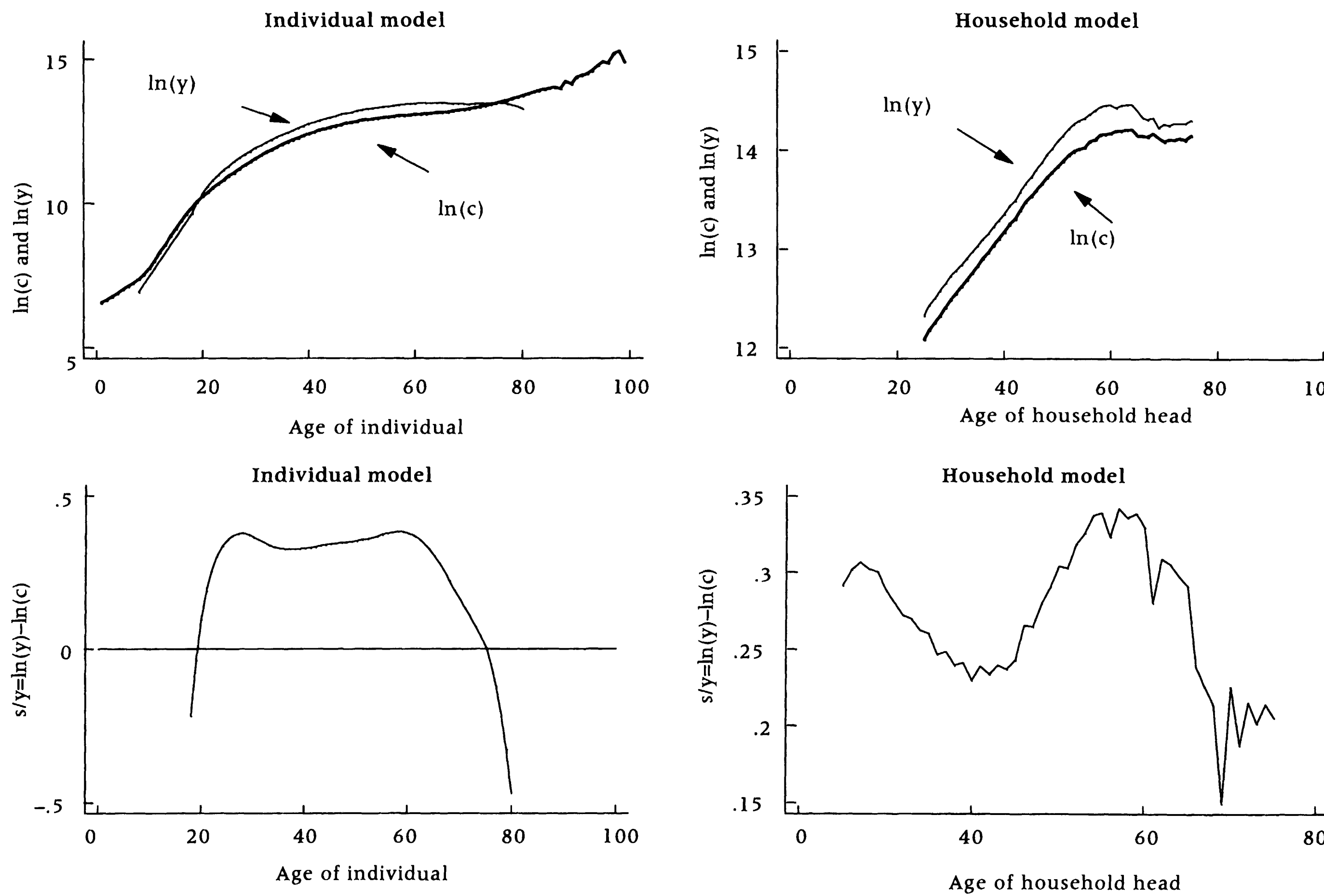
Our empirical procedures are explained in detail in Deaton and Paxson (2000), and the main equations are given in the Appendix, equations (A7) and (A8). Here we present a nontechnical summary. As before, our starting point is the set of 20 cross-sectional surveys on household income, consumption, and saving. For each cross-section in turn, we regress household consumption on the numbers of people of each age in the household, with age running from 0 to 99. Each regression, which is estimated without a constant, thus has 100 right-hand side variables (most of which are zero for any given household). Suppose we write the coefficient on age a from the survey in year t as $\beta(t, a)$. This quantity is the average consumption in year *t* of people of age *a*, which, according to the theory, is the product of an age effect (preferences) and a cohort wealth effect (the lifetime budget constraint). We can therefore treat each $\beta(t, a)$ in exactly the same way as we treated the household consumption data in the household approach in the previous section. That is, taking logarithms, we regress on a set of age and cohort dummies. The resulting coefficients are the estimated age and cohort effects for individual consumption, not household consumption. As before, the procedure is replicated for income and for the saving ratio, or at least its approximation, the difference between the logarithm of income and the logarithm of consumption.

There are two main differences between this approach and that outlined in the previous section. First, allowing for all ages separately allows needs to vary with age in a flexible way; this is something like including general controls for household demographic structure in the household regressions. Second, we are tracking individuals, not households, through the successive cross-sections, thus avoiding the problem of selection into and out of household headship.

Where there are only a few observations for an age group, particularly among the elderly, the estimates of the β's are imprecise and occasionally are negative. We deal with these by smoothing the estimates over adjacent age groups, essentially by taking moving averages. We impose a priori the restriction that incomes are zero for those aged 16 or less. Because these numbers are small in any case, and occasionally negative if children take a parent out of the labor force, we would risk obtaining many negative numbers by attempting to estimate these effects. We also impose the restriction that income is zero for those aged 80 and older. An alternative procedure for estimating age and cohort effects, one that does not require taking logarithms and so can accommodate zero or negative values, is described by us in Deaton and Paxson (2000). That method yields results very similar to those shown here.

Figure 5 (top row) shows the resulting age profiles for the logarithms of income and consumption for both the individual (left panel) and household (right panel) approaches, together with the saving profiles for both approaches (bottom row). (The bottom right panel reproduces Figure 2.) The issue of time trends in saving rates is the same for the household and individual approaches so that, as before, we restrict the cohort effects in income and consumption to be identical in the top row. The saving profiles in the bottom row are obtained simply by regressing the "saving rate," defined as the difference between the average logarithm of income and the average logarithm of consumption, on a set of age dummies. No cohort effects are included because these are restricted to be equal in income and consumption. A set of year effects can be included (but are not in these results); their inclusion makes little difference to the age profile of saving.

FIGURE 5 Cohort and age effects, log income, log consumption, and the saving rate: Taiwan, individual and household models



NOTE: ln(y) is the logarithm of income, ln(c) is the logarithm of consumption, and s/y is the (approximate) saving ratio, measured as ln(y)–ln(c).

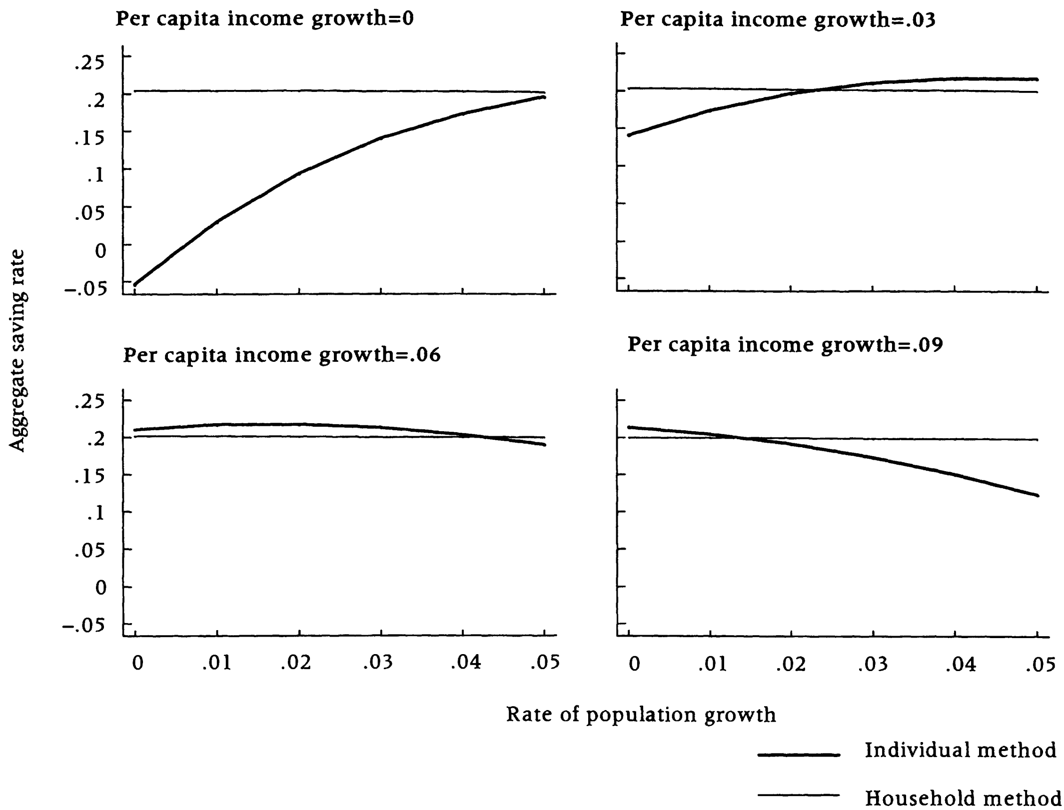
In the household approach we must restrict age to the range in which there are household heads, here 25–75. In the individual approach we cover the full age range, 0–99 for consumption and 17–79 for income. We graph the saving rate for the age range 17–79, for which income is positive. Note that we are not assuming that saving is zero for individuals either older than 79 or younger than 17. Since income is assumed to be zero for these groups, and consumption positive, saving is negative and the saving rate is not defined.

The two graphs in the top row are reassuringly similar; after all, we are looking at the same data. Over the common age range, the two pairs of age profiles are quite similar, with log income lying above log consumption. The main difference lies in the range of ages not covered by the household approach. Partly by construction and partly by measurement, consumption exceeds income at low and high ages. As a result the two saving-rate profiles in the bottom row look much more different from each other than do the two profiles for either consumption or income (but note the different scales). In the individual model, saving rates are negative at the beginning and end of the life cycle. At intermediate ages, saving rates are similar to those based on the household data—indeed there is still a trough around age 40—but higher, as must be the case to compensate for the dissaving of children and the elderly.

It is straightforward to use the age profiles of consumption and income shown in Figure 5 to examine the effects of population growth on the national saving rate. The consumption and income levels of a cohort of individuals at each age are simply the product of lifetime wealth, which is assumed to grow at a constant rate across cohorts, and the exponents of the age effects of the logarithm of income and of consumption shown in Figure 5. Different rates of population growth imply different distributions of the population across ages. For any rate of population growth, the aggregate saving rate can be calculated as the ratio of the population-weighted sum of saving (income minus consumption) to the population-weighted sum of income, as shown in Appendix equation (A12). This aggregate rate can be calculated by using either the "household" or "individual" results in Figure 5, although when working with households it is necessary to make assumptions about the fractions of each age group that are household heads (Deaton and Paxson 1997). Another difference is that, when working with households, we compute the sums only over the age range 25–75, for which we have estimates; for individuals we use the full age range, 0–99.

Figure 6 shows aggregate saving rates as a function of the rate of population growth, with each panel calculated at a different rate of economic growth across cohorts. We show results using both the "individual" and "household" methods. Using either method, the results confirm our calcu-

FIGURE 6 Aggregate saving rates and rates of population growth for four rates of per capita economic growth: Taiwan



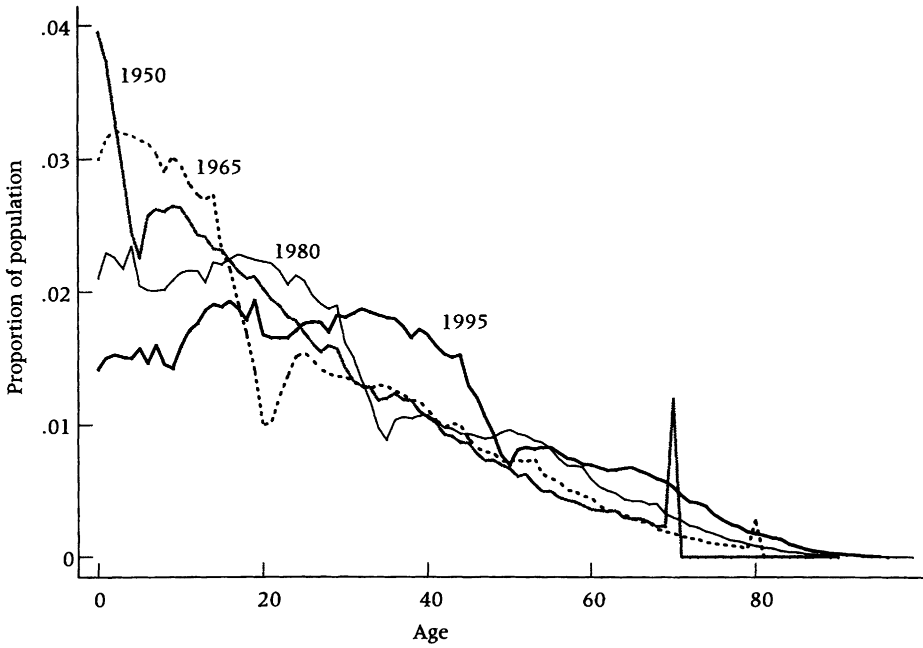
lations in Deaton and Paxson (1997) that at the high growth rates of per capita income that Taiwan has enjoyed for much of the last quarter-century, changes in the rate of population growth have little effect on national saving (see the bottom left panel). Higher population growth increases the numbers of middle-aged savers in relation to elderly dissavers; but it also increases, by even more, the numbers of the young who are dissaving, and the net effect is small. The results using the individual method are different, however, at lower and higher rates of income growth. In the top left panel we have assumed a per capita growth rate of zero, so that lifetime wealth is identical across cohorts. Because the youngest dissavers are not wealthy relative to middle-aged savers, the dominant effect of a decline in equilibrium population growth is through the increase in the numbers of the elderly relative to the middle aged—the young have insufficient resources to count for much—and the aggregate saving rate falls. Fertility decline can have strong negative effects on aggregate saving in Taiwan, but only when per capita incomes are growing slowly. The bottom right panel shows the other extreme, in which the growth rate of per capita income is very high, illustrated here at 9 percent per annum. Because young people are now so much richer than the old—at 9 percent growth a 5-year-old is 8.6 times richer than her 30-year-old father, 74 times richer than her 55-year-old grandfather, and 641 times richer than her 80-year-old great-grandfather—the dissaving associated with children is large enough to become the dominant effect when the young are more plentiful. At high enough growth rates of per capita income, saving declines with increases in the rate of growth of the population. The "household" method does not deliver these predicted effects of population growth on the saving rate, because (using this method) saving rates are similar across age groups.

Demographic structure and the past and future of saving

The calculations in Figure 6 are of saving rates when demographic and economic growth are in equilibrium, and when the growth rates of income and population have been the same for an indefinite period of time. Because these equilibria take so long to be established—we have to wait for the whole population to be replaced before the new patterns of age groups and lifetime wealth effects are established—it is possible that they are not relevant or useful for interpreting history over a few decades, or for projecting future saving, except in the very distant future. Indeed, as Higgins and Williamson (1997) argue, the effects that arise from a baby-boom generation working through the population are unlikely to be captured by a model that can handle only equilibrium demographic structures. Figure 7 and Table 1 show the actual structure of the Taiwanese population at 15-year intervals from 1950 through 1995, and the progress of the postwar baby boom is clearly visible. (The "missing" 20-year-olds in the 1965 data were in the military, who were not included in the population data until 1969. The massive age heaping at age 70 in the 1950 distribution reflects the fact that, in that year, the highest age category was "70 or older.")

It is straightforward to calculate the effects of the actual demographic structure on saving using the results that we have already obtained. The procedure is essentially the same as that which produced the results in Figure 6, except instead of using the steady-state age distribution of the population implied by different rates of population growth, we use the actual age distribution of the Taiwanese population from 1947 to the present. As before, consumption and income at each age for each cohort is the product of the lifetime wealth of cohort members and the exponents of the age effects in Figure 5 (with income set to zero for the youngest and oldest individuals). The cohort-specific lifetime wealth terms can be obtained up

FIGURE 7 Age structure of the population: Taiwan, 1950–95

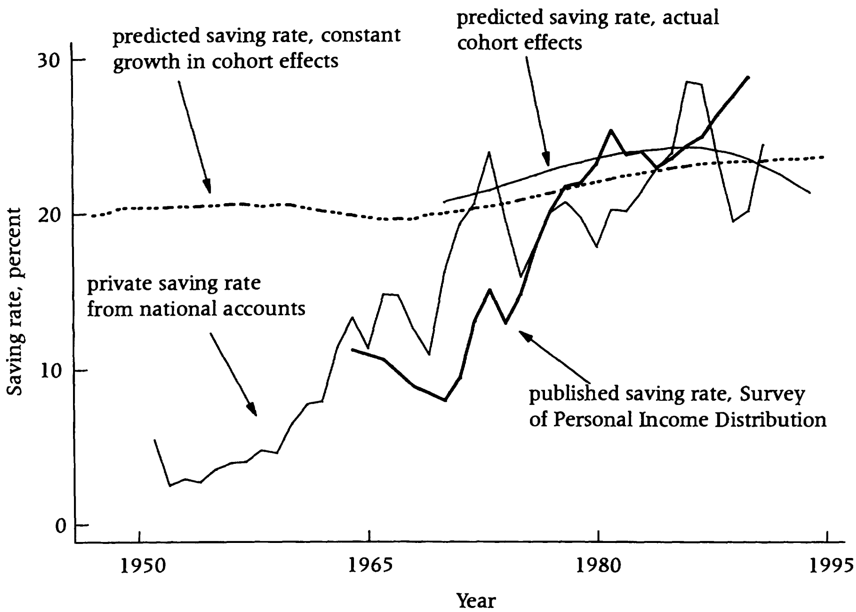


SOURCES: See Table 1.

to scale—and the scale factor cancels in the aggregate saving rate—in one of two ways: either by using the actual estimated cohort effects from the regressions shown in Figure 5, or by assuming that cohort effects grow from year to year at a constant rate equal to the average growth in our estimated cohort effects. The latter approach, which yields a growth rate of lifetime wealth across cohorts of 6.08 percent per year, has the attraction of allowing us to project backward as far as we like, while the former, although more realistic, confines us to cohorts alive during our data period of 1976 through 1995. (Since the estimated cohort effects grow fairly steadily, the difference is not large, as we shall see.) These calculations are not intended to capture year-to-year fluctuations in saving rates, for example those associated with oil shocks or other unanticipated events. But they should give us a good guide to trends and an indication of the contribution of demographic changes to those trends.

Figure 8 and Table 2 present the results graphically and numerically. It is important to start by establishing that the data from the surveys on which our analysis rests are consistent with the aggregate data. The first three columns of Table 2, the first two of which are illustrated in Figure 8, show the aggregate private saving from the national accounts, the private saving rate from the survey documentation, and the private saving rate as calculated by us from the survey data. The first two series differ somewhat,

FIGURE 8 Actual and counterfactual saving rates: Annual figures, Taiwan 1950–95



NOTE: The lines in this figure correspond to columns 1, 2, 4, and 5 in Table 2.

which is not surprising given that the former is private saving (including that by not-for-profit institutions) and the latter is household saving out of disposable income. However, both series follow similar trends. Our own calculations are a point or two lower than the published survey tables, again because of the precise definitions of consumption and income (we include transfers made to others in consumption, whereas the survey tables report net transfers out of income), not because our calculations differ from those of the government statisticians. The microdata are consistent with the aggregate behavior in the national accounts.

Table 2 and Figure 8 also show the two hypothetical saving figures that come from applying the actual age structure of the population to our estimates of age effects. Neither set of counterfactuals explains more than a very small fraction of the growth in the aggregate saving rate, and none at all before the 1970s. None of this should be surprising in the light of the results presented in the earlier sections of the chapter. From the first household estimates it was clear that, in order to fit the data, it was necessary to supplement the age profile of saving with a set of year dummies to capture the secular rise in the saving rate. As we saw then, and as reappears now, the life cycle hypothesis cannot explain the rising saving rate in Taiwan. That rise comes from a secular trend in saving rates among all cohorts at

TABLE 2 Actual and projected saving rates (percent): Taiwan, alternate years, 1952–94

Year	Private saving rate from national accounts (1)	Published saving rate, Survey of Personal Income Distribution (2)	Calculated saving rate, Survey of Personal Income Distribution (3)	Predicted saving rate, actual cohort effects (4)	Predicted saving rate, constant growth in cohort effects (5)
1952	2.55				20.41
1954	2.75				20.47
1956	3.95				20.59
1958	4.79				20.46
1960	6.52				20.56
1962	7.93				20.18
1964	13.34	11.23			19.88
1966	14.84	10.61			19.63
1968	12.55	8.87			19.63
1970	16.27	8.00		20.73	20.01
1972	20.62	13.12		21.26	20.30
1974	19.65	12.96		21.82	20.64
1976	18.03	17.92	16.53	22.47	21.09
1978	20.73	21.73	20.06	23.05	21.56
1980	17.86	23.17	21.43	23.54	22.03
1982	20.13	23.76	21.62	23.91	22.44
1984	22.90	22.96	20.38	24.14	22.75
1986	28.53	24.36	22.16	24.25	23.06
1988	23.57	26.38	23.80	24.07	23.25
1990	20.17	28.80	25.75	23.48	23.37
1992			26.43	22.55	23.48
1994			25.07	21.35	23.54

NOTES: The private saving rate from national accounts is calculated as the saving of households and private nonprofit institutions, divided by saving plus final private consumption expenditure. Columns 4 and 5 are predicted saving rates that are based on actual population figures and our estimates of expenditure and income by age, and estimates of cohort-specific lifetime wealth.

SOURCES: Column 1 is based on data from Directorate General of Budget, Accounting and Statistics (1991a: Tables 16 and 18). Column 2 is from Directorate General of Budget, Accounting and Statistics (1991b: Table 9). The calculations in column 3 are based on the series of cross-sectional household surveys described in the text.

all ages; it cannot be attributed to changes in the age distribution of the population or to changes in the distribution of spending power over an unchanging but age-varying profile of saving.

What, then, of the future? The baby-boom generation is aging, and according to our estimates the elderly save less. Does this mean that aggregate saving rates will fall? The answers, given in Figures 9 and 10, are based on population projections taken from Bos et al. (1994). The differences in the three graphs are due to differences in assumptions about the rate of per capita income growth, and to differences in the way we handle the cohort effects.

In both parts of Figure 9, cohort effects are set according to their equilibrium pattern for the relevant rate of economic growth. In the left panel the rate of growth is set at 6 percent, close to its historical value, and is held constant as the population ages; this can be taken as our central projection. The growth in saving rates still has some way to go, but will become negative after 2010. Even so, the effects are modest, and the aggregate household saving rate in 2030 will be only a percentage point or two lower than it is now. The right panel repeats the calculation, but with the cohort wealth effects growing at 3 percent and 9 percent in addition to the original 6 percent, which is shown for comparison (note the change in scale from left to right panel.) In the case in which the assumed growth rate of income is halved, from 6 to 3 percent, the fall in saving rates is large, and by 2035 the saving rate is below 11 percent.

These last calculations can be criticized on the grounds that, although we are using actual demographic data and the best available demographic projections, the cohort wealth effects are set at their equilibrium values so that, when income growth is 3 percent, we assume not only that it will be 3 percent in the future, but also that it was 3 percent in the past. We correct this problem in Figure 10. There we assume that growth changes from 6.08 percent to its stipulated new value in 1998 and calculate new wealth figures for each cohort, assuming that everyone knows immediately that the change will be permanent. For persons beyond age 65, we assume that lifetime resources are set and are unaffected by the change in income growth. For those who are in the middle of their working careers, their lifetime wealth is adjusted downward according to age, with the youngest suffering the largest change because they have the largest number of years to work at the new, lower growth rate.

FIGURE 9 Projections of aggregate saving rates under alternative assumptions about the annual rate of economic growth: Taiwan, 1947–2035

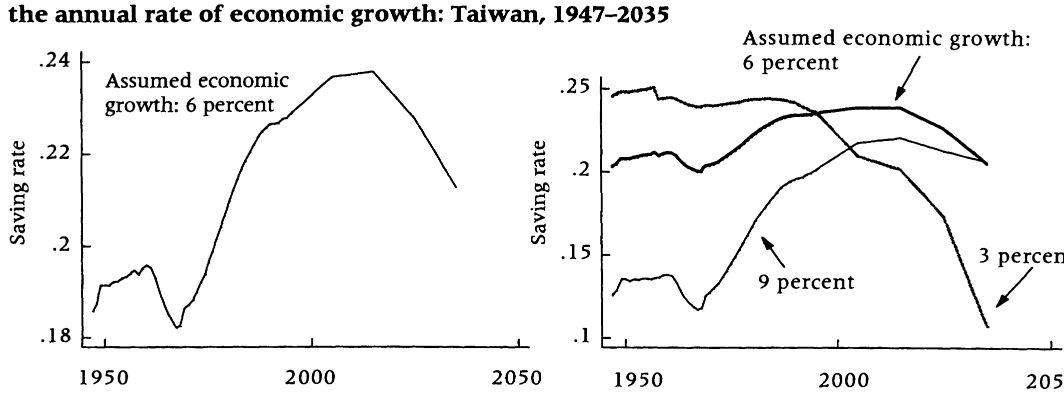
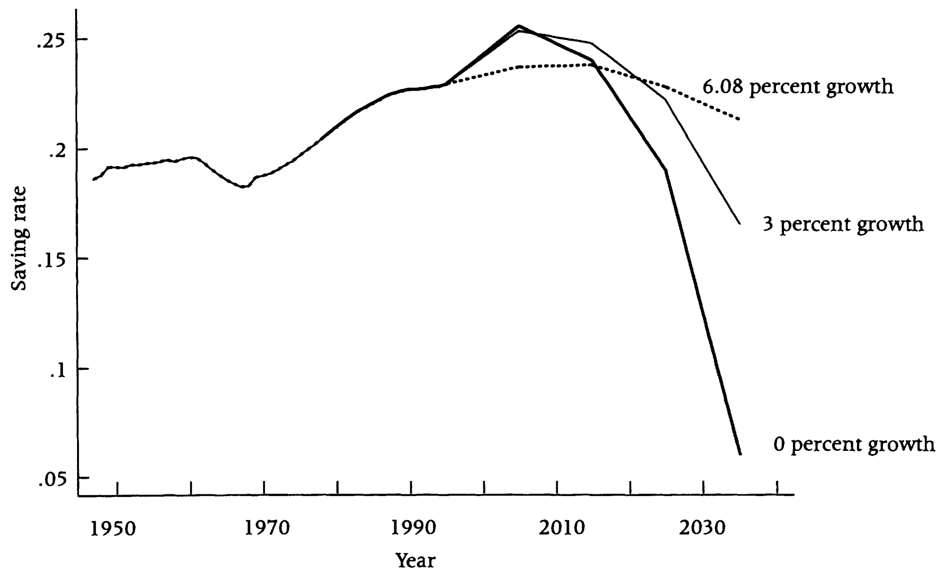


FIGURE 10 Projected saving rates, Taiwan 1947–2035, at the annual rate of income growth of 6.08 percent and under two alternative assumptions as to the rate of growth beginning in 1998



With these modifications, the drop in saving rates with lower growth is less severe than previously: compare the 3 percent line in Figure 10 with the 3 percent line in the right panel of Figure 9. Nevertheless, the same general effect is present. If Taiwan's economic growth rate falters, the combination of lower growth and the aging of the baby-boom generation is capable of sharply reducing the rate of saving. If economic performance is maintained, likely changes are small enough to be of little concern, and in that circumstance there is no reason to see the graying of Taiwan as a threat to its rate of saving.

Summary and conclusions

The life cycle hypothesis of saving supposes that the profile of consumption over the life cycle is set by preferences, including demographic choices and outcomes, whereas the position of the profile is set by lifetime resources. As a result the average consumption, income, and saving of a birth cohort in any given year can be decomposed into the product of an age effect, which is the same for all cohorts, and a cohort effect that summarizes the average lifetime resources of the cohort. In this chapter we have used time series of cross-sectional household surveys from Taiwan to estimate these age profiles for consumption, income, and saving; and we have used the results to investigate the extent to which demographic change and economic growth can account for the increase in Taiwan's saving rate within a life cycle story of saving. The methodological advance of the study, apart from an updated and extended data base, consists in the use of an "individual" version of the life cycle model in which we apply the life cycle hypothesis to the complete life cycle of individuals and trace cohorts of individuals through the various surveys, rather than use the more conventional approach of treating households as the unit of analysis and tracking them by the age of the household head. The new approach allows us to recognize that people regroup from one household to another over time, for example as the elderly move in with their children, and it requires no arbitrary assumptions about how changes in population structure affect household formation and structure.

Several important results emerge from the analysis. First, as in previous work, we find that the increase in Taiwan's saving rate, like the decline in the saving rate in the United States, cannot be explained by the life cycle mechanism, which attributes changes in aggregate saving to changes in relative population and relative resource weights over an unchanging age profile of saving. As in our own and others' previous work, we find that the upward trend in saving is not an aggregation effect, but an individual effect. Young Taiwanese now save a larger fraction of their resources than did their parents at the same age.

Once this is admitted, and the main part of the change in saving is attributed to unexplained time trends, more modest effects can be attributed to the changing structure of the population and changing patterns of lifetime resources. In particular, we find an age profile of saving with "two troughs," one associated with children, the other associated with old age. There is no overall correlation between age and saving rates, so that there are no large differences in aggregate saving rates across populations in demographic equilibrium at different population growth rates. Nevertheless, because of the two-trough pattern, changes in population structure through a demographic transition can have temporary effects on saving rates, where "temporary" is understood to be relative to demographic equilibrium. We use the model to assess the historical evidence in Taiwan, and to see how much of the actual increase in saving can be attributed to its actual demography and economic growth. Between 1970 and 1990, Taiwan's household saving rate rose from around 10 percent to around 30 percent. Of this 20 percentage point increase, only about 4 percentage points can be attributed to life cycle effects generated by economic growth and population change. Nor does the demographic future of Taiwan, and in particular its rapid aging, threaten its saving rate, at least if economic growth is maintained. It is only in the most pessimistic scenarios, in which very much slower income growth interacts with aging, that saving rates are predicted to fall sharply.

Our results are rather different from those in the two related chapters in this volume, by Lee, Mason, and Miller, who attribute a substantial share of the increase in Taiwan's saving rate to demographic change over the transition, and by Tsai, Chu, and Chung, who find that the higher saving rates of successive cohorts of Taiwanese can be tied to their own rising life expectancy and to the enhanced probabilities of survival for their children. Perhaps the most fundamental difference between our work and that of the others is the lesser extent to which we believe that the life cycle hypothesis provides an adequate account of household saving in Taiwan, or indeed elsewhere. In our earlier work (Deaton and Paxson 1994b), which is the platform on which Tsai, Chu, and Chung build, we assume that the life cycle hypothesis is valid and estimate parameters conditional on its truth. In our subsequent work, particularly Paxson (1996) and Deaton and Paxson (1997 and 2000), and the current study, the anomalies that seemed minor in our first study reappeared in much more serious forms, not only for Taiwan, but for other countries as well, including the United States. In consequence we were forced to conclude that time trends in saving ratios—upward in Taiwan and downward in the United States—could not be well explained within the life cycle framework, a conclusion that other researchers have also reached and is increasingly accepted in much of the recent consumption literature (e.g., Bosworth, Burtless, and Sabelhaus 1991; Poterba 1994). If this conclusion is denied and an attempt is made to fit the life cycle hypothesis to the Taiwanese data, the result is an upward trend of saving rates with age in the age profile and an offsetting upward trend with date of birth in the cohort profile. This latter result can be linked to other trending variables, such as the declining force of mortality, as discussed in Tsai, Chu, and Chung. The question then arises whether other trending variables might not do the same job as well or better, or indeed whether cohort effects are not simply a label for the time trend in Taiwanese saving for which we have no explanation. Lee, Mason, and Miller's simulations, like our own earlier work, take the truth of the life cycle model for granted. As we know, such a model can be used to make demographic trends affect saving rates, but the validity of the simulations depends on denying the central empirical anomaly that is revealed by our work and by other research in the literature.

Like all analyses and forecasts, our results rest on a number of assumptions, and we conclude by noting the most important and most controversial. In particular, we assume the constancy of various age profiles over time. As in most of the work on life cycle saving, and following Modigliani's (1970) original lead, we assume that the age profile of earnings is not changed by economic growth, so that economic growth affects earnings only across cohorts and not the age pattern of earnings for any given cohort. That this assumption may not be true has been pointed out many times in the past, as has the fact that the prediction that economic growth increases saving depends on it. Unfortunately, an examination of how growth changes age profiles requires more than the 20 years of data that are currently available, and we have maintained the standard (Modigliani) assumption on the grounds that it gives the growth-to-saving link the best chance of accounting for the data. Similar considerations prevent us from examining the effects of changes in female labor force participation on the age profiles of earnings. Our attempts to allow for it were frustrated by the brevity of the time series, at least for this purpose. We are also conscious of the absence of any treatment of decreases in the force of mortality. In a world where retirement ages are legislated and fixed, lengthening of the retirement span can be expected to increase the rate of individual saving if retirement saving is important. In an economy as flexible as Taiwan's, and without state-mandated retirement, we would expect an increase in life expectancy to increase the work span as well as the retirement span, with no obvious predictions for the rate of saving. If this were to be the case, the age profile of earnings would change in response to decreases in mortality rates, and for the same reasons as before we have made no attempt to take this into account.

Appendix

In the life cycle hypothesis with perfect certainty, consumption at any age is proportional to lifetime resources. Hence for individual i (household or person) born at date b and observed at age a (i.e., at date $b + a$), consumption c_{iab} is given by

$$c_{iab} = f_i(a)W_{ib} \ , \tag{A1}$$

where $f_i(a)$ is the age profile of consumption and W_{ib} is a measure of lifetime resources. Note that whereas the age profile is indexed on i, and so varies over individuals, it is independent of birth date b, so that the distribution of age profiles over individuals within each cohort is the same for all cohorts. The measure of resources W_{ib}, however, is invariant with respect to age. Taking logarithms of (A1) and averaging over all members of the same cohort at the same age, we obtain

$$\overline{\ln c_{ab}} = \overline{\ln f(a)} + \overline{\ln W_b} \ , \tag{A2}$$

where the lines over the variables denote means. Equation (A2) can be estimated by regressing the average of the logarithm of consumption for those born in b and observed in $b + a$ on a set of age and cohort dummies—that is, from the regression

$$\overline{\ln c} = D^a\beta_c + D^c\gamma_c + u_c \ , \tag{A3}$$

where $\overline{\ln c}$ is a stacked vector of log consumption with elements corresponding to each cohort in each year, D^a is a matrix of age dummies, and D^c is a matrix of cohort dummies. The coefficients β_c and γ_c are the age effects and cohort effects in consumption (c subscripts stand for consumption, c superscripts for cohorts), and u_c is the sampling (or, equivalently, measurement) error that comes from the fact that $\overline{\ln c_{ab}}$ is a sample estimate of the average log consumption of all individuals born at b and observed at $b + a$.

Earnings, like consumption, are assumed to follow an invariant age profile over the life cycle, but to shift up with growth. Income is earnings plus the interest income on accumulated wealth. Given that (log) consumption and (log) earnings can both be decomposed into cohort and age effects, so can income y_{iab}. Thus we can write, corresponding to (A3),

$$\overline{\ln y} = D^a\beta_y + D^c\gamma_y + u_y \ , \tag{A4}$$

where β_y and γ_y are the age and cohort effects in income. The difference between (A3) and (A4), if consumption is close to income, is approximately the saving ratio, so that

$$s/y \approx \overline{\ln y} - \overline{\ln c} = D^a(\beta_y - \beta_c) + D^c(\gamma_y - \gamma_c) + (u_y - u_c) \ . \tag{A5}$$

The age and cohort effects in Figure 1 are from estimates of equations (A3), (A4), and (A5), where averages of the logarithm of income and consumption are computed over household heads of the same age in the same year.

Under the usual assumptions that there are no bequests and that lifetime consumption exhausts lifetime resources, the cohort effects in income and consumption will be the same, so that (A5) will have only age effects. It can therefore be rewritten as

$$s/y \approx D^a(\beta_y - \beta_c) + (u_y - u_c) \ . \tag{A6}$$

Figure 2 graphs the age effects from this equation.

In the "household" version of the model, the subscript i in the foregoing is interpreted to refer to a household, whose age is given by the age of the household head. In the "individual" version, i is taken to be an individual, and (A1) is modified to read

$$c_{iab} = c_{ab} + \varepsilon_{iab} = f(a)W_b + \varepsilon_{iab} \ , \tag{A7}$$

where ε_{iab} is a mean zero error. We are now decomposing the mean cohort consumption into an age effect $f(a)$, and a cohort effect, W_b, interpretable as cohort average lifetime resources. For a household, h, included in the survey at time t, we observe household consumption, c_{ht}, which is the sum of individual consumption, so that

$$c_{ht} = \sum_{a=1}^{N} n_{aht} f(a) W_{t-a} + \sum_{i \in h} \varepsilon_{iat-a} \ , \tag{A8}$$

where n_{aht} is the number of people aged a in household h at time t, where N is the maximum age in the population, and where we have used the fact that someone aged a and observed in t was born in $t-a$. In the main text we refer to coefficients $\beta(t,a)$, which are defined as the product $f(a)W_{t-a}$ in (A8). These coefficients are calculated from (A8), which we estimated from regressions, one per survey year, of household consumption on the numbers of people of each age in the household. The estimated $\beta(t,a)$ are then "smoothed" as described in Deaton and Paxson (2000). We then treat them as estimates of individual consumption that we further decompose into age and cohort effects by taking logs and regressing on age and cohort dummies as in the household version of the model. These age effects are shown in Figure 5.

In Deaton and Paxson (2000) we describe an alternative procedure for estimating age and cohort effects that does not require taking logarithms and so avoids having to "smooth" out nonpositive values. This procedure involves stacking the coefficients $\beta(t,a)$ into a BxA matrix, where B is the number of birth cohorts and A is the number of ages. This matrix can be expressed as the product of a Bx1 vector of cohort effects and a 1xA vector of age effects. We estimate these vectors using an iterative principal components technique. This chapter reports results based on the log-linear decomposition, but results using the alternative technique are similar.

The fact that time trends in saving rates show up as offsetting cohort and age effects can be demonstrated as follows. Suppose that the saving rate for age a at time t is σ_{at} and that, for "reasons unknown," these rates are increasing over time at rate θ; that is,

$$\sigma_{at} = a_a + \theta t \,. \tag{A9}$$

Cohort c is measured as age in a base year, for example in 1976, so that year of birth b is $1976-c$ and we have the identity

$$t = 1976 - c + a \,. \tag{A10}$$

Substituting (A10) into (A9) gives

$$\sigma_{at} = \left(a_a + 1976\theta\right) + \theta a - \theta c \,, \tag{A11}$$

so that the time trend appears as offsetting age and cohort effects in the saving ratio. When there are "genuine" age and cohort effects, the time trend will be added to one and subtracted from the other.

The aggregate saving ratios in any given year are calculated from formulas of the form

$$\left(\frac{S}{Y}\right)_t = \frac{\sum_{a=1}^{A} \eta_{at} \gamma_{t-a} \left[\exp\left(\beta_{ay}\right) - \exp\left(\beta_{ac}\right)\right]}{\sum_{a=1}^{A} \eta_{at} \gamma_{t-a} \exp\left(\beta_{ay}\right)} \,, \tag{A12}$$

where S and Y are aggregate saving and aggregate income, η_{at} is the number of people aged a at time t, γ_{t-a} is the cohort wealth level for people born in $t-a$ and β_{ay} and β_{ac} are respectively the age effects in the logarithmic income and consumption profiles. These β's are estimated as described above, as are the γ's in the case where the estimated profiles are used. Otherwise, when we assume that cohort effects are generated by an equilibrium economic growth path along which per capita income is growing at rate g, γ's are set to be $(1+g)^{t-a}$. Similarly the η's are either the actual numbers of people, or in equilibrium population growth are taken to be $(1+n)^{t-a}p_a$, where n is the rate of population growth and p_a is the probability of living to age a. In the household model, p_a must be replaced by p_a^h, the probability of surviving to age a and being a household head at that age.

Note

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