Population Aging, Intergenerational Transfers, and Saving in Thailand

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Amonthep Chawla
University of Hawaii at Manoa, East-West Center and
Nihon University Population Research Institute
amonthep@hawaii.edu

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Abstract

Saving rates are simulated in order to measure how change in age structure influences saving in the economy. There is controversial and important empirical issue on how much change in age structure can account for a significant change in saving rates. Several empirical studies find that saving rates change substantially as population age structure changes. Some studies find that change in population age structure has modest effects on aggregate saving rates. This paper replicates the methodology used by Deaton and Paxson (2000) to simulate saving rates in Thailand. Deaton and Paxson method does not explicitly include intergenerational transfers. This paper contributes to taking into account intergenerational transfers, using the NT Flow Account methodology (Mason et al. forthcoming), to simulate saving rates. Simulated saving rates from Deaton and Paxson model are then compared with results using Mason and Lee (2006) model. The main finding, based on both methods, shows that change in age structure influences saving rates in Thailand before 1985. However, after 1985 change in saving rates are not due to change in age structure but some other secular trend.

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1. Introduction

Changes in population age structure influence saving rates. The conventional lifecycle saving hypothesis implies that the elderly heavily rely on dis-saving to support their consumption during retirement periods. If this model is correct, saving rates will decline as population ages. Recent econometric studies have provided evidence for this possibility. However, there are controversial and important empirical issues concerning how much change in age structure can account for a significant change in saving rates. Several empirical studies, based on the analysis of aggregate cross-national panel data, show that saving rates change substantially (i.e. Higgins and Williamson 1997; Kelly and Schmidt 1996) as population age structure changes. Other groups of studies, based on disaggregated measures of saving rates using cross-sectional family income expenditure surveys, and historical and projected population age structure conclude that change in population age structure has modest effects on aggregate saving rates (i.e. Deaton and Paxson 2000; Lee et al. 2000).

One possible resolution for this empirical controversy is to include intergenerational transfers with lifecycle saving to measure changes in saving rates due to population aging. Recent empirical studies by Mason et al. (Mason et al. forthcoming; www.ntaccounts.org) in the "National Transfer Flow Accounts" show that intergenerational transfers are substantial and important for providing support for the elderly. This paper sheds light on measuring to what extent change in age structure can account for an important change in saving rates, using the National Transfer Flow Accounts methodology.

Two different models are used in this paper to estimate how changes in age structure affect saving rates. The major difference between these two models is how age profiles of saving are modeled. The first model follows the lifecycle hypothesis, relying on the empirical framework developed by Deaton and Paxson (2000). This model is based on the assumption that age profiles of consumption and income are fixed for all cohorts, resulting in the fixed age profiles of saving. The second model follows the simulation model, outlined by Mason and Lee (2006). The simulation model by Mason and Lee shows that intergenerational transfers could affect the levels of consumption and asset holdings, resulting in different age specific saving rates by different cohorts.

Thailand is used as a case study to assess how much a change in population age structure is associated with a change saving rates. During the past few decades the proportion of the working ages in Thailand increased substantially. However, the favorable demographic structure of high proportion of working ages is about to dissipate. Continual decline in fertility and mortality as well as an increase in life expectancy leads to population aging. The proportion of the elderly, ages 65 and older, in Thailand increased from 3 percent in 1950 to 6 percent in 2000. Even though the proportion of the elderly in Thailand is lower than in many countries, the speed of population aging is high. The proportion of the elderly is expected to increase to 21 percent by 2050 (UN 2005)[1].

The results of my study based on the Deaton and Paxson model and the Mason and Lee model show that change in age structure affects saving rates in Thailand. However, the magnitude of the change in saving rates that is associated with the change in population age structure is different. Both models also show that population aging leads to a decline in saving rates. Further, there are possibilities that a saving rate may not decline much despite population aging. Both the Deaton and Paxson model and Mason and Lee model predict that high economic growth could prevent a saving rate from dropping severely.

This paper is organized as follows. In section 2, the literature on the effects of demographic changes, economic growth and transfers on saving is reviewed. Section 3 presents data used for the estimation. In section 4, saving rates are simulated based on Deaton and Paxson (2000)'s and Mason and Lee (2006)'s model. Section 5 concludes the study.

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[1] Please note that there is uncertainty about these population projections by the UN. See Lee (2003, pp.179-180) for a discussion.

2. Literature Review

There is a large body of literature that investigates the effects of population age structure on saving rates. Most studies based on the lifecycle hypothesis of saving show that changes in age structure and economic growth influences saving rates. However, few studies include intergenerational transfers with lifecycle saving to measure the effect of change in age structure on saving rates. This study includes comprehensive measures of transfers from both the family and the public sector to measure the effect of change in population age structure on saving rates.

Most studies that discuss the effects of demographic changes on saving are based on the lifecycle hypothesis of saving, developed by Modigliani and Brumberg (1954). Assuming a perfect annuity market and no bequests, individuals choose an optimal consumption path subject to the constraint that the present value of lifetime consumption cannot exceed the present value of lifetime earning and current assets. The major assumption for this model is that the shape of the lifetime path of consumption is independent of the shape of the expected path of income. Based on the lifecycle hypothesis, rational forward looking individuals will not consume more in one period than another period. Individuals' income may increase with age until individuals reach the retirement age and earn no income. Individuals save some fraction of their income when they earn more than they consume during working ages in order to dis-save when they earn no income during retirement. Thus, consumption by the elderly does not necessarily decline with income because the elderly can dis-save or run down assets to support consumption during the elderly years.

The lifecycle model predicts that both demographic and productivity growth will generate savings. There will be no net saving in the economy as a whole if there is neither of these. Given population growth, there are more young people than old people. Total saving by young people offset total dis-saving by old people, leading to positive net saving in the whole economy. Similarly, productivity growth allows younger workers to be richer than an older generation at the same age, leading to a larger level of saving than that of older generation. Thus, there exists positive net saving in the whole economy. Based on this prediction, population aging is likely to lower net saving because the share of the elderly, who dis-save, increases relative to working ages, who save.

There are several studies on how the lifecycle hypothesis is used to explain the effects of the change in age structure on saving. Many models are also used to predict saving rates. There are two general ways that the lifecycle model is used to study the effects of age structure on aggregate saving.

One approach is highly aggregative, using cross-national panel data, and depends on estimating a saving model that includes one or more measures of age structure. There are many examples: Leff (1969), Mason (1987, 1988), Bloom et al. (2003), Higgins and Williamson (1997) and Kelly and Schmidt (1996). Most studies find that population aging (or slow population growth) will lead to lower saving rates. A recent study by Kinugasa and Mason (2006) raises the possibility that saving rates may not decline with aging if increases in life expectancy have a sufficiently strong effect.

The second approach, and the one that is emphasized here, is more disaggregated and relies on simulation. The authors of this approach explicitly model the age profile of saving (or consumption and income). Age specific saving rates are then aggregated using a historical or projected population age structure to determine the household or national saving rates. Two different approaches are used to defining the age profile. One uses the household as the unit of analysis and constructs profiles by the age of household head (Paxson 1996; Deaton and Paxson 1997; 2000; Jappelli and Modigliani 2003; Attanasio 1998). The other approach uses the individual as the unit of analysis and constructs the age profile of the individual (Deaton and Paxson 2000; Demery and Duck 2006; Mason and Lee 2006). Further, some simulation studies have relied on consumer theory, such as the lifecycle model, to determine the age profile of saving. Cutler et al. (1990) use the Ramsey Model. Lee et al. (2003) and Attanasio (1998) use the lifecycle model.

Even though lifecycle hypothesis is important to describe the relationship between age structure and saving, it does not present a comprehensive view of the support systems. Apart from saving, intergenerational transfers are large and important mechanisms used to support consumption by children and the elderly. People make transfers when they are productive, and receive transfers when they earn lower or no income. Combining transfers with lifecycle saving is necessary to explain the effect of change in age structure on saving rates. Population aging leads to more burdens for the working ages to provide larger transfers to the elderly because the share of the elderly who receive transfers increases, whereas the share of working ages declines. The working ages have fewer resources available to save, resulting in a decline in saving rates. Overlooking the importance of transfers may mislead the measurement of saving by people in different age groups and the effect of change in age structure on saving.

The contribution of this paper is to apply the methods by Deaton and Paxson (2000) with comprehensive measures of intergenerational transfers estimated using the National Transfer Flow Accounts methodology to measure effects of change in age structure on saving rates in Thailand. Further, this paper compares saving rates based on the simulation model from Deaton and Paxson with the ones from Mason and Lee. The key distinguishing features of the simulation models are the ways in which the age profiles of saving are modeled. The first model is based on the Deaton and Paxson model, assuming individuals rely only on dis-saving without transfers to support consumption during the retirement period. Age specific saving rates, measured from age profiles of consumption and income using repeated cross-sectional surveys, are fixed for all cohorts. The unit of analysis of this model is at the household level, represented by the age of a household head. The second model is based on the simulation model by Mason and Lee, assuming individuals rely on reallocations through assets and transfers received from younger ages to support their consumption during the retirement period. Saving or asset accumulation by different cohorts allows individuals in different cohorts to vary their consumption, resulting in different age profiles of saving across periods. In addition, the unit of measurement in the Mason and Lee model is at the individual level rather than at the household level.

In summary, the lifecycle hypothesis is a fundamental framework to explain how changes in age structure and economic growth affect saving rates. Lifecycle hypothesis is important; however, it does not take into account intergenerational transfers. Change in age structure affects transfers from working ages, which could affect saving rates. Thus, overlooking the importance of transfers could mislead the measurement of how change in age structure can account for change in saving rates.

3. Data

There are three sources of data used to estimate saving rates: household income and expenditure surveys, national income accounts, population estimates and projections by age. First, the household income and expenditure surveys of Thailand called the Socio-economic Survey (SES) are used to estimate age profiles of consumption, earning, and other sources of income. There are eleven rounds of surveys used in this paper, starting from the year 1981 and every two years from 1986-2004. The SES is operated under the direction of the National Statistical Office Field Division. The survey provides information at the household level, such as household expenditures and income, and at the individual level, such as education level and age of household members. There are, on average, 75,906 individuals from 20,763 households interviewed in each survey year. Data from each survey include 91 cohorts, or all individuals aged 0 to age group 90 and older. The total includes 115 cohorts (i.e. born between 1890 and 2004) who are observed for up to 24 years each (i.e. cohorts born in 1981 are observed until aged 23 in 2004). The data for cohorts in each survey are then pooled to estimate age and cohort effects in consumption and income. A descriptive summary of the surveys is shown in Table 1. Second, the national income accounts of Thailand are used to control the aggregates from the surveys as well as the aggregates from other government documents. The National income account is the macroeconomic depiction of the national income cycle, which measures the flows of five main institutional units that are resident in the economy, i.e.

Table 1: Summary of Mean Statistics from Surveys, Real Prices

Survey Years	Household Characteristics					
	Age of Head (years)	Consumption (Baht/Month)			No. of Households	Household Size (persons)
		Education	Health	Total		
1981	44.4	66.5	127.3	3,757.8	11,894	4.4
1986	45.0	76.4	141.9	4,027.6	10,889	4.1
1988	45.5	53.0	135.7	3,699.9	11,017	3.9
1990	46.3	78.6	181.4	4,938.7	13,162	4.0
1992	46.2	112.2	221.5	6,167.7	13,432	3.7
1994	47.2	134.8	260.6	6,761.2	25,176	3.7
1996	47.8	165.9	331.2	7,936.7	25,069	3.6
1998	48.1	241.4	233.7	8,937.6	23,515	3.7
2000	48.5	244.8	261.5	8,473.2	24,705	3.5
2002	48.6	252.5	249.3	9,496.9	34,735	3.4
2004	49.7	263.8	262.1	10,809.3	34,803	3.3
Mean	47.04	153.62	218.75	6,818.77	20,763.4	3.77

Survey Years	Individuals Characteristics					
	Age of Individuals (years)	Income (Baht/Month)				No. of Observations
		Wage	Farm	Non-farm	Property	
1981	25.8	345.0	153.2	244.1	14.7	52,004
1986	27.2	422.2	134.3	227.7	14.6	45,072
1988	27.5	335.8	212.3	140.7	13.7	42,843
1990	28.3	516.4	253.8	217.9	15.2	52,879
1992	28.9	766.0	264.5	313.8	35.8	50,309
1994	30.2	936.0	272.2	402.3	26.6	93,735
1996	30.8	1,220.4	401.7	529.5	40.0	90,133
1998	31.2	1,411.0	429.6	602.0	65.9	85,891
2000	32.5	1,471.2	362.0	595.9	46.4	87,231
2002	32.5	1,677.5	439.3	736.9	51.6	118,550
2004	33.6	1,922.4	515.1	805.0	51.7	116,317
Mean	29.87	1,002.19	312.55	437.77	34.20	75,905.8

Source: Author's calculation based on the SES 1981-2004

non-financial corporations, financial corporations, government units (including social security funds), non-profit institutions serving households and households. The national income of Thailand is compiled by the National Account Division at the National Economic and Social Development Board (NESDB). The methodology used to compile the national account of Thailand follows the System of National Accounts (SNA) 1993 (UN 1993). Third, population estimates and projections by age are used from the United

Nations (UN 2005). Data for population projections up to 2300 are based on the assumption that total fertility rates (TFR) are constant at 1.85 throughout the projection periods. Migration is included in the projection. Population projections also consider the epidemic of HIV/AIDS in Thailand to forecast mortality**.** Between 2005 and 2050, life expectancy at birth for men and women is assumed to increase from 68.5 and 75.0 years to 76.6 and 81.6 years.

The following presents empirical strategy used to construct the National Transfer Flow Accounts for Thailand. Details for the estimation methods are described in Chawla (2008). There are mainly three steps required to estimate components for the NT Flow Accounts.

The first step is to estimate consumption by individual. Surveys and government documents do not directly report consumption at the individual level. Individual's consumption for both private and public consumption can be estimated, distinguishing education, health, and other[2]. Per capita private education consumption is estimated using a regression model. The household consumption of education is regressed on the number of household members in each age group enrolled in school. The coefficients from the regression equation are used as weights to allocate household education consumption to enrolled members. Per capita private health consumption is estimated relying on information on per capita private health consumption in 2002, which is the only survey year that reports health consumption by age of each member. Household health consumption for other survey years is regressed on the per capita private health consumption in 2002 weighted by the number of household members in each age group, allowing that there is the systematic relationship between age and health expenditure by

2 The estimation method for consumption used in this paper is different from the one by Deaton and Paxson (2000). Deaton and Paxson estimate consumption at the individual level using a regression model by regressing household consumption on the number of individuals of each age group in the household, with age running from 0 to 99, without a constant. The coefficients from the equation measure the average consumption of people in each age group. Their method is simple; however, it does not take into account of the different types of consumption needs by people in different age groups. For example, children usually consume large education, and the elderly consume health care. In addition, coefficients from the regression may be negative for some age groups.

age in a polynomial model. In addition, a dummy for individuals at age 0 is added to the health consumption equation in order to capture the characteristic of a high level of health consumption by newborns and cost of delivery. The newborns are usually subject to high mortality than nearby age groups, which could lead to higher health consumption. Per capita private consumption of other goods is estimated assuming that children consume less than adults and the consumption is allocated to individuals in the household by using an equivalence scale that gives more weight to adults than children[3]. Public education consumption is allocated to students by using age- and education-level specific enrollment rates, assuming that the cost per student varies across primary, secondary, or tertiary education levels, but does not vary by age within the education level. Public sector health consumption consists of expenditure for public hospitals and various public health programs. Age profile of public hospital follows private health consumption age profile. Other public sector health consumption and public consumption of other goods and services are allocated on a per capita basis.

The second step is to estimate income by individual. There are labor income, asset income, net public transfers received and net private transfers received. Some sources of income are reported directly in the SES at the individual level. For example, earnings and a labor share of entrepreneurial income measure labor income; property income and other non-labor income measure asset income. Based on Mason et al. (forthcoming), individuals receive labor income, but only household heads receive asset income. Net public transfers received is the difference between benefits individuals receive through the government (i.e. public consumption, social security benefits and other public cash transfers) and taxes or other contributions individuals made through the government. Net private transfers received include net transfers between households (inter-household transfers) and net transfers within households (intra-household transfers). Inter-household transfers can be tabulated directly from the survey data, and they are assumed to flow between household heads. For intra-household transfers, household members who

[3] For more detail of the estimation of private consumption of other goods and services please refer to http://www.schemearts.com/proj/nta/web/nta/show/Documents/Flow%20Account%20Methods#H-84r1w3

consume more than their "disposable income" receive intra-household transfers from those who consume less than their "disposable income". Disposable income is defined as labor income plus net public cash transfers (cash inflows less taxes) plus net inter-household transfers. If a household has total disposable income of all members combined more than total private consumption of all members combined, the surplus is transferred to the household head and saved. On the other hand, if a household has total disposable income less than total private consumption, the household head makes additional intra-household transfers to finance this deficit by using asset income, dis-saving or by acquiring debt. Intra-household transfers to support consumption are financed by imposing a household specific flat-rate tax on each member's surplus income. Within the household, each member is taxed at the same rate. The tax rate does not vary by age. Please refer to Mason et al. (forthcoming) and www.ntaccounts.org for more details.

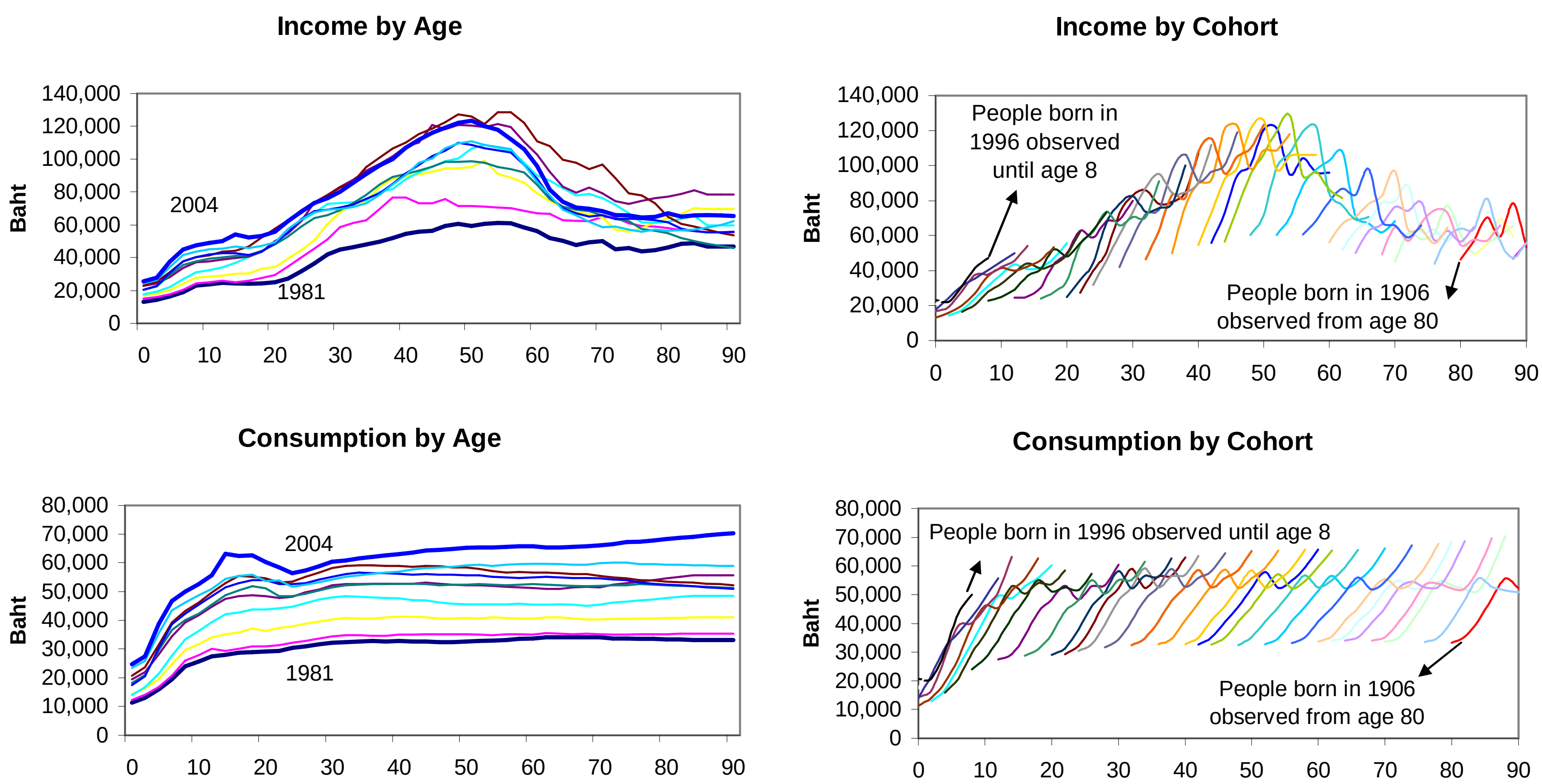
The third step is to adjust consumption and income estimated from the surveys to match with the aggregate private consumption and different sources of income reported in the national income accounts. Thus, saving rates estimated in this paper can be used to compare with the aggregate national saving rates reported in the national income accounts.

The results shown in Figure 1 present per capita consumption and income by age and by cohort, for every fourth cohort. Please note that the income described here includes labor income, asset income and net transfers received from both the public and private sectors.

The left panel shows cross-sectional income and consumption by age from 1981 to 2004. The shape of the cross-sectional age profiles of consumption does not change much over time, whereas the shape of the cross-section age profiles of income fluctuate around working and retirement ages. The changes in income are mainly caused by the decline in asset income after the economic crisis in 1997. Children do not work or earn asset income. The major source of income for children is net private and public transfers received. Consumption by adults and the elderly is rather stable for most survey years. In contrast, cross-sectional income for most survey years show that income increases with age during the working ages before declining after around ages 60 and older. The decline in income is mainly due to the decline in labor and asset income as individuals are older.

The right panel shows income and consumption by cohort. The cohorts are shown every fourth cohort. For example, the first line in Figure 1 is income and consumption for a cohort born in 1996 observed until aged 8 in 2004; the last line is a cohort born in 1906 observed from aged 80 in 1986 until aged 90 and older in 1996. The results show that most cohorts observed during working ages receive higher income with age. For example, real income for those born in 1970 increased at the rate of 17 percent per year between the ages of 16 and 34. However, as cohorts grow older, the rate of growth is less, falling with age and eventually becoming negative. Consumption by cohort is not so much different from one cohort to another as observed in income by cohort. Consumption by younger cohort steeply increases with age. Consumption by older cohorts increases but less steeply than younger cohorts.

Figure 1: Per Capita Consumption and Income by Age and by Cohort, Thailand, Real Prices (2004 Prices)



4 Population Aging and Saving Rates

In this section, the effects of population aging on saving rates of Thailand are simulated using the models developed by Deaton and Paxson (2000) and Mason and Lee (2006).

4.1 Deaton and Paxson Model

Specification

Saving rates can be simulated using the age profile of income and consumption. However, age profiles of individual income and consumption cannot be simulated directly using cross-sectional surveys if age effects are confounded with cohort effects. For example, older people come from an earlier cohort, which may have different experiences and resources. Given continual technological progress, older cohorts are lifecycle poorer than younger cohorts. Thus, it is important to distinguish age and cohort effects in consumption and income in order to measure saving rates.

Consumption over the lifecycle, for any individual i born at date b and observed at age a (i.e., at date $b+a$), follows an age profile of consumption $f_i(a)$, *age effect*, and lifetime resources W_{ib}, *cohort effect*. The shape of the age profile of consumption is fixed for all cohorts, assuming there are no changes in tastes or in incentives to postpone consumption. The level of the age profile is set by lifetime resources. Thus, consumption c_{iab} is given by

$$c_{iab} = f_i(a)W_{ib}, \qquad 1$$

Then, the logarithm of consumption can be expressed as the sum of an age profile and a fixed lifetime wealth component:

$$\ln(c_{iab}) = \ln f_i(a) + \ln(W_{ib}). \qquad 2$$

There are no panel data for Thailand that can track individual consumption trajectory overtime to measure age and cohort effects. Repeated cross-sectional surveys can be used to measure consumption by cohort. Some individuals may be observed only once in survey; however, the sample from the same birth cohort is observed in a later survey. Thus, consumption can be tracked of a representative sample of individuals of the same cohort. This can be done by taking averages of equation 2 across all individuals of the same cohort at the same age, then equation 2 can be shown as:

$$\overline{\ln c_{ab}} = \overline{\ln f(a)} + \overline{\ln W_b}\,, \qquad 3$$

where the lines over the variables denote means. For example, for a birth cohort born in 1950 observed at age 40 in 1990, the average logarithm of consumption is the sum of the age effect (that of age 40) and a cohort effect (that of persons born in 1950). Equation 3 can be obtained 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[4], i.e.,

$$\overline{\ln c} = D^a \beta_c + D^c \gamma_c + u_c\,, \qquad 4$$

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 dummy and D^c is a matrix of cohort dummy. The coefficients β_c and γ_c are the age effects and the cohort effects in consumption, and u_c is sampling error.

Similarly, income profiles retain a characteristic profile that does not change shape across cohorts and they are determined by lifetime resources. Taking averages of the logarithm of income can be decomposed into age and cohort effects, i.e.,

$$\overline{\ln y} = D^a \beta_y + D^c \gamma_y + u_y\,, \qquad 5$$

where β_y and γ_y are the age effects and the cohort effects in income, and u_y is sampling error.

If consumption is close to income, the ratio of saving to income is approximately equal to the difference between Equation 5 and Equation 4. Then, saving ratio can be decomposed into age and cohort effects, i.e.,

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[4] The regression includes the constant term and drop one age and one cohort. Year effects are included in the regression model. However, the year effects need some adjustment to avoid the multicolinearity problem with age and cohort. The adjustment method follows Deaton (1997) by restricting the year effects to sum to zero and orthogonal to time trend.

$$s/y \approx \overline{\ln y} - \overline{\ln c} = D^a(\beta_y - \beta_c) + D^c\left(\gamma_y - \gamma_c\right) + (u_y - u_c) \qquad 6$$

Assuming bequests are zero or an unchanging fraction of lifetime wealth, the level of the saving will be the same for all cohorts. In addition, the lifecycle hypothesis assumes the lifetime consumption exhausts lifetime resources[5], thus the cohort effects in income and consumption will be the same. Consequently, equation 6 will have only age effects, which can be rewritten as:

$$s/y \approx D^a(\beta_y - \beta_c) + (u_y - u_c) \qquad 7$$

Saving rates from the lifecycle hypothesis are estimated by dividing total saving, the difference between total income and total consumption, by total income. Total income is the sum of the product of population by age and the exponential of the age effects of income by age. Similarly, total consumption is the sum of the product of population by age and the exponential of the age effects of consumption by age. Consequently, the aggregate saving ratios in any given year can be calculated as:

$$\frac{s}{y} = \frac{\sum_a \eta_{at}(1+g)^{-a}[\exp(\beta_{ay}) - \exp(\beta_{ac})]}{\sum_a \eta_{at}(1+g)^{-a}\exp(\beta_{ay})}, \qquad 8$$

where *s* and *y* are aggregate saving and aggregate income, η_{at} is the number of people aged *a* at time *t*, β_{ay} and β_{ac} are respectively the age effects in the logarithm income and consumption profiles, *g* is the growth rate of per capita income.

Empirical Results

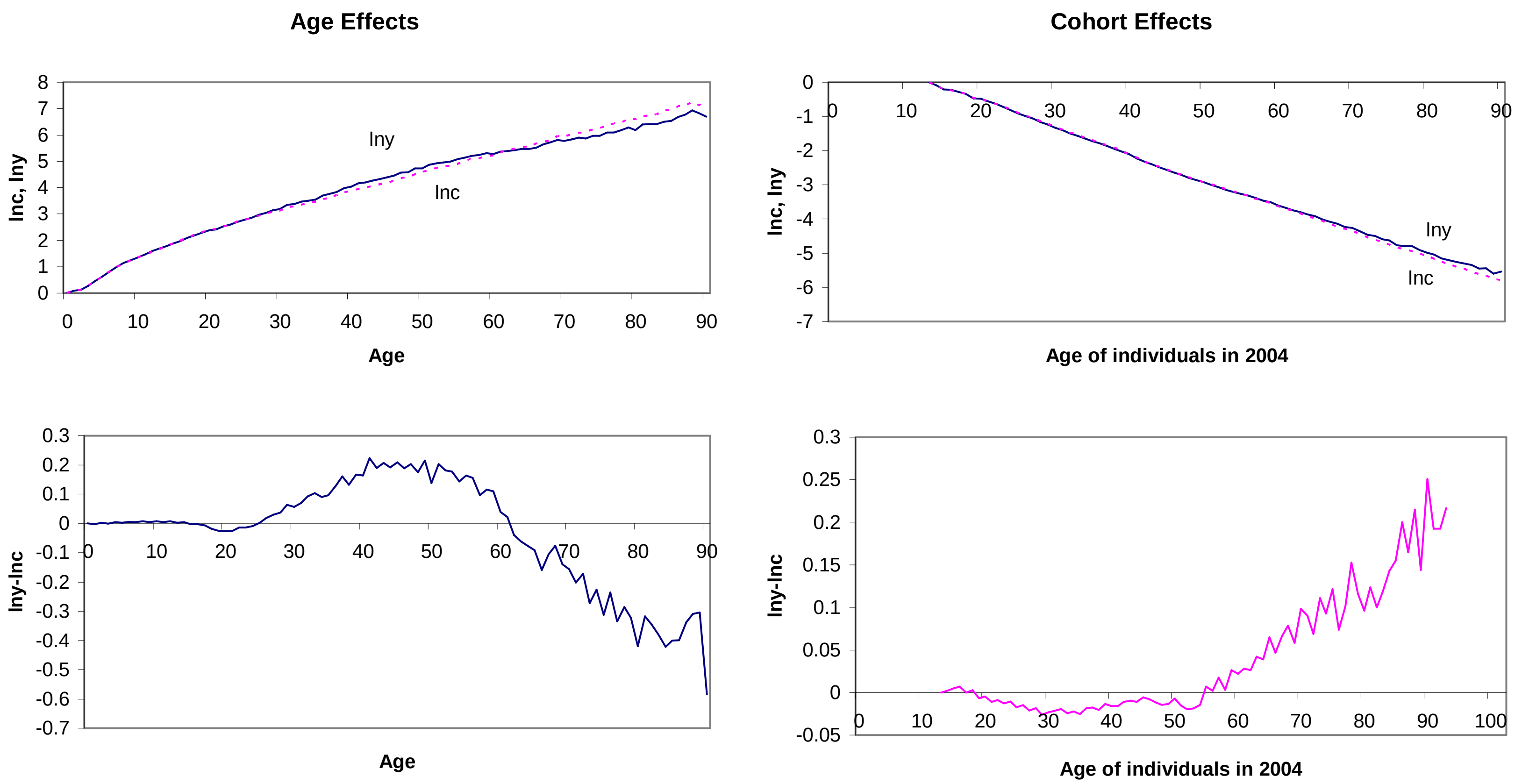
Cohort effects in log consumption, log income and the saving ratio are shown in Figure 2 in the two right panels, and the corresponding age effects are shown in the two left panels. Cohorts are defined by age of individuals in 2004, which show the movement from the later-born cohorts from the left to the earlier-born cohorts to the right. The earlier born cohorts are poorer over their lifetime leading to a decline in cohort effects for both income and consumption from left to right. For the age effects, income increases

[5] However, at any period, consumption may not equal income. Borrowing and lending make up the difference between consumption and income at any period, assuming that capital markets are sufficiently developed to allow people to borrow against future income.

steeply until around ages 55-60, then consumption increases more steeply than income. The more interesting finding is on the age effects of consumption. Age effects of consumption in Thailand continually increase with age. That consumption is growing is inconsistent with the prediction by the lifecycle hypothesis. Attanasio and Weber (1995), using the household model, finds that consumption by the age of head could be hump shaped because of changes in household composition. However, in the individual model age effects of consumption are assumed to be flat in the lifecycle hypothesis. There are important studies that explain the age effects of consumption. For example, Carroll (1994) and Deaton (1992) explain that consumption tracks income because of precautionary saving incentive and liquidity constraint.

That consumption among older ages increases more steeply than income is also interesting. An increase in consumption by the elderly could be influenced by the income of others, not their own, because of intergenerational transfers, which supports the Mason and Lee model. The results of downward sloping cohort effects and upward sloping age effects of logarithm income and logarithm consumption are similar to what Paxson (1996) found for Thailand, using the ages of household heads instead of individuals.

Figure 2: Age and Cohort Effects, Log Income, Log Consumption and Saving Rates, Thailand

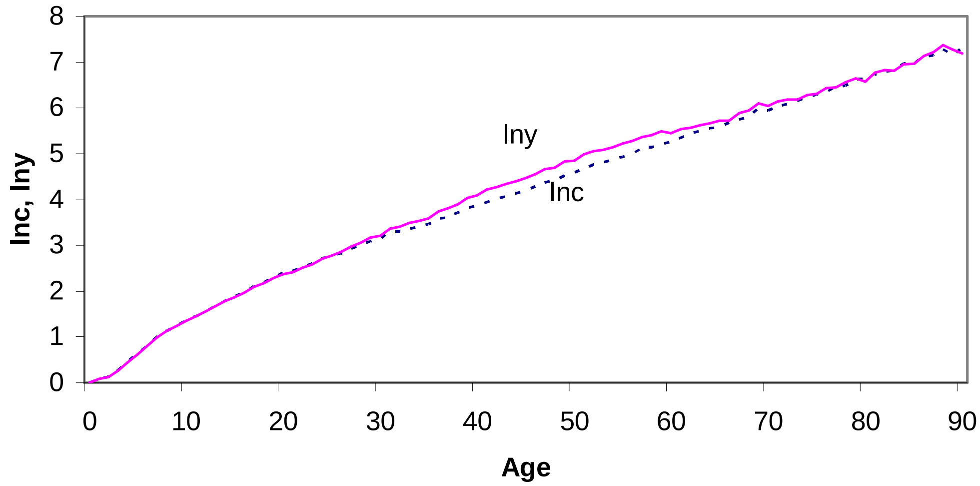


The lower left panel shows that the age profile of saving has a hump shape, suggesting the important relationship between age structure and saving rates. The results show that people save more as they are older until they reach around age 50. People start to dis-save at around age 62. The lower right panel shows that cohort effects of saving are upward sloping. Cohort effects of saving are upward sloping because more recently born people in Thailand are consuming a larger share of their lifetime resources. The finding here contradicts to the lifecycle hypothesis, which assumes that bequests are zero or a fixed fraction of lifetime resources. There are some possibilities for the upward sloping cohort effects of saving. People in Thailand at all age groups may decide that it is less important to save, so that all cohorts, at all ages, slowly decrease their saving ratios over time. The other possibility is that people in Thailand at younger cohorts may plan to bequeath less than the older cohorts. In contrast to Thailand, Deaton and Paxson (2000) find that cohort effects of saving in Taiwan are downward sloping, indicating younger cohorts save more than older cohorts.

The lifecycle hypothesis cannot explain what causes the changes in saving behavior across cohorts; however, the results can be adjusted by forcing the age effects and cohort effects in both income and consumption regression to be the same[6]. Consequently, the cohort effects of saving ratios are eliminated. The results shown in Figure 3 restrict cohort effects of consumption and income to be identical. Saving ratios have a hump shape and they are negative for young adults and the elderly.

[6] The method involves using the simultaneous regression for log consumption and log income on ages and cohorts, constraining cohort effect from log income regression to be equal to cohort effect from log consumption regression for each cohort.

Figure 3: Age Effects in Log Income, Log Consumption and Saving Rates with Restricted Cohort Effects

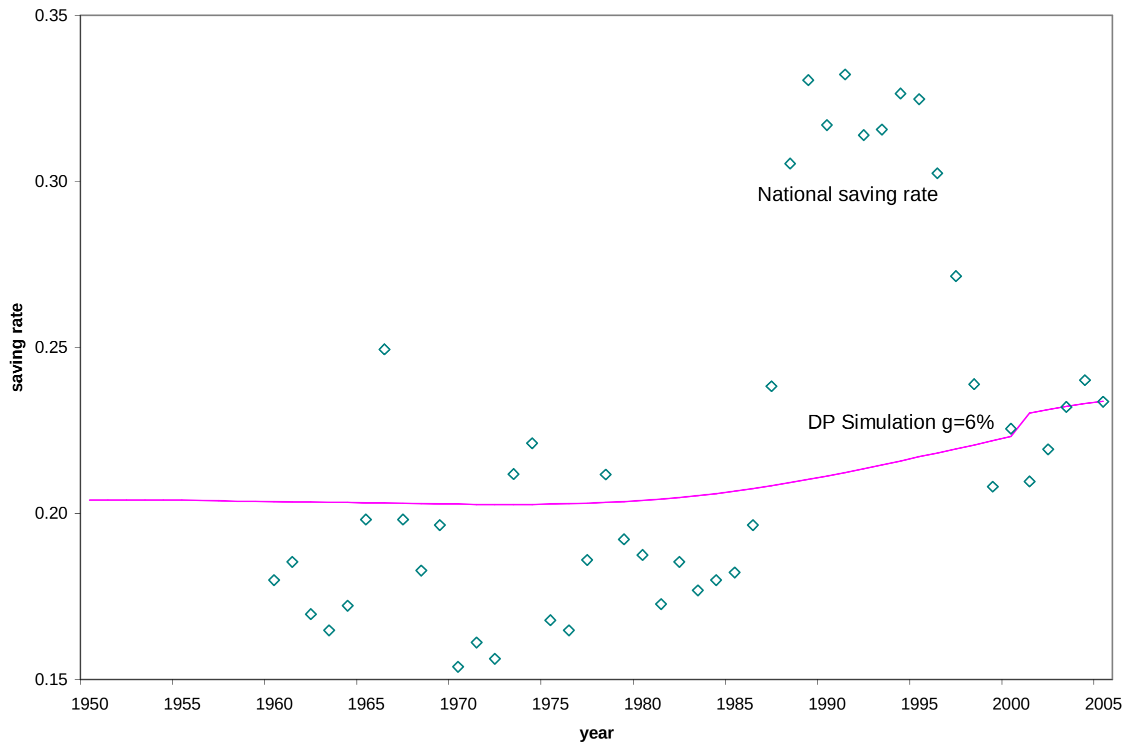


Finally, the effects of demographic changes on aggregate saving rates can be simulated using the age distribution of population in Thailand from 1950 to 2005. Consumption and income at each age for each cohort is the product of lifetime wealth of cohort members and the exponents of the age effects in Figure 3. The cohort-specific lifetime wealth terms are assumed to grow from year to year at a constant rate of 6.0 percent, which is close to the average economic growth rate of Thailand during 1981-2004, the period of the surveys used in the simulation. The estimation results show how age structure affects saving rates. Please note that the analysis does not explain how saving rates change due to short-term fluctuations, such as income shocks during the economic crisis in 1997-1998.

Figure 4 shows the predicted saving rates[7] and actual national saving rates. The simulated saving rates were stable around 20 percent of national income during 1950-1975. There was not much change in saving rates because there was large consumption by children due to high child dependency rates, leaving few resources available for saving. Then, saving rates increased after 1975, which is the period when total fertility rates started to decline, leading to a smaller share of children and a larger share of working ages. These calculations show that if lifecycle hypothesis is literally implemented, the lifecycle model could explain the increase in saving rates in Thailand before 1985. The simulated results fit actual saving rates, which show that there was no secular trend during the period. However, it may not explain the fluctuation in saving rates after 1985. There is a study showing that the decline in saving rates during the late 1990s is caused by high spending in durable goods, import luxury goods and increase in consumer debt during the period (Pootrakool et al. 2005). This paper shows that the large increase in saving observed in Thailand, or many other East Asian countries, may not be caused by change in age structure as described by Higgins and Williamson (1997) and Kelly and Schmidt (1996). In contrast, the lifecycle hypothesis implemented by Deaton and Paxson show that change in saving rates was not mainly due to change in age structure or economic growth, but due to a secular trend. In addition, the results that change in saving rates is not mainly due to change in age structure as described by the lifecycle hypothesis are consistent with what Deaton and Paxson (2000) found for Taiwan.

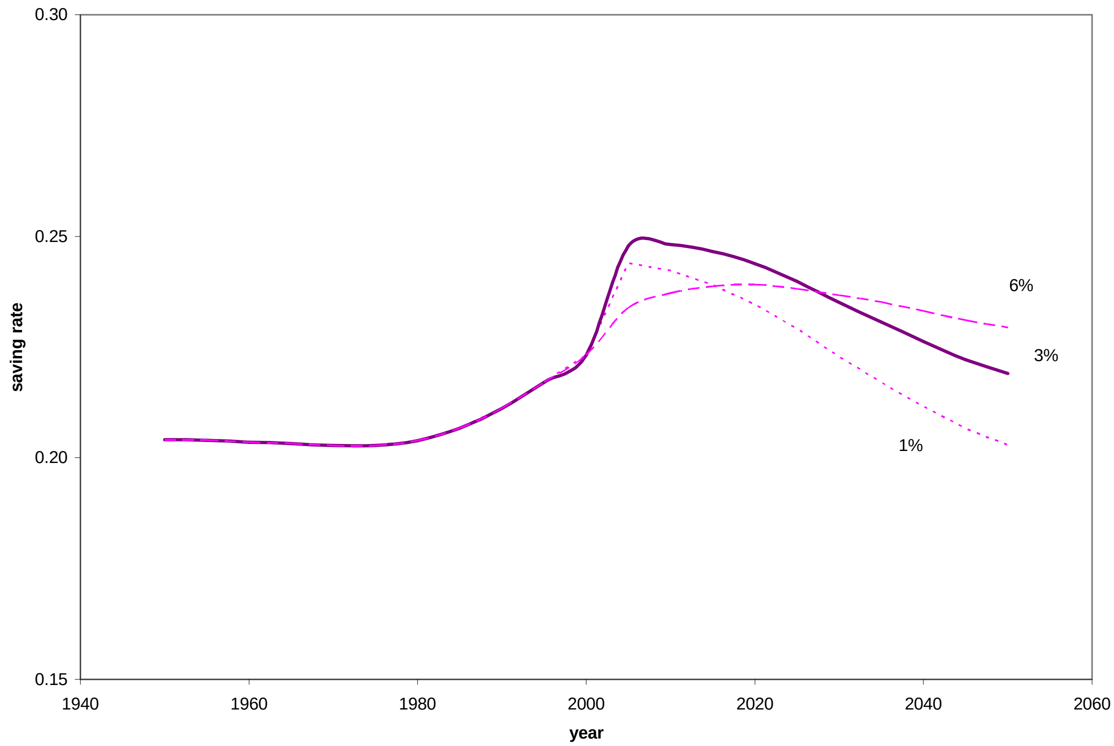
[7] Coefficients of income and consumption estimated from the regression are adjusted to match with the aggregate control for income and consumption in the year 2000. This is implemented by adding a constant value to the coefficients to allow the sum of the product between the exponential of the coefficients (average of the logarithm of consumption and income) and population by age to equal aggregate consumption and income reported in the national income accounts.

Figure 4: Saving Rate Projections: Deaton and Paxson Model



Saving rates of Thailand can be forecast using the population projections from the UN and the age effects of consumption and income shown in Figure 3. The results of future saving rates vary owing to different assumption about per capita income growth. Each cohort is assumed to have new wealth effects due to the change in per capita income growth from 6 percent to other levels at the year 2000. It is also assumed that everyone will know immediately that the change is permanent. Figure 5 presents the changes in saving rates when per capita income growth rates are 1 percent, 3 percent and 6 percent. The results show that saving rates will increase for a short period of time. An increase in saving rates could be from an increase in the share of the working ages as predicted by the lifecycle hypothesis. After increasing for a short period, saving rates are predicted to decline. The decline in saving rates is predicted to be rapid with the scenario of slow economic growth. The slow economic growth provides older ages with relatively more lifetime wealth than younger ages. Thus, slow economic growth will increase the share of dis-saving by elderly relatives to saving by working ages. On the other hand, if the economy of Thailand can maintain its growth at a high level, population aging is not likely to affect saving rates much. For example, given an economic growth rate at 6 percent per year, saving rates in 2050 are predicted to decline about 4 percent from the peak in 2020.

Figure 5: Saving Rate Projections with Different Growth Rates, Thailand



4.2 Mason and Lee Model

Specification

There are a few steps used to simulate saving rates. The first step is to simulate aggregate lifecycle wealth from the consumption and labor income age profiles. Aggregate lifecycle wealth is the wealth that adults must hold, as a group, in a given period in order to achieve a given path of consumption and labor income over the remainder of their collective existence. The aggregate demand for wealth depends on the future trajectories of consumption and labor income. The shapes of cross-sectional age profiles of consumption and labor income are assumed to be fixed and shifting upwards over time. The labor income profile is assumed to shift at some exogenously specified rate of technological progress. The consumption profile shifts at endogenous rates, depending on technological progress, population age structure, the shape of consumption and labor income profile and public policy. Given the trajectory of labor income, the aggregate lifecycle wealth of all adults of age *a* in year *t*, *W(a,t)*,can be calculated for any consumption trajectory as the difference between the present value of consumption and the present value of labor income of all adults over the remainder of their lives. Let PV[] be the present value operator. Then,

$$W(a,t) = PV[C(a,t)] - PV[Y(a,t)] \qquad 9$$

where *C(a,t)* and *Y(a,t)* are vectors of current and future consumption and current and future labor income, respectively, for the cohort of age *a* in year *t*[8].

The second step is to calculate different forms of wealth. Wealth can be held in three forms: assets (*A*), child transfer wealth (T_k) and pension transfer wealth (T_p). Assets are, for example, funded pensions, private savings and capital stock. Child transfer wealth is the present value of the net costs of supporting children through the family or the public sector. Child transfer wealth can be estimated as the present value of the gap between consumption and labor income by children. Child transfer wealth is negative. Pension transfer wealth is the present value of the net transfers that the elderly receive from the working ages, such as familial old age transfers or pay-as-you-go pensions. Adults at a given point in time decide how much assets and transfer wealth they need to hold in order to achieve their lifecycle path that lifetime consumption does not exceed lifetime labor income. Either assets or pension transfer wealth can be used to support future consumption when it is greater than future income. From the perspective of the individual, they are equivalent. However, from the perspective of the macroeconomy, pension transfer wealth and assets are not the same. By accumulating more assets, higher levels of aggregate consumption can be sustained in the future. Assets combined with pension transfer wealth, called pension wealth ($W_p = A + T_p$), are used to support old age consumption. A different fraction of pension transfer wealth to total pension wealth may affect asset accumulation and the aggregate consumption level. Following Mason and

[8] Averages age profiles of consumption and income from eleven survey years during 1981-2004 are used to measure aggregate lifecycle wealth. The consumption and production profiles are scaled so that when they are applied with population in 2000, they match with aggregate consumption and labor income from the National Transfer Flow Account in 2000.

Lee (2006), the ratio of assets to pension wealth is assumed to be constant and assets can only be held by adults. Thus, at a given point in time how much year *t* adults demand for assets to support old age consumption depends on how much they expect to receive transfers from their children, or pension transfer wealth. Consequently, assets for year *t* adults at a given point in time can be simulated as a residual between aggregate wealth and transfer wealth, i.e., $A(t) = W(t) - T_k(t) - T_P(t)$. Further, assets accumulated by year *t* adults increase when current labor income exceeds current consumption and adults receive returns to assets, i.e., $A(t+1) = (1+r)A(t) + Y(t) - C(t)$, where r is rate of return to assets.

The final step is to solve for consumption. Aggregate consumption during each period is determined by several variables, such as the level of assets, interest rate and population age structure. The simulation strategy is to solve for the trajectory of assets and consumption at the steady state level, and then employ backward recursion to the present and historical periods. There are important and necessary assumptions to describe variables at the steady state level. Population is assumed to achieve stability and the model reaches steady state at some point in the distant future, which is assumed to be at the year 2300. Consumption per effective number of consumer as well as assets is assumed to grow at the same rate as productivity. Given these assumptions, aggregate consumption and assets can be solved in steady state year and years thereafter. Provided that consumption and assets in all subsequent periods are known, consumption, assets and lifecycle wealth in the year before the steady state can be solved.

There are some major differences between simulation models by Mason and Lee and Deaton and Paxson. First, saving behavior of adults and the elderly in Mason and Lee model can be changed, whereas that in Deaton and Paxson is constant. For example, the decline in the number of children allows adults to accumulate more assets, leading to a higher consumption and/or saving; an increase in life expectancy leads to lower consumption at all ages and higher saving. Second, there is a strong altruism motive included in the Mason and Lee model. The Mason and Lee model includes intergenerational transfers to simulate asset accumulation, whereas the Deaton and

Paxson model does not take into account intergenerational transfers. Adult people make transfers to the elderly to ensure the elderly can maintain their living standard.

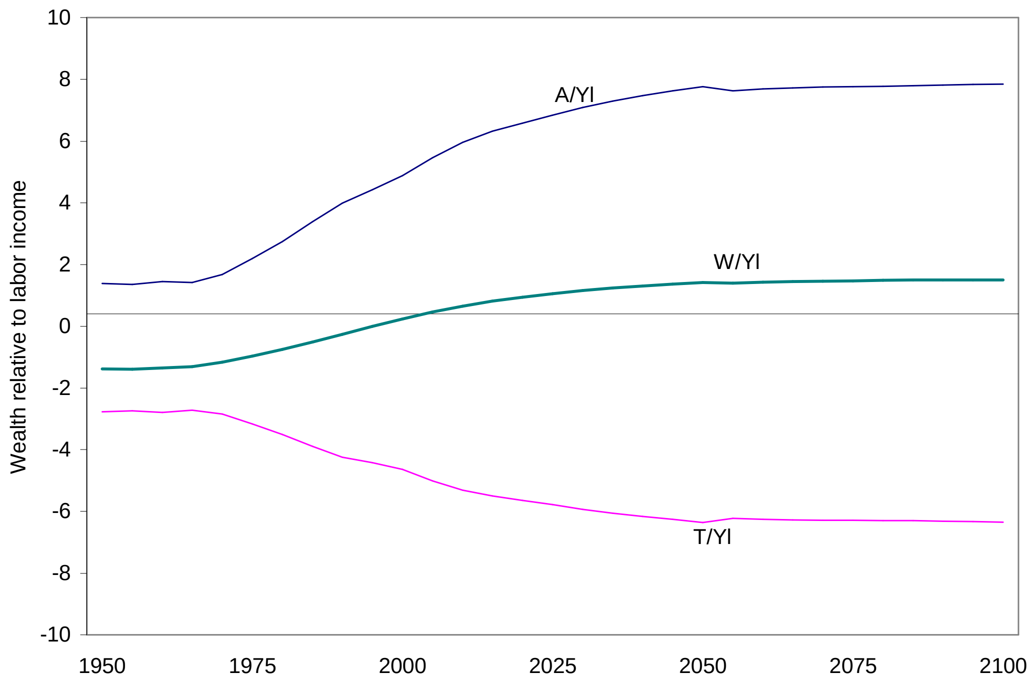
Based on Mason and Lee (2006), there are necessary assumptions for the simulation. Discount rate is assumed at 3 percent. Depreciation rate is assumed at 3 percent. The international real rate of return on assets is assumed at 6 percent, declining linearly to a a steady-state rate of interest at 4.42 percent in 2300. Productivity growth rate is 1.5 percent. In addition, there are some important assumptions, relating to how individuals accumulate lifetime wealth. The assumptions of wealth accumulation are used based on the National Transfer Flow Account for Thailand in 2004. Child transfer wealth is simulated assuming two-thirds of child costs in Thailand are financed by familial transfers and one-third by public transfers. Pension transfer wealth is simulated assuming the old age support systems in Thailand are based on assets at 64 percent and pension transfer wealth at 36 percent.

Empirical Results

Figure 4-6 shows wealth (*W*), assets (*A*) and transfer wealth (*T*) relative to labor income (*Yl*) during 1950-2100. Between 1950 and 2000, assets increased steeply from about 1.5 to about 5 times of labor income. An increase in assets during this period is associated with an increase in the support ratio[9]. People during productive ages accumulate assets to prepare for their old age consumption. Thus, an increase in people at these ages leads to an increase in assets. Wealth during this period is negative due to greater negative transfer wealth than assets. After the year 2000, assets do not increase as steeply as the previous periods. Even though assets do not increase any further, assets remain at a much higher level.

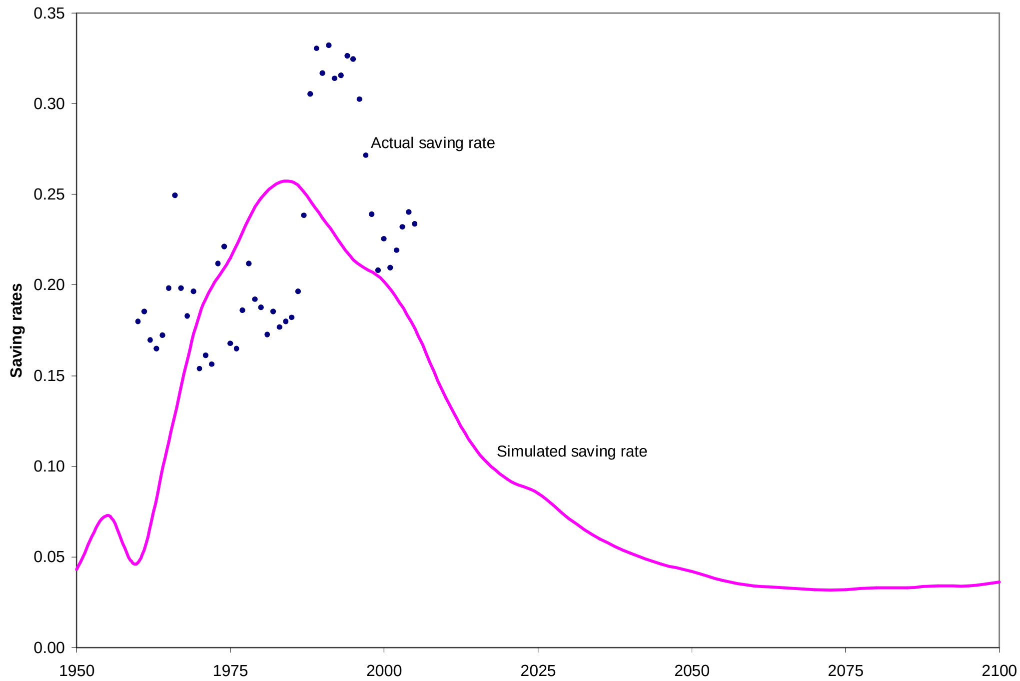
[9] Mason and Lee (2006) define support ratio as total effective number of producers divided by total effective number of consumers, which can be measure by summing the product of population by age and per capita age profile of production and consumption. This method takes into account of different productivity and consumption needs by people in different age groups, instead of using broad population age groups, such as those ages 20-64 divided by total population, to estimate support ratio.

Figure 6: Aggregate Demand for Wealth and Its Components, Thailand, 1950-2100



Simulated national saving rates are compared with the actual net national saving rates of Thailand as shown in Figure 7. The simulation results show that saving rates reach the peak at around 27 percent of national income between 1980 and 1985. High saving rates during this period contributed to a steep increase in assets as shown in Figure 6. The simulation results explain the relationship between age structure and saving rates well before 1985. These findings are similar to the simulated results based on the Deaton and Paxson model. Both the Mason and Lee model and the Deaton and Paxson model show that change in age structure in Thailand had major effects on change in saving rates before 1985. Then, simulated saving rates gradually decline, whereas actual saving rates remained at a high level during the 1990s and early 2000s. Similar to findings based on the Deaton and Paxson model, change in age structure in Thailand after 1985 did not affect change in saving rates much. In contrast, change in saving rates during these periods was mainly due to a secular trend. Further, based on the simulation, the saving rates decline to about 5 percent around 2050, which is about 80 percent lower than the peak during 1980-1985.

Figure 7: Saving Rate Projections: Mason and Lee Model



Results based on the Mason and Lee simulation model show that even though population aging leads to a decline in saving rates, assets per labor income increase and remain at a high level in the future period. These findings, using Thailand's data, are consistent with the results by Mason and Lee (2006) using Taiwan's data. An increase in assets allows individuals to earn a higher asset income, which can be used to support a higher level of consumption.

5. Conclusions

Population aging leads to a decline in saving rates. However, the effects of population aging on saving rates are not so severe. There are two models used to simulate saving rates under different assumptions about how age profiles of saving are modeled.

The first method, using the Deaton and Paxson (2000) simulation model, assumes the age profiles of saving are fixed for all cohorts. Saving can be decomposed into age and cohort effects. Age effects of saving in Thailand show a hump shape. People save less during young working ages than old working ages, then they dis-save when they retire. The cohort effects show that younger cohorts in Thailand save less than older cohorts. Using population estimates and projections, saving rates can be simulated. The results based on the Deaton and Paxson model show that saving rates in Thailand increased after 1975, which corresponds to the period when the fertility rates in Thailand declined and the share of the working ages increased. Simulated saving rates would increase until 2020 before declining slowly with an increase in the share of the elderly. The simulated saving rates would decline more rapidly if the economic growth is slow.

The second method, using Mason and Lee (2006)'s simulation model, assumes the saving age profiles may vary for all cohorts. The results show that simulated saving rates increased during the period when the effective number of producers relative to effective number of consumers was high. Then, simulated saving rates decline when assets increase slowly. Even though, population aging leads to a decline in saving rates, population aging leads to higher assets and asset income in the economy, allowing people to consume at higher level of consumption.

This paper finds that simulated saving rates based on both the Deaton and Paxson model and the Mason and Lee model show similar effects of change in age structure on change in saving rates in Thailand. Change in age structure in Thailand had major effects on change in saving rates before 1985. However, after 1985 changes in saving rates were mainly due to secular trends rather than change in age structure. The major difference between these two models is on the level of simulated saving rates for the future. Simulated saving rates based on the Deaton and Paxson model would not change much with population aging. In contrast, simulated saving rates based on the Mason and Lee model would decline significantly with population aging.

APPENDIX

Mathematical Explanation for Mason and Lee (2006) Simulation Model

This section presents how saving rates are simulated using Mason and Lee (2006) model. This part is drawn substantively from Mason and Lee (2006). First, simulation methods for lifecycle wealth and its components, which are assets, child transfer wealth and pension transfer wealth, are presented. Then, this section describes how to solve for consumption at the steady state level.

Aggregate lifecycle wealth

Aggregate lifecycle wealth of all adults of age *a* in year *t*, *W(a,t)*, is the combined lifecycle wealth of all adults of age *a* in year *t*. It is equal to the present value of the consumption less the present value of the labor income of those adults over the remainder of their lives. Let PV[] be the present value operator. Then,

$$W(a,t) = PV[C(a,t)] - PV[Y(a,t)] \tag{1}$$

where *C(a,t)* and *Y(a,t)* are vectors of current and future consumption and current and future labor income, respectively, for the cohort of age *a* in year *t*.

The effect of age on earnings is captured in the effective number of producers (*L*) where:

$$\begin{aligned} L(a,t) &= \gamma(a)P(a,t) \\ L(t) &= \sum_{a=0}^{\omega} L(a,t), \end{aligned} \tag{2}$$

and *P(a,t)* is the population aged *a* at time *t*, ω is the oldest age achieved and $\gamma(a)$ is an age-specific, time-invariant vector of coefficients measuring age variation in labor income. Similarly, the effective number of consumers (*N*) is:

$$\begin{aligned} N(a,t) &= \phi(a)P(a,t) \\ N(t) &= \sum_{a=0}^{\varpi} N(a,t) \end{aligned} \tag{3}$$

where $\phi(a)$ is an age-specific, time-invariant vector of coefficients measuring relative levels by age of cross-sectional consumption.

Total labor income in year *t* is determined by the total number of effective producers and the level of labor productivity as measured by the labor productivity index, $\bar{y}(t)$. Likewise, total consumption in year *t* is determined by the total number of effective consumers and the level of consumption as measured by the consumption index, $\bar{c}(t)$:

$$\begin{aligned} Y(t) &= \bar{y}(t)L(t) \\ C(t) &= \bar{c}(t)N(t) \end{aligned} \tag{4}$$

The rate of growth of labor productivity (g_y) is exogenous and constant so that:

$$\bar{y}(t+x) = \bar{y}(t)G_y(x) \tag{5}$$

where $G_y(x) = (1+g_y)^x$. The rate of growth of the consumption index will vary over time and is endogenously determined. The consumption index can be represented as an annual series of endogenously determined growth rates:

$$\begin{aligned} \bar{c}(t+x) &= G_c(t,x)\bar{c}(t) \\ G_c(t,x) &= \prod_{z=0}^{x-1}(1+g_c(t+z)) \end{aligned} \tag{6}$$

where $g_c(t+z)$ is the rate of growth in the consumption index between year *t+z* and *t+z+1*.

These general rules can be applied to year *t* adults to determine their labor income and consumption over their remaining adult years and, hence, their wealth in year *t*. Let *NTOT(t,x)* denote the number of effective consumers in year *t+x* who were adults in year *t*. Similarly, *LTOT(t,x)* denotes the number of effective producers in year *t+x* who were adults in year *t*, where a_0 is the age of adulthood:

$$\begin{aligned} NTOT(t,x) &= \sum_{a=a_0+x}^{\omega} N(a,t+x) \\ LTOT(t,x) &= \sum_{a=a_0+x}^{\omega} L(a,t+x). \end{aligned} \tag{7}$$

In a closed population NTOT and LTOT would depend only on survival rates, but in an open population they will include migrants who were adults in year *t*.

The labor income of year *t* adults at age $a \geq a_0 + t$ in year *t+x* is:

$$Y(a,t+x) = \overline{y}(t+x)L(a,t+x) \tag{8}$$

and consumption by year *t* adults in year *t*+*x* is:

$$C(a,t+x) = \overline{c}(t+x)N(a,t+x). \tag{9}$$

The present value in year *t* of the current and future lifetime consumption of all adults is given by:

$$PVC(t) = \overline{c}(t)\sum_{x=0}^{\omega-a_0} D(x)G_c(x,t)NTOT(t,x), \tag{10}$$

and the present value in year *t* of the current and future lifetime production of all adults is given by:

$$PVY(t) = \overline{y}(t)\sum_{x=0}^{\omega-a_0} D(x)G_y(x)LTOT(t,x), \tag{11}$$

where $D(x)$ is the discount factor $(1+\delta)^{-x-1}$. Substituting into equation (1), the lifecycle wealth of all adults in year *t* is:

$$\begin{aligned} W(t) &= \overline{c}(t)\sum_{x=0}^{\omega-a_0} D(x)G_c(x,t)NTOT(t,x) \\ &\quad -\overline{y}(t)\sum_{x=0}^{\omega-a_0} D(x)G_y(x)LTOT(t,x). \end{aligned} \tag{12}$$

Components of Wealth

Lifecycle wealth in year *t* for the cohort comes in three forms: assets (*A*), transfer wealth associated with childrearing (T_K) and pension transfer wealth (T_P), i.e.,

$$W(a,t) = A(a,t) + T_k(a,t) + T_P(a,t). \tag{13}$$

Pension wealth is defined as $W_P(a,t) = A(a,t) + T_P(a,t)$, i.e., assets plus pension transfer wealth.

Assets can be negative, but by assumption they can only be held by adults. Aggregate assets in year *t* are calculated by summing over all adult cohorts:

$$A(t) = \sum_{a=a_0}^{\omega} A(a,t) \tag{14}$$

Summing transfer wealth variables over all adult ages:

$$A(t)+T_P(t)=W_p(t)=W(t)-T_k(t). \tag{15}$$

where $T_P(t)$ is pension transfer wealth, $T_k(t)$ is child transfer wealth, and $W_p(t)$ is pension lifecycle wealth equal to the sum of assets and pension transfer wealth.

The relative size of pension transfer wealth is captured by $\tau(t)=T_P(t)/W_p(t)$ and the relative size of child transfer wealth by $\tau_k(t)=T_k(t)/W(t)$. Substituting into equation (15) and rearranging terms gives the total assets of adults in year t and, because only adults hold assets, aggregate assets in year *t*:

$$A(t)=(1-\tau(t))\left(1-\tau_k(t)\right)W(t). \tag{16}$$

In the analysis presented here, pension transfer policy, $\tau(t)$, is assumed to be exogenous.

The following explains how to simulate child transfer wealth, pension transfer wealth and assets. Next, the solutions to estimate assets and consumption at the steady state level are described. Then, the methods to simulate assets, consumption and other variables at years before steady state using backward recursion are presented.

Child Transfer Wealth

The cost of children to year *t* adults also depends on their share of the costs of children in future periods. By assumption all of the *current* costs of children are born exclusively by year *t* adults. Year *t* adults are responsible only for a portion of the cost of children in subsequent years, because some portion of the costs of children is shifted to persons who become adults after year *t*.

The model distinguishes two ways in which child costs are financed: familial transfers and public transfers. Adult parents are assumed to bear the cost of familial transfers. Public transfers are financed through a proportional tax on labor income. The relative mix of these two mechanisms is an exogenously determined policy variable.

The cost of all children age *z* in year *t+x* is:

$$\begin{aligned} COST(z,t+x) &= Y(z,t+x) - C(z,t+x) \\ &= \overline{y}(t)G_y(x)L(z,t+x) - \overline{c}(t)G_c(t,x)N(z,t+x) \qquad z < a_0 \end{aligned} \tag{17}$$

A fraction of the cost of children of age *z* in year *t+x* is financed through transfers by year *t* adults; the remainder is financed through transfers by persons who became adults between year *t* and *t+x*. Let $TAX_k(z,t,x)$ be the share of child costs paid by year *t* adults. Then, child transfer wealth in year *t* for year *t* adults is:

$$T_k(t) = \sum_{x=0}^{\omega-a_0} D(x) \sum_{z=0}^{a_0-1} \mathrm{TAX_k}(z,\mathrm{t},\mathrm{x})\,\mathrm{COST}(z,\mathrm{t+x}) \tag{18}$$

Substituting for COST from equation (17) yields:

$$\begin{aligned} T_k(t) &= \overline{y}(t)\sum_{x=0}^{\omega-a_0} D(x)G_y(x)KLTOT(t,x) - \overline{c}(t)\sum_{x=0}^{\omega-a_0} D(x)G_c(t,x)KNTOT(t,x) \\ KLTOT(t,x) &= \sum_{z=0}^{a_0-1} \mathrm{TAX_k}(z,\mathrm{t},\mathrm{x})L(z,t+x) \\ KNTOT(t,x) &= \sum_{z=0}^{a_0-1} \mathrm{TAX_k}(z,\mathrm{t},\mathrm{x})N(z,t+x) \end{aligned} \tag{19}$$

where $KLTOT(t,x)$ is the total number of children in year *t+x* dependent on year *t* adults measured in equivalent production units and in year *t+x* and $KNTOT(t,x)$ is the total number of children in year *t+x* dependent on year *t* adults measured in equivalent consumption units.

Tax burden of year *t* adults depends on whether child costs are financed through public or private (familial) transfer programs. Mason and Lee assume that the shares of public and private transfers are constant and exogenous, i.e., they are a matter of public policy. Let the familial share be τ^f and the public share be $1-\tau^f$. Then the share of cost paid by year *t* adults is a weighted sum of the taxes paid through a familial transfer system and the taxes paid through a public transfer system, i.e.,

$$TAX_k(z,t,x) = \tau^f TAX_k^f(z,t,x) + (1-\tau^f)TAX_k^g(z,t,x) \tag{20}$$

where $TAX_k^f(z,t,x)$ is the share of child costs paid by year *t* adults under a familial transfer system and $TAX_k^g(z,t,x)$ is the share of child costs paid by year *t* adults under a public transfer system.

All public transfers to children are assumed to be financed by a proportional tax on labor income. Thus,

$$TAX_k^g(z,t,x) = \sum_{a=a_0+x}^{\omega} Y(a,t+x)/Y_A(t+x) \tag{21}$$

where $Y_A(t+x) = \sum_{a=a_o}^{\omega} Y(a,t+x)$ is the total labor income of all in year $t+x$.

The tax share of year t adults is in year $t+x$ is their share of labor income in year $t+x$. Note that the public tax share is independent of the age of the child, *z*. Henceforth, the z argument can be dropped.

Mason and Lee assume that familial transfers are determined by parentage. If F(z,t,x) equal the proportion of those aged z with parents (mothers) age $a_0 + x$ or older in year $t+x$, then

$$TAX_k^f(z,t,x) = F(z,t,x) \tag{22}$$

where F is calculated using the distribution of births to women:

$$\begin{aligned} F(z,t,x) &= \frac{\sum_{a=a_0+x-z}^{AGEM} B(a,t+x-z)}{\sum_{a=a_0}^{AGEM} B(a,t+x-z)} \quad \text{for } x > z \\ &= 1 \quad \text{for x} \le \text{z.} \end{aligned} \tag{23}$$

and $B(a,t+x-z)$ is births to women aged a in year $t+x-z$. Children who are x years or older are all the offspring of year t adults (mothers) and hence F has a value of 1. The value of F declines to zero as x increases. (Note that F can be represented as a function of t and x-z. It isn’t really three dimensional.)

Substituting into equation (20), the share of year t adults is:

$$TAX_k(z,t,x) = \tau^f F(z,t,x) + (1-\tau^f) \sum_{a=a_0+x}^{\omega} Y(a,t+x)/Y_A(t+x) \tag{24}$$

Substituting into equation (19) yields child transfer wealth for year t adults. Note that the tax shares devoted to childrearing are determined exogenously by population age structure, fertility, the age profile of earnings – all exogenous factors. Thus, in the determination of child transfer costs, the only endogenous variable is the vector of the consumption index. Child transfer wealth is equal to:

$$T_k(t) = \bar{y}(t)\sum_{x=0}^{\omega-a_0} D(x)G_y(x)KLTOT(t,x) - \bar{c}(t)\sum_{x=0}^{\omega-a_0} D(x)G_c(t,x)KNTOT(t,x) \tag{25}$$

where $KLTOT(t,x)$ and $KNTOT(t,x)$ are the effective numbers of child producers and consumers, respectively, in year $t+x$ for which year t adults are financially responsible.

Lifecycle Pension Wealth: $W_p(t)$

Pension wealth is equal to lifecycle wealth less child transfer wealth. Combining the results from equations (12) and (25) and rearranging terms yields:

$$\begin{aligned} W_p(t) = \bar{c}(t)\sum_{x=0}^{\omega-a_0} D(x)G_c(t,x)\left(NTOT(t,x) + KNTOT(t,x)\right) \\ -\bar{y}(t)\sum_{x=0}^{\omega-a_0} D(x)G_y(x)\left(LTOT(t,x) + KLTOT(t,x)\right). \end{aligned} \tag{26}$$

Lifecycle pension wealth is the discounted present value of current and future consumption by year t adults and their dependent children less the present value of current and future production by year t adults and their dependent children.

Assets

Total assets are governed by the lifecycle accounting just described, but also by a macroeconomic constraint: the change in assets from one period to the next must equal saving during the period. Mason and Lee assume that assets are measured at the beginning and that consumption and labor income accrue at the end of the period and, hence:

$$(1+r)A(t) + Y(t) - C(t) = A(t+1). \tag{27}$$

Steady-state Results

In steady-state, assets grow at the same rate as total labor income, g_Y. Substituting $(1+g_Y)A(t)$ for *A(t+1)*, substituting for income and consumption, and rearranging terms, assets in steady state must satisfy:

$$A(t^*) = \frac{1}{r - g_Y}\left[\bar{c}(t^*)N(t^*) - \bar{y}(t^*)L(t^*)\right]. \tag{28}$$

From the analysis of the lifecycle the relationship between assets and lifecycle pension wealth is governed by exogenously specified pension transfer policy:

$$A(t^*) = (1-\tau(t^*))W_P(t^*), \tag{29}$$

where $W_P(t)$ is given in equation (26). Combining the macro and lifecycle conditions, and noting that the growth rate of the consumption index must equal the growth rate of the production index in steady-state, the consumption index in steady-state must satisfy:

$$\frac{1}{r - g_Y}\left[\bar{c}(t^*)N(t^*) - \bar{y}(t^*)L(t^*)\right] = (1-\tau(t^*))W_p(t^*). \tag{30}$$

Rearranging terms yields:

$$\frac{\bar{c}(t^*)}{\bar{y}(t^*)} = \frac{L(t^*)}{N(t^*)}\left[1 + (r - g_Y)(1-\tau(t^*))w_p(t^*)\right], \tag{31}$$

where $w_p(t^*)$ is the ratio of lifecycle pension wealth to current labor income.

Equation (40) tells us the level of consumption that can be sustained in steady-state given any level of labor productivity. Age-structure determines the steady-state consumption ratio through two multiplicative factors – the economic support ratio and a second factor that captures the influence of age structure on lifecycle pension wealth and, hence, assets.

Backward Recursion

The backward recursion solution computes the consumption index and, hence, all other variables in period *t-1* conditional on the values in period *t*. The steady-state values are known. Hence, we can begin in period *t**, solve for period *t*-1*, and recursively solve for all periods *t*.

From lifecycle accounting, assets in period *t-1* depend on pension policy and lifecycle wealth in year *t-1*. From equations (26) and (29):

$$\begin{aligned} A(t-1) = \bar{c}(t-1)(1-\tau)\sum_{x=0}^{\omega-a_0} D(x)G_c(t-1,x)\big(NTOT(t-1,x)+KNTOT(t-1,x)\big) \\ -\bar{y}(t-1)(1-\tau)\sum_{x=0}^{\omega-a_0} D(x)G_y(x)\big(LTOT(t-1,x)+KLTOT(t-1,x)\big). \end{aligned} \tag{32}$$

Pension policy may vary with year, but here we drop *t* to simplify notation. The right-hand-side variables include consumption in year *t-1*, consumption in year *t* and subsequent years, and labor income terms in year *t-1* and later. Only the consumption terms in year *t-1* are unknown and must be solved for. These are distinguished in:

$$\begin{aligned} A(t-1) &= \bar{c}(t-1)(1-\tau)N(t-1)D(0) \\ &+(1-\tau)\sum_{x=1}^{\omega-a_0} D(x)\bar{c}(t-1+x)\big(NTOT(t-1,x)+KNTOT(t-1,x)\big) \\ &-\bar{y}(t-1)(1-\tau)\sum_{x=0}^{\omega-a_0} D(x)G_y(x)\big(LTOT(t-1,x)+KLTOT(t-1,x)\big). \end{aligned} \tag{33}$$

From macro-accounting, we know that:

$$A(t-1) = \frac{A(t)+\bar{c}(t-1)N(t-1)-\bar{y}(t-1)L(t-1)}{1+r}. \tag{34}$$

This gives us two equations in two unknowns, assets and the consumption index in period *t-1*. Substituting for *A(t-1)* yields:

$$\begin{aligned} &\bar{c}(t-1)(1-\tau)N(t-1)D(0)+(1-\tau)\sum_{x=1}^{\omega-a_0} D(x)\bar{c}(t-1+x)\big(NTOT(t-1,x)+KNTOT(t-1,x)\big) \\ &-\bar{y}(t-1)(1-\tau)\sum_{x=0}^{\omega-a_0} D(x)G_y(x)\big(LTOT(t-1,x)+KLTOT(t-1,x)\big) \\ &=\frac{A(t)+\bar{c}(t-1)N(t-1)-\bar{y}(t-1)L(t-1)}{1+r} \end{aligned} \tag{35}$$

Multiplying both sides by $1+r$ and rearranging terms yields:

$$\begin{aligned} &\bar{c}(t-1)N(t-1)\big((1-\tau)(1+r)D(0)-1\big) \\ &= A(t)-(1+r)(1-\tau)\sum_{x=1}^{\omega-a_0} D(x)\bar{c}(t-1+x)\big(NTOT(t-1,x)+KNTOT(t-1,x)\big) \\ &+\bar{y}(t-1)(1+r)(1-\tau)\sum_{x=0}^{\omega-a_0} D(x)G_y(x)\big(LTOT(t-1,x)+KLTOT(t-1,x)\big)-\bar{y}(t-1)L(t-1) \end{aligned} \tag{36}$$

Further algebra gives the consumption index for *t-1:*

$$\bar{c}(t-1)=\frac{\left\{\begin{array}{l} A(t)-(1+r)(1-\tau)\sum_{x=1}^{\omega-a_0} D(x)\bar{c}(t-1+x)\left(NTOT(t-1,x)+KNTOT(t-1,x)\right) \\ +\bar{y}(t-1)\left\{(1+r)(1-\tau)\sum_{x=0}^{\omega-a_0} D(x)G_y(x)\left(LTOT(t-1,x)+KLTOT(t-1,x)-L(t-1)\right)\right\} \end{array}\right\}}{N(t-1)\left((1-\tau)(1+r)D(0)-1\right)}. \tag{37}$$

Assets in period *t-1* can be calculated using either equation (33) or equation (34).

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