Saving, Wealth, and Population *

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The connection between saving, population, and economic growth is most easily explained using the neo-classical growth model. Solow (1958) describes an economy in which output per worker is determined by only two variables, capital per worker and the level of technology. Assuming that technology is constant for the moment, economic growth occurs because of an increase in capital per worker or *capital deepening*. Solow (1958) shows that the rate

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of capital deepening is determined by the rate of saving s and the rate of population growth n. Formally,

$$\dot{k}_t = sy_t - nk_t, \tag{1}$$

where y_t and k_t are output and capital per effective worker, respectively, and $\dot{k}_t$ is the change in k_t per unit of time. The first term on the right-hand-side of the equation is the amount of new capital being providing each period by the average worker. The second term is the amount each worker must provide in order to equip new workers at the prevailing capital-labor ratio. If saving exceeds that necessary to equip new workers, the capital-labor ratio increases, i.e., capital deepening occurs.

Given a constant saving rate and a constant population growth rate, the neo-classical model tends towards an equilibrium in which saving is just sufficient to maintain the ratio of capital per worker. The equilibrium occurs when $sy_t = nk_t$ or, in a form that is useful below, when:

$$K^e/Y^e = s/n. \tag{2}$$

If output is a constant returns to scale function of capital and labor and the elasticity of output with respect to capital is β, then equilibrium output per worker is given by:

$$y^e = (s/n)^{\beta/(1-\beta)}. \tag{3}$$

Several important implications follow from the model. First, an increase in the saving rate or a decrease in the population growth rate yields a higher equilibrium capital-output ratio and a higher equilibrium output per worker. Second, an increase in the saving rate or a decline in the population growth rate produces a *transitory* increase in the growth rate of output per worker. Third, neither the saving rate nor the population growth rate influence the *rate of growth* of output per worker once equilibrium is established.[1]

Introducing technological change into the model leaves these conclusions intact. In equilibrium, capital per worker and output per worker grow at the

[1]Equations 1-3 are not defined when the population growth rate is zero; or, incorporating the rate of technological progress, λ, when $n+\lambda=0$. In this case, income will grow without limit.

rate of technological change, λ. Total capital and total output grow at $\lambda + n$. The equilibrium ratio of capital to output is given by $s/(\lambda + n)$.[2]

The neo-classical model obviously abstracts from important features of the growth process. It neglects, to name a few obvious examples, development policy, the financial sector, and human resources. However, the importance of capital deepening and the importance of understanding the underlying factors that lead to capital deepening are borne out by many recent studies of economic growth (citations, e.g., Harberger, Young, Kim and Lau, World Bank).

The analysis summarized below draws heavily on the experience of Taiwan and other East Asian economies. The rapid increase in capital per worker is one of the distinguishing features of the most successful economies of the post-World War II era. For four East Asian economies for which data are available the annual growth rate in capital per worker from 1965 to circa 1990 ranged from 6.6 percent in Thailand to 8.7 percent in Taiwan as compared with only 2.7 percent in the United States (Figure 1).

Figure 1. Capital per worker, US and East Asia.

Estimates of the rates of productivity growth or technological progress vary, but the observed rates of capital deepening are at least two to three times the rate of technological progress. For example, Harberger (1998) reports total factor productivity growth rates for Taiwan, South Korea, and Thailand in the 2.4 to 3.7 percent range (p 25). If Young's (1994) more modest estimates of productivity growth in East Asia are accurate, then capital deepening exceeds technological progress by an even greater factor.

In the Solow framework, two sources can account for capital deepening that is more rapid than the rate of technological progress: a rise in the saving rate or a decline in the population growth rate. Both have operated to some extent in East Asia. Trends in saving rates are shown for six East Asian economies in Figure 2. In 1960, South Korea, Singapore, and Indonesia had gross domestic saving less than ten percent of gross domestic product. Saving rates in Taiwan and Thailand were below twenty percent. By the early 1990s, saving rates in the 30 to 40 percent range were typical (Figure 2). Capital deepening in Japan can also be traced to rising saving rates, but they were already quite high by 1960.[3]

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[2] Solow assumes that technological growth is labor-augmenting.

[3] Following Solow, we have to this point ignore international capital flows. The rate

Figure 2. Saving rates.

Declining population growth rates have also influenced the rate of capital deepening in East Asia, but the experience is varied. Taiwan and South Korea have both experienced sharp drops in their population growth rates in recent decades. Japan's population growth rate has dropped to near zero, although Japan did not experience population growth as rapid as other Asian countries (Figure 3). Thailand's population growth rate has declined substantially only recently.

Figure 3. Population growth rates.

Labor force growth rates have not dropped as rapidly as population growth rates in East Asia. In part, this reflects the underlying dynamics of the demographic transition. Populations growth slows from the bottom of the age-distribution up, i.e., growth in the number of children begins to slow earliest, growth in the working ages later. Hence, the population in the working ages has grown more rapidly in East Asia than the general population. In addition, female participation rates have increased substantially in some East Asian populations, including Taiwan and South Korea, helping to sustain a relatively rapid rate of growth in the labor force.

The changes in population growth rates and saving rates in East Asia, and no doubt elsewhere, raise important questions about the neo-classical model. First, can the decline from a high rate of population growth to a low rate of population growth be characterized as the movement between two equilibria? Probably not. High rates of population growth are a transitory phenomenon in East Asia and elsewhere. Populations before the demographic transition, when population growth rates were low, might be adequately described as in equilibrium. If demographic transition "theory" proves accurate, populations of the future will reach equilibrium again at a slow population growth rate. If low fertility rates persist in the future, negative population growth may become common. But in the midst of the demographic transition, population growth rates (and population age structures) often change quickly.

Second, why have saving rates increased so substantially in East Asia? Are they likely to reach some equilibrium in the future? And, if so, at what level? These issues are taken up in the remainder of this paper.

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of capital deepening within an economy depends on the investment rate rather than the saving rate. Investment rates have also increased in East Asia although by less than saving rates particularly in Japan, Taiwan, and Singapore which have had large current account surpluses in recent years.

Saving and population growth

Fisher (1935), among many others, recognized the connection between population and saving. Life-cycle variation in individual productivity leads individuals to vary their saving over their lifetime in order to smooth their consumption. If saving varies by age, then changes in population age-structure, that inevitably accompany changes in population growth rates, will affect aggregate saving rates. If lifecycle saving is dominated by pension motives, as hypothesized by Modigliani and others (Modigliani and Brumberg (1954); Modigliani and Ando (1957)), saving is concentrated among working age adults while the elderly dissave. Thus, slower population growth leads to an older population and lower aggregate saving. Coale and Hoover (1958) pointed out, however, that the high costs of childrearing in a rapidly growing, high fertility population, may impede saving so that slower population growth, by reducing the burden of supporting children, may lead to increased saving.

The life-cycle saving model is readily incorporated into the neo-classical growth model because, in equilibrium, the lifecycle saving rate is constant (see, for example, Mason 1987).[4] As with the Solow model, the saving rate, the population growth rate, and the rate of growth of income and income per worker are all constant. Income per worker grows at the rate of technological progress. However, the impact of population growth on the equilibrium level of income is greater than or less than under the simple neo-classical model with a constant saving rate depending on whether population growth results in an increase or a decline in the saving rate.

Tobin (1967) provides an alternative approach to analyzing lifecycle saving within the neo-classical model. Tobin shows that the aggregate demand for wealth, K/Y, by households governed by lifecycle behavior is constant in equilibrium. He explores the impact of changes in the number of children and the changes in age structure that accompany changes in population growth rates. His calculations, based on US data, show that slower population growth leads to an increase in the K/Y ratio. This implies, in turn, an

[4] A population, closed to migration, will reach an equilibrium or stability when the age-specific probabilities of childbearing and dying are constant for a sufficiently long period of time. Once in equilibrium, the population grows at a constant rate and the age-structure of the population is constant. The economy is in equilibrium when the rate of interest is constant, technological progress is constant, i.e., wages shift up by the same percentage in each year, and the age-earnings profile does not change from year to year.

increase in equilibrium output per worker. Tobin does not consider, however, whether the increase in K/Y is greater than or less than that implied by the simple neo-classical model nor whether the equilibrium saving rate is higher or lower given slower population growth.

The analysis presented here builds on previous studies that have explored the impact of population change on saving and wealth using a lifecycle framework. The accumulation of wealth by households is illustrated in a stylized manner in Figure 4 taken from Lee, Mason, and Miller (forthcoming). Adults enter the workforce and begin to accumulate wealth. They continue do so until they retire. Under some circumstances they may continue to accumulate wealth during the early years of their retirement living off interest income. Then, they draw down their wealth supporting themselves in the absence of labor income. Tobin and Modigliani use "pure" lifecycle models in which households leave no bequests, but Figure 4 is drawn to accommodate the possibility that households leave bequests. Uncertainty about time of death may lead people to over-accumulate wealth on average. People may hold additional wealth as a buffer against uncertain income streams or consumption needs, and people may save to provide bequests for their children. The need to provide for old age consumption is only one of a number of factors that motivates accumulation. Irrespective of the motivation, wealth profiles typically increase with age. The extent to which wealth declines among the elderly is an empirical issue about which there is considerable debate (Hurd, 1997).

Figure 4. Stylized Wealth and the Life-cycle

Over the demographic transition, the number of children rises and then falls. The influence on the age-wealth profile is illustrated, again in highly stylized fashion, in Figure 4. If children are, on net, a cost to their parents, an increase in the number of children reduces the average consumption per household member in all years. Because the household smooths over the life-cycle, consumption in years in which there are no childrearing costs, including retirement years, declines. Hence, less wealth is accumulated to support retirement. A rise in the number of children leads to increased consumption during childrearing years. The increase is by less than the full-cost of children, because parents bear some of the costs by reducing their own consumption. This leads to a wealth profile that is more bowed than would otherwise be the case. Accumulation is concentrated more heavily in the post-childrearing years. If children are net contributors to household income when they are older, the bowing effect would be reinforced. If adults do not immediately begin bearing children, they would accumulate more wealth early in their adult lives in anticipation of higher future childrearing costs. The impact of children will be attenuated if there are substantial economies of scale to childrearing or if parents reduce spending on their other children. (This latter response may lead to lower accumulation of human capital.) Changes in the number of children may also influence other saving motives, such as bequests or uncertainty, affecting the wealth profile in ways that cannot be determined *a priori*.

Most previous studies of wealth, saving and population focus on fertility and age-structure. But changes in mortality that occur over the demographic transition potentially have a large impact on saving. The retirement motive for wealth accumulation is a relatively weak force in a high mortality, pre-transition population because the expected duration of retirement is so short. For the pre-transition mortality rates used to characterize Taiwan below, a typical individual could expect to live only 0.078 years after age 65 for every year lived between the ages of 20-64. A modest level of wealth is sufficient to finance retirement needs in such a population. In a post-transition population, the number of years lived after age 65 are greater by a factor of 4 or 5. To provide the same measure of economic support in old age, wealth also must be substantially greater (Figure 4) by a factor of 3 to 4, as will be shown below.

Lifecycle Wealth: Transfer Wealth or Capital?

The forms of wealth that can resolve lifecycle problems are more varied than frequently envisioned in lifecycle saving models. Working age people must develop claims on future output beyond their own expected future production. These claims or wealth can be held in three forms: physical wealth (or capital), credit, or transfers. An individual can hold positive wealth in the form of credit, but aggregate credit wealth is always zero because credits and debits are in balance.[5] Transfer wealth is the present value of the difference between the transfers you expect to receive in the future, and the transfers you expect to make. Aggregate transfer wealth can be positive because of transfers from future generations. In traditional societies and in some industrial ones, most people expect to be supported in their old age by

[5] Through foreign lending and borrowing individual countries can create aggregate credit wealth, but global credit wealth must be zero.

their own adult children. Under these circumstances, the wealth represented in Figure 4 may consist largely of transfer wealth not capital. Many countries have developed pay-as-you-go social security systems that provide support to the elderly by transferring resources from those who are currently workers. These systems also create transfer wealth, rather than capital.

Any form of wealth can be used by the elderly to sustain their consumption, but transfer wealth has no use in economic production. Increasing transfer wealth does not lead to a higher equilibrium output per worker.

Economic development typically, perhaps always, erodes the system of family transfers. If the family system is replaced by a pay-as-you-go public pension system which transfers income from those who are currently working to those who are currently retired, one form of transfer wealth (public) is simply substituted for another form (private). Under these circumstances, the demographic transition increases transfer wealth (or the size of the public pension system), has a fiscal impact (raising taxes on earnings), but has no direct impact on capital formation.

However, if the family transfer system is replaced by a system based on individual responsibility in which workers accumulate real wealth in order to fund their retirement, then demographic transition leads to increased holdings of capital. The institutional form of the individual responsibility system varies from country to country. Farmers and small businessmen may save by investing directly in productive enterprises. Workers may save directly through a variety of financial instruments or by participating in funded company-sponsored pension programs. Some countries, Singapore and Malaysia, for example, have now institutionalized such individual "life cycle saving" through large mandatory saving/retirement programs.

The shift away from the traditional family support system is evident in East Asia although family transfers are still considerably more important than is true of the West. The percentage of Japanese elderly living with their children declined by 30 percentage points between 1950 and 1990. About half continued to live with their children in 1990 (Feeney and Mason, 1998). In 1973, more than 80 percent of Taiwan's elderly lived with their children (Weinstein et al., 1994) In 1993, sixty percent of elderly men and seventy percent of elderly women were living with their children (calculated by authors employing the Family Income and Expenditure Survey).

The accumulation of wealth depends more on expectations about support by those who are currently working than by the current arrangements of those who have already retired. Surveys of young Japanese adults indicate that they are increasingly likely to discount the family as a future source of old age support. In 1950, 65% of women of childbearing age expected to rely on their children in old age. By 1990, only 18% expected to turn to their children for support in the future (Ogawa and Retherford, 1993).

The following table illustrates how the demographic transition and institutional arrangements for old age support interact to determine saving behavior and capital. The biggest effect on saving rates and on capital formation occurs when the demographic transition is combined with a transition to individual responsibility for old age support.

	Transfers	Individual Responsibility
Pre-Transition	Initial Situation	Small increase in s and K
Post-Transition	Small increase in s and K	Big increase in s and K

In this paper, we analyze the effect of the demographic transition on savings and capital accumulation under the assumption that the system of individual responsibility has existed throughout. This will exaggerate the effect of a movement down the left hand column, passing through the transition while maintaining the system which relies heavily on transfers. It will understate the effect of a movement diagonally from the upper left to the lower right. We believe that this diagonal movement is the most appropriate representation of the changes taking place in East Asia and eventually in other Third World countries. In a number of countries of Latin America, currently switching to mandatory private savings for retirement, the movement to the lower right cell has already taken place or is in process.

THE SAVING MODEL

The simulation model used in this paper determines how aggregate saving rates and wealth change during demographic transition if saving by members of the population is governed by lifecycle considerations. The model is described in detail in Lee, Mason, and Miller (forthcoming) and only its main features will be explained here. The demographic component of the model is detailed. The population by single years of age is determined each year based on assumptions about fertility and mortality. Some results presented below are based on mortality and fertility data drawn Taiwan's experience over the twentieth century. We assume that the population is closed to immigration in all simulations presented here. In earlier work, we treated immigration in a more realistic manner without important implications for the results (see Lee, Mason, and Miller (forthcoming).)

Simulations are intended to track a population from the beginning to the end of its demographic transition. We begin with a low life expectancy at birth (e0) and high total fertility rate (TFR) which remain constant for a period of time sufficient to produce a stable population. Beginning in 1900, life-expectancy begins to rise with a speed that varies from one simulation to the next. The total fertility rate begins to decline around 1950 reaching replacement fertility, 2.05 births per woman, with a speed that again varies from simulation to simulation. Age-specific fertility and mortality rates are determined from TFR and e0 assumptions using techniques described in Lee and Carter (1992) and Lee (1993). In none of the simulations do we explore the implications of baby-booms or catastrophic increases in mortality.

We assume that children remain in the parental home, pooling their income with that of their parents, until age 25, although some marry and begin childbearing at an earlier age. Until this age, their income is treated as income of their parents, and its disposition is governed by the parents' life cycle budget constraint and consumption plan. The age of economic independence is based on our work on Taiwan, where, in 1980, only about a quarter of males aged 25-29 were household heads. Thus, the actual age of leaving home is typically later than 25. However, we expect (with no direct evidence) that co-resident children would increasingly have control over their earnings as they grow older, whether or not they remain co-resident. Once children establish their economic independence, we assume that they remain independent from their parents for the remainder of their lives.

The household saving model is an extension of Tobin's (1967) formulation and is somewhat similar to Attanasio et al. (1997) although their model incorporates uncertainty and precautionary savings in addition to demographic factors. Household behavior is governed by a utility maximization model. In each period, adults decide how much of their income to consume and how much to save based on their current wealth, family size, interest rates, and expectations about future childbearing, mortality conditions, and earnings. We make no allowance for intergenerational transfers, i.e., parents make no bequests to their children and adult children provide no support to their parents. (Lee, Mason, and Miller (forthcoming) analyzes the impact of transfers in steady state models.)

Our integration of demographic factors into the life cycle saving model is a straightforward extension of earlier work. Each couple calculates the present value of future life time earnings, including the earnings of co-resident children. The present value of expected lifetime household consumption is constrained to equal this amount. Couples distribute household consumption over time so as to maximize their life time utility. Given the life time utility function employed, household consumption per equivalent adult consumer rises at a rate equal to $(r - \rho)(1/\gamma))$, where r is the real rate of interest, ρ is the rate of subjective time preference, and $(1/\gamma)$ is the intertemporal elasticity of substitution. In our simulations, we take ρ to be 0. For $(1/\gamma)$ we use an estimate of .6 for Taiwan by Ogaki et al (1996). We assume that the weight of children in consumption calculations by their parents rises with the children's age, and averages 0.5. Additional elements of the simulation model are described in the appendix to Lee, Mason and Miller (forthcoming).

For life cycle planning, it is anticipated future values of the demographic and economic variables that matter. We assume that couples' correctly anticipate their fertility and the survival of all family members. These expectations take the form of proportions or probabilities, but we assume that all the uncertainty around these average rates is absorbed by institutions, whose exact nature we do not consider. We would like to experiment with the assumption that couple's base their planning on current period life tables rather than foreknowledge of future life tables, but have not yet done this.

Earnings in each year are determined by changes in the general wage level, the productivity growth rate, and a fixed cross-sectional age-earnings profile. The profile is equal to the average shape over the years 1976 to 1990 in Taiwan calculated from the Family Income and Expenditure Survey. The level of this profile shifts according to the assumed rate of productivity growth. We depart here from the standard implementation of the life cycle model, which has assumed that the longitudinal earnings profile has a fixed shape. We believe our specification to be preferable on both theoretical and empirical grounds as discussed in Lee et al. (forthcoming**b**). [Add to references: Lee, Ronald, Andrew Mason, and Tim Miller, forthcoming**b**. "Reply", in Andrew Mason, Tom Merrick, and Paul Shaw, eds., Macroeconomics and Population Momentum (Washington, D.C.: The World Bank).]

For the interest rate and productivity growth rate, we do not assume perfect foresight. We instead make the *ad hoc* assumption that people base their expectations on the average experience of the past four years. Then, rather than assuming this rate to continue for the rest of their lives, they expect the rate to tend exponentially toward a long run target rate, which is their long run future expectation. These we have taken in our baseline simulation to be r=.03, and productivity growth = .015. Our thought is that long-term interest rates will converge to international levels as global capital markets are increasingly integrated and that productivity growth will depend only on technological advance at a rate similar to those experienced in mature economies once the economy reaches equilibrium.

The simulation results presented below are dis-equilibria outcomes that occur over the demographic transition. But the starting and ending points are equilibrium outcomes that are of interest in their own right. The sharp difference between demographics in a pre-transition and a post-transition population and the consequences for saving and wealth, are summarized in Table 1. The expected number of years lived at old ages is substantially greater in a post-transition population, the average number of children reared is smaller, and the percentage of the population concentrated at older ages is greater. Each of these demographic factors pushes the demand for wealth higher and, in concert, dramatically so. The equilibrium wealth/income ratio is higher by 3.4 times at the end of the transition as compared with the beginning. The equilibrium saving rate doubles.[6]

Table 1. Equilibrium results: pre- and post-transition populations.

The impact of the demographic transition on equilibrium output is shown in Figure 5 for a closed economy and Figure 6 for a small open economy. There are no international capital flows in a closed economy and the capital stock is equal to the wealth held by residents. Output per worker and capital per worker are in equilibrium at the intersection of two curves: the production function that determines the relationship between output per worker and capital per worker and the supply of capital (i.e., the demand for wealth by households) which in equilibrium is represented by a ray with slope of Y/K. Employing the results reported in Table 1, the equilibrium supply of capital increases in the post-transition economy. The slope of the equilibrium supply curve changes from 1/1.6 in the pre-transition economy to 1/5.4 in the post-transition economy.

Equilibrium output per worker increases over the demographic transition,

[6] The rate of technological progress is 0.015 and both pre- and post-transitions satisfy the equilibrium condition that $K/Y = s/(\lambda + n)$.

as shown. Of course, with technological innovation output and income per worker will grow at the rate of technological innovation.

Figure 5. Closed Economy Equilibrium

In a small open economy, the capital stock is determined by international conditions, namely the world-wide rate of return to capital. If the domestic supply of capital is insufficient, rates of return in the domestic economy exceed those available externally. Foreign investment increases until rates of return are equalized. Similarly, if the domestic supply of wealth is more than sufficient, rates of return are depressed and domestic wealth will be invested abroad.

The impact of demographic transition on the small open economy is shown in Figure 6. Domestic capital per worker, k_D. At that point, an increase in capital produces additional output equal to the rate of return available abroad, i.e., $f'(k)$ is equal to the global rate of interest, r. Before the transition, the supply of capital ($K/Y = 1.4$) from residents is well below the equilibrium level and capital flows in from abroad. Total output is equal to $y(k_D)$. A portion of that output accrues to foreign investors, $r(k_D - k_1)$. The income by residents is the height of the "Income" line at k_1.

After the transition, the economy has become a capital exporter. The amount of capital invested domestically does not change. Any additional wealth is invested abroad at rate r. National income, output plus net returns on foreign investment, is the height of the "Income" line at k_2, determined by the intersection of the "Income" line and the supply of wealth, K/Y. Figure 6 is drawn so that the country in question moves from being a net capital importer to being a net capital exporter in lines with Williamson and Higgins (1997) empirical work. This need not be the case, but an increase in the supply of wealth will clearly lead to a decrease in net dependence on foreign capital.

Figure 6. Open Economy Equilibrium

Dynamic Simulation Results: "Taiwan" case

Figures 7 and 8 chart the trend in saving and wealth from 1900 to 2050 for the baseline simulation and several alternatives. In the baseline scenario growth in output per worker varies in a highly stylized representation of Taiwan. The pre-transition rate of growth is 1.0%. Rapid increase beginning around 1950 leads to a peak rate of growth of 5.5% during the 1970s and 1980. Thereafter, the rate drops gradually eventually reaching 1.5% per annum around 2050. The most prominent feature of the baseline simulation is the very substantial swing in saving that begins about 1975. The saving rate increases by almost 15 percentage points, doubling the 1975 rate by the time it peaks. The increase in the baseline is followed by an even greater decline in the saving rate. The large swing in saving is a phenomenon that is missed entirely by steady-state analyses but noted above as a possible outcome of rapid demographic transition. Higgins (199?) also notes the possibility of a swing in saving based on his overlapping generations model. The swing in saving rates is accompanied by a rapid increase in K/Y.

A second important feature of the saving simulation is the dip in saving that occurs in the 1960s and early 1970s. The decline is a consequence of reduced saving and increased consumption by young adults who are anticipating the decline in their childbearing and childrearing costs.

In the baseline simulation, demography, interest rates, and productivity growth rates are all changing and influencing the outcome. The direct impact of demography is isolated by a simulation which holds the interest rate and productivity growth rate constant at 3 and 1.5 percent, respectively, throughout the simulation. If only demographic factors change, the saving rate reaches a lower peak and declines more modestly than in the baseline. Note, however, the artificial nature of assuming a constant rate of interest (return to capital) and a constant productivity growth rate in light of the large increase in capital. In a more complete model of the economy, currently being developed, interest rates and growth would be determined in large part by the changes in capital induced by demographic factors. As K/Y approaches its equilibrium level, productivity growth would decline to a lower long-term growth governed solely by technological innovation.

Figure 7. Saving simulation

Figure 8. Wealth simulation

More detailed results reported in Lee et al, forthcoming, assess the impact of variations in the interest rate and the rate of productivity growth. An increase in the rate of productivity growth accompanied by an equal increase in interest rates leads to a higher saving rate. The impact of demography is relatively independent of the rate of interest or the rate of productivity growth.

Comparison with other recent studies

Several recent studies have examined the relationship between population and saving. Williamson and Higgins (1998) analyze pooled cross-section, time-series aggregate saving data using an overlapping generations model to capture the dynamic aspects of the lifecycle framework also modeled here. Their econometric results are similar to the Lee, Mason, and Miller simulation results (LMM) summarized in the previous section. Williamson and Higgins find that changes in age structure produce a very large swing in saving that begins somewhat earlier and is somewhat greater in magnitude than found in our simulation results. Kelley and Schmidt (1997) also employ a macro based approach. They conclude that demographic factors matter, but the size of the effects are more moderate than in the WH estimates.

Deaton and Paxson (1997, forthcoming) employ a very different, micro-based approach. Relying on Taiwan's annual National Family Income and Expenditure survey they construct age profiles of consumption, income, and saving. They hold these profiles constant, consistent with the lifecycle model *in equilibrium*, and determine how changes in age-structure would influence aggregate household saving. In their 1997 analysis, Deaton and Paxson find that demographic change essentially has no impact on saving. Their more recent analysis deals with several technical issues that arise in their earlier work and concludes that demographic change has a modest effect on saving. Results from the more recent analysis are displayed in Figure 9, below.

The Williamson and Higgins (WH) and Deaton and Paxson (DP) results are of particular relevance to the work presented here because both studies provide estimates specific to Taiwan. Indeed, the Deaton and Paxson analysis uses the same data for Taiwan that are used to construct some of the underlying parameters of our dynamic simulation model.

The results of these alternative approaches are compared to each other and to actual trends in saving in Taiwan in Figure 9. The Williamson and Higgins estimates track the actual gross saving rate quite well and suggest that essentially all of the increase in saving rates in Taiwan are accounted for by changing demographics. There are, of course, short term fluctuations that are unrelated to longer term demographic processes. The greatest discrepancy appears to be the downturn in the late 1980s. None of the analyses suggest that demographic factors account for the downturn in gross saving rates (or net saving rates). Although all analyses suggest that early in the next century saving rates will decline.

Figure 9. A Comparison of predicted and actual saving rates

The DP predictions show a much more attenuated response of saving to changing demographic conditions. They find that, had other conditions remained constant, household saving would have dipped in the late 1960s as a consequence of rising child-dependency. Household saving rates did decline between 1964 and 1970, although more substantially than predicted. Beginning in the late 1960s, demographic conditions pushed household saving to higher levels with a peak saving rate anticipated around 2005. The swing from trough to peak is about seven percentage points, much smaller than in WH, but still large enough to have an important impact on growth. The Deaton and Paxson analysis indicates that most of the rise in household saving in Taiwan is due to non-demographic factors. In their analysis, they ascribe these changes to cohort or time effects the sources of which are not explored.

It is not clear which saving series is the appropriate basis of comparison for the LMM simulations. It depends on whether saving by firms or by the government are substitutes or not for saving by households. There is disagreement on the issue and we will skirt it by comparing our simulations both to net private saving, which includes saving by corporations, and to household saving. Both net private saving and household saving increased faster than can be accounted for by changing demographic conditions in the dynamic simulation model. Net private saving does not show a dip around 1970 that we find in the simulations and in household saving. The large decline in net private saving beginning in the late 1980s is not mirrored in household saving rates nor in the simulations.

Our results fall quite clearly between the WH and DP findings. Our simulations show a swing in saving rates that is almost twice that of the DP swing between 1970 and 2005, but substantially less than the WH estimates. Obviously, reconciling these competing assessments would help to forge some consensus about the impact of demographic factors on saving.

One possibility is that the lifecycle saving model employed in the dynamic simulations may be a poor representation of saving behavior. We consider this issue in some detail in Lee, Mason, and Miller (forthcoming) by comparing more detailed features of our simulations with the Taiwan survey data also used in the Deaton and Paxson study. We show that the cross-sectional age-saving profiles from our simulations are similar to Taiwan's actual profiles. Households with young heads and older heads have higher saving rates than in our simulations. However, it is unclear whether the differences indicate behavior inconsistent with our simulations or whether it reflects selectivity problems associated with living arrangements and identification of the head in multi-generation households.

A second issue highlighted in several recent studies is the tendency for consumption to track income (Carol and Summers, 1991; Paxson, 1996). In the standard lifecycle model, the path of consumption is independent of current income (except in so far as changes in income affect total expected lifetime income). Attanasio considers this issue in his research and shows that demographic factors and uncertainty can also lead to tracking in a lifecycle saving model. We examine this issue with respect to our simulation model and show that our model generates consumption and income trajectories that are very similar to those presented in Deaton and Paxson (1997:104).

One feature of the Deaton and Paxson analysis may have a particularly important bearing on the difference between their results and ours. Deaton and Paxson (1997) find large cohort effects (later born cohorts have substantially higher saving rates than earlier born cohorts), but they attribute these to non-demographic factors. If we replicate their statistical analysis using our simulated data, we find very similar cohort effects caused by changes in demographic variables, e.g., increased life-expectancy and lower lifetime childbearing. Our simulated saving rates rise much more rapidly than those in Deaton and Paxson, because of these cohort effects. In Deaton and Paxson (forthcoming) the cohort effects are constrained to zero. (They include time effects.) Again this has the effect of excluding from consideration the impact of trends in life-expectancy and lifetime childbearing on saving. A more complete accounting might well lead to the conclusion that demographic factors played a more important role in the rise in Taiwan's saving rates.

It is interesting to note that the three studies share a similar view about the likely impact of demographic changes in the future. Our simulations assume that life-expectancy and fertility will change little in the future; hence, changes in population age structure are primarily driving the future decline in saving rates. Given that the DP analysis captures these same changes in age structure, the similarity in the forecasts is reassuring. Caution about these forecasts should be exercised, however. There is a great deal of uncertainty about whether or not life-expectancy will stabilize. Alternative simulations which we do not present show that a continued rise in life-expectancy at a plausible rate could offset the impact of age-structure and lead to rising rather than declining saving rates.

Rapid or slow transition: does it matter?

In this final section we examine how saving and wealth dynamics are influenced by the features of the demographic transition. In all of the simulations presented below, we vary only the demographics (fertility and mortality) in ways that will be described. The rate of growth of output per worker is held constant at 1.5% per annum and the interest rate at 3.0% per annum. The earnings profile and other model parameters are based on Taiwan as detailed above. The purpose then is to ask how saving and wealth dynamics would have varied had Taiwan been subject to a demographic transition that was different than the one actually experienced.

First, we look at the speed of the transition by repeating simulations for Taiwan. The fast transition simulation assumes that the transition to a high life-expectancy and low fertility required only 65 years to complete (1900-1965) rather than one hundred and thirty years to complete. Mortality and fertility rates decline twice as fast. The delay between the onset of mortality decline and fertility decline is reduced by half. The slow transition simulation assumes that the 260 years were required to complete the shift to high life-expectancy and low fertility; mortality and fertility rates take twice as long to achieve any given level.

The saving and wealth simulations are presented in Figures 10 and 11. The more rapid the transition the greater the peak in the saving rate. This is not surprising because in a rapid transition, the equilibrium wealth-income ratio must be reached over a shorter period of time. Higher rates of saving are required to accomplish that task. Because our alternative transitions all begin at the same date, the faster transitions also complete the transition in an earlier year. If we date any transition by its mid-point, the fast transition is centered on 1932.5, the historical transition on 1965, and the slow transition on 2030. By these rough calculations, the fast transition occurs about 30 years earlier than the historical transition; the slow transition about 65 years later than the historical transition. The peaks in the saving rates are separated by a similar lengths of time as are the paths of the wealth/income profiles. The patterns for the historical and fast transition saving rates are quite similar. More rapid changes in fertility and mortality influence household behavior, but age-structure is greatly affected by the past and relatively unresponsive to the changes in vital rates that distinguish the historical and rapid transition cases. A slow transition produced a swing in saving rates with a smaller amplitude but one that is longer lasting.

The wealth/income ratios reflect the saving rate trends. The wealth/income ratio increases as rapidly in the historical projection as in the fast projection. This suggests that a more rapid transition in Taiwan would have caused incomes to begin increasing at an earlier data but the rate of growth would not have been any more rapid. On the other hand, the wealth/income ratio rises more slowly, as would income, given the slower demographic transition.

Figure 10. Speed of transition: Saving simulations

Figure 11. Speed of transition: Wealth simulations

A few East Asian countries have had demographic transitions with a duration as short or shorter than Taiwan's, but the great majority of countries have had slower transitions. Fertility decline has been particularly rapid in East Asia. In one recent empirical assessment, Feeney and Mason (1998) conclude that the transition from high to replacement fertility is taking twice as long among Latin American countries as has been true of Taiwan or several other East Asian countries. Demographic transitions in the industrialized countries has also been very different. They began much earlier, but mortality conditions improved much more slowly, fertility rates dropped much more gradually, population growth rates did not reach such high levels, and age-structures changed less radically.

We look first at the implications of a Western style demographic transition using demographic data from the US and France. To maintain our focus on demographic transition, the US demographics are purged of the post-World War II baby boom by assuming that fertility remained at replacement level after 1937. In the US and France, for example, life-expectancy at birth was around 50 at the beginning of the twentieth century, almost twice the Taiwan level. The gap remained wide until after 1950 but Taiwan has converged rapidly during the last four decades. Fertility declined in the US and France throughout the 19th century, reaching replacement even before fertility decline began in Taiwan. French fertility was much lower than US fertility throughout the nineteenth and the first half of the twentieth century. Population growth rates were quite low in France throughout the last two centuries. In the US, population growth rates were close to 3 percent per annum in 1800 and dropped steadily falling below 1 percent around the 1920s. In contrast Taiwan's era of rapid population growth began about that same time.

The impact on saving and wealth of these very different demographic histories are shown in Figures 12 and 13. Note that the US simulation does not include the effects of the baby-boom so as to maintain our focus on demographic transition. For the purposes of this comparison we have assumed that the total fertility rate remained at replacement level after 1937.

Figure 12. US, France, and Taiwan: Saving simulations

Figure 13. US, France, and Taiwan: Wealth simulations

Simulated saving rates increase gradually in France starting around 1800 and in the US from 1850 to peak in around 1950 in both countries. French demographics produce a swing in the saving rate from 1900 to the peak of about 5 percentage points. The saving rate reaches only 12 percent of income. The US saving rate peak is 14 percent of income, 6 percentage points greater than the level in 1900. In contrast, Taiwan's demographics produce a peak saving rate of almost twenty percent of income and the swing between 1960 and 2000 is about 12 percentage points.

The French and US wealth-income ratios have moved in parallel fashion with the French ratio higher than the US ratio. The ratios began to increase much earlier and grew more slowly than in Taiwan. Thus, one would expect economic growth that began earlier, was slower, but more sustained given the US-type transition.

The final comparison we make is with the "Latin American" scenario (Figures 14 and 15). Fertility decline begins in about the same year as in the Taiwan scenario, however the transition to replacement fertility takes twice as long in the Latin American scenario, 60 instead of 30 years.

Figure 14. Latin America and Taiwan: Saving simulations

Figure 15. Latin America and Taiwan: Wealth simulations

The results are very much in accord with the simulations presented earlier. A large swing in saving is produced in either a rapid or a more moderate fertility transition, but the peak saving rate is lower and occurs later when fertility declines at a slower pace. A higher rate of saving is sustained over a longer period a longer period of time. The ratio of wealth to output rises much faster in the Taiwan scenario and the rate of economic growth would be correspondingly more rapid. The Latin American transition eventually produces the same wealth/output ratio as in Taiwan and output and worker and income per capita will be the same, but Taiwan reaches a high income level several decades earlier

Conclusions

The paper examines how changes in demographic variables that occur over the demographic transition affect saving and wealth, and consequently standards of living. The analysis supports the following conclusions:

First, the demand for material wealth relative to income, if met through savings rather than transfers, is much higher given a modern demographic regime rather than a traditional one. The change reflects the impact of lower rates of childbearing and longer life-expectancy on household saving behavior and the influences of population age structure on aggregate wealth and saving. Given widely accepted views about the importance of capital accumulation to development, an increase in the demand for wealth is accompanied by an increase in output per worker or per capita income.

Second, the transition to a wealthy society is not a smooth one. Particularly in countries experiencing rapid demographic transitions, saving rates reach historically high levels for a period of several decades. This leads to a correspondingly rapid increase in capital and income. Countries proceeding through their demographic transitions more slowly experience a more moderate swing in saving and rates of economic growth. Demographic transitions as slow paced as those experienced in the West also produce swings in saving and growth but ones that are much more modest than in a country like Taiwan.

The simulations that lead to these conclusions do not, by themselves, prove anything. We have not offered any formal empirical analysis. Rather, we have drawn out the implications of a particular behavioral model or set of assumptions. By doing so, we produce quite dramatic results that have not been appreciated by those whose empirical work is based on the lifecycle saving model. The simulations also establish the possibility that life cycle saving motives, interacting with the demographic transition, may account for a substantial portion of the rise of East Asian savings rates to unprecedentedly high levels.

Questions remain about the validity of the lifecycle model. In recent work, described briefly here, we have explored in more detail whether important empirical features of saving in Taiwan are consistent with our model. Our model produces cross-sectional profile that are similar to those found in Taiwan. Moreover, cohort-specific trends produced by our model are also similar to those found in Taiwan. There are, however, ambiguities in the data that leave important issues unresolved.

A particularly important issue not adequately addressed to this point is the change in support systems. The shift from a traditional family system in which family transfers are used to solve lifecycle problems to a system of self-reliance has important implications for the impact of demographic factors on saving. In some countries the shift has been rapid and encouraged by government policy. In Singapore and Malaysia, for example, the creation of funded public pension programs essentially mandates that material wealth rather than transfer wealth be accumulated to deal with the lifecycle needs of an aging society. Recent social security reform in Chile has similar effects. The United States and many European and Latin American countries, however, have implemented pay-as-you-go programs that mandate the accumulation of transfer wealth rather than material wealth. This issue is important to policy but also to improving empirical analysis of the impact of demographic change.

Earlier in this paper we noted the multiplicity of saving motives and acknowledged that people may accumulate wealth in order to leave bequests to their children or to protect themselves from uncertainty or for other reasons. But in this paper we have only explored how aggregate saving rates change when all saving is motivated by lifecycle purposes. We have experimented with non-standard models that contain elements of life cycle saving, but which build on simpler "rule of thumb" specifications, modified by demographic factors. One such model we have examined assumes that households save a fixed proportion of income throughout their lives until "retirement", with the amount set to provide a retirement income equal to 70% of their average income in the preceding five years. In this setup, the presence of children has no effect on saving behavior (contrary to reality), but there is still a substantial effect of the demographic transition on saving rates and wealth due to longer life and the changing age distribution of household heads. There is obviously room for a good deal more work exploring the implications of demographic change when saving is governed by other motives. But any realistic model most conform to an important empirical reality, that wealth rises with age. So long as that is the case, changes in age structure accompanying the demographic transition will lead to a greater demand for wealth.

Reaching a consensus about the impact of demographic factors on saving requires consistency with empirical analyses such as those by Deaton and Paxson and Williamson and Higgins. The simulation analysis presented here may contribute to that effort by demonstrating that the relationship between aggregate saving and demographic variables, fertility, mortality, or population growth, is quite complex. Age-structure variables have been used most successfully in empirical studies of saving. However, the impact of age structure on saving depends on the underlying age-profile of saving, which itself is influenced by life-expectancy and childbearing. Reconciling micro and macro empirical analyses with each other and with our results will be possible only when they incorporate these effects.

Finally, the research reported here, like Tobin's (1967) earlier work, demonstrates the importance of moving beyond the simple neo-classical growth model that treats the saving rate as an exogenously determined variable. The assumption of a constant saving rate in the Solow growth model is without theoretical foundation. Once the connections between demographic variables and saving rates are acknowledged, the simple relationship between per capita income and population growth implied by the Solow model no longer holds. If our model accurately characterizes that relationship, then population growth has a greater impact on standards of living than implied by the standard neo-classical model. However, if lifecycle problems were resolved entirely or primarily through transfer systems, then population growth would have a more modest effect. This point also bears on empirical studies of economic growth that often treat saving rates as exogenous variables, thereby providing a biased assessment of the impact of population on economic growth.

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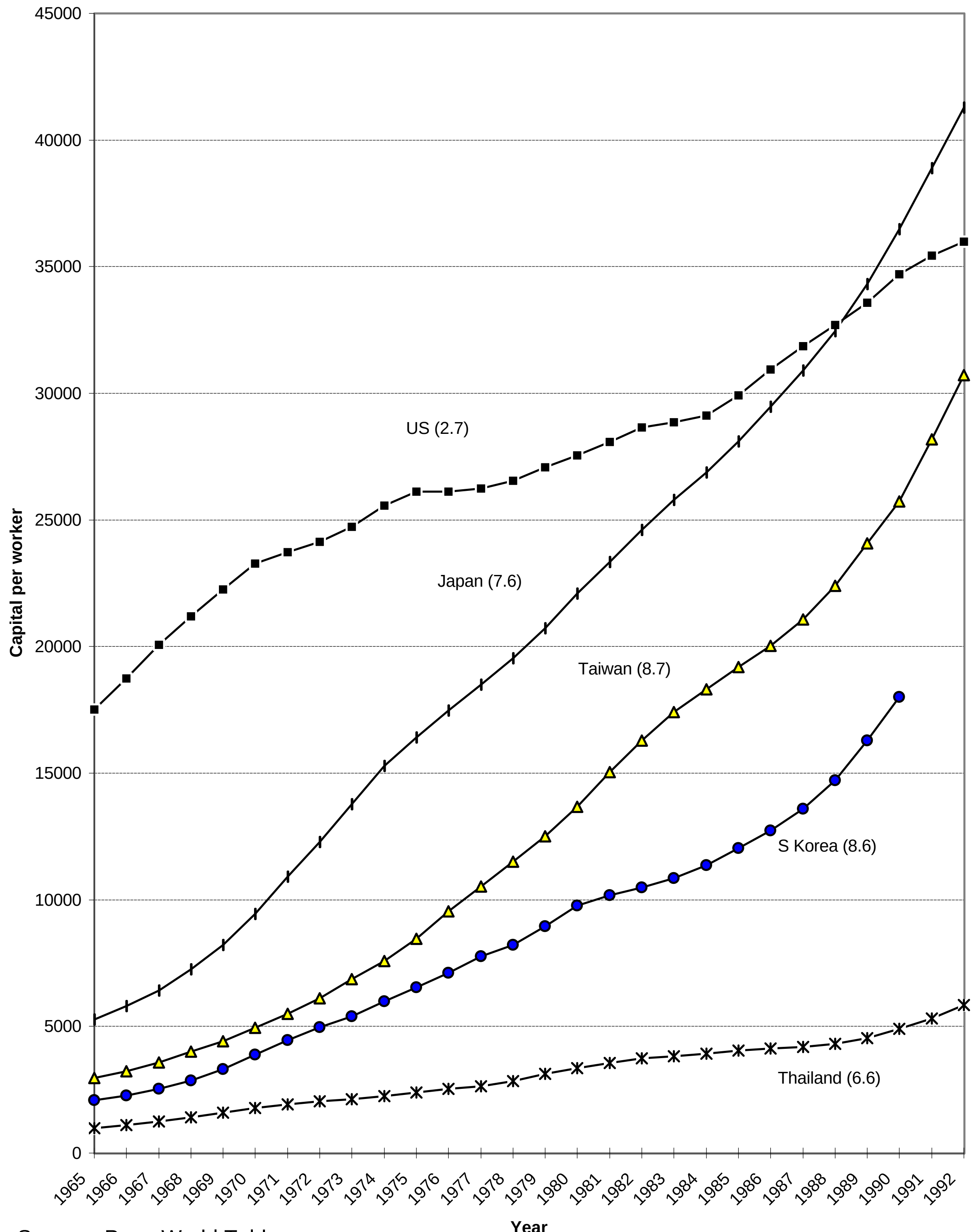
Table 1. Equilibrium demographic variables related to saving.

Variable	Pre-Transition	Post-Transition	Ratio
Population growth rate	1.1%	0.0%	---
Life-expectancy at birth	28.3	78.8	2.8
Retirement years/Working years	0.078	0.361	4.6
Total fertility rate	6.0	2.0	0.3
Average number of children	3.1	2.0	0.6
Pop (0-19) / Pop	49%	26%	0.5
Pop (50+) / Pop (20+)	21%	50%	2.4
Wealth/Income	1.6	5.4	3.4
Saving/Income	4.0%	8.3%	2.1

Figure 1. Capital per worker, US and East Asia



Source: Penn World Tables

Note: Annual growth rates of K/L in parentheses.

Figure 2. Gross Domestic Saving as a Percentage of GDP

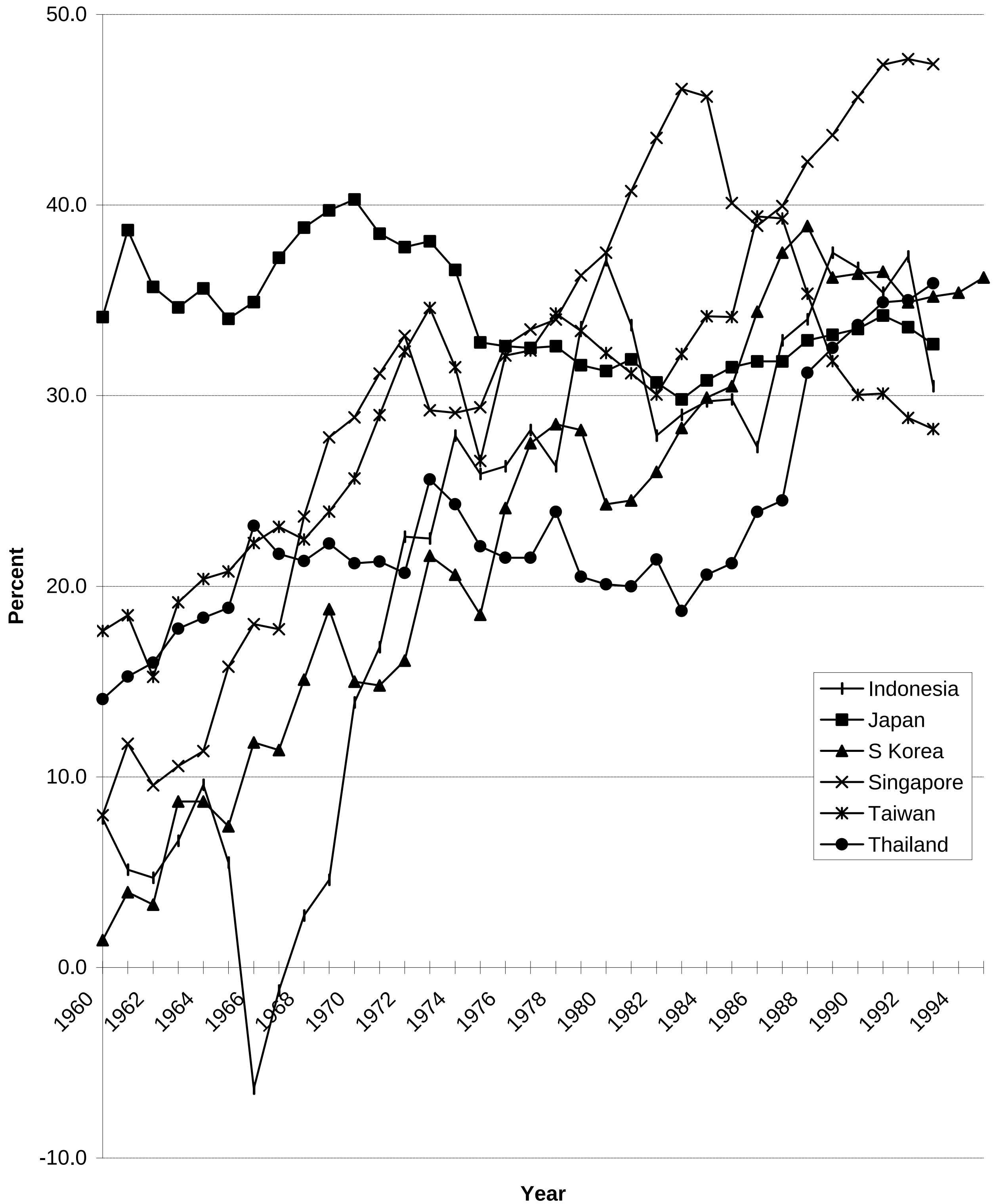


Figure 3. Population growth rates

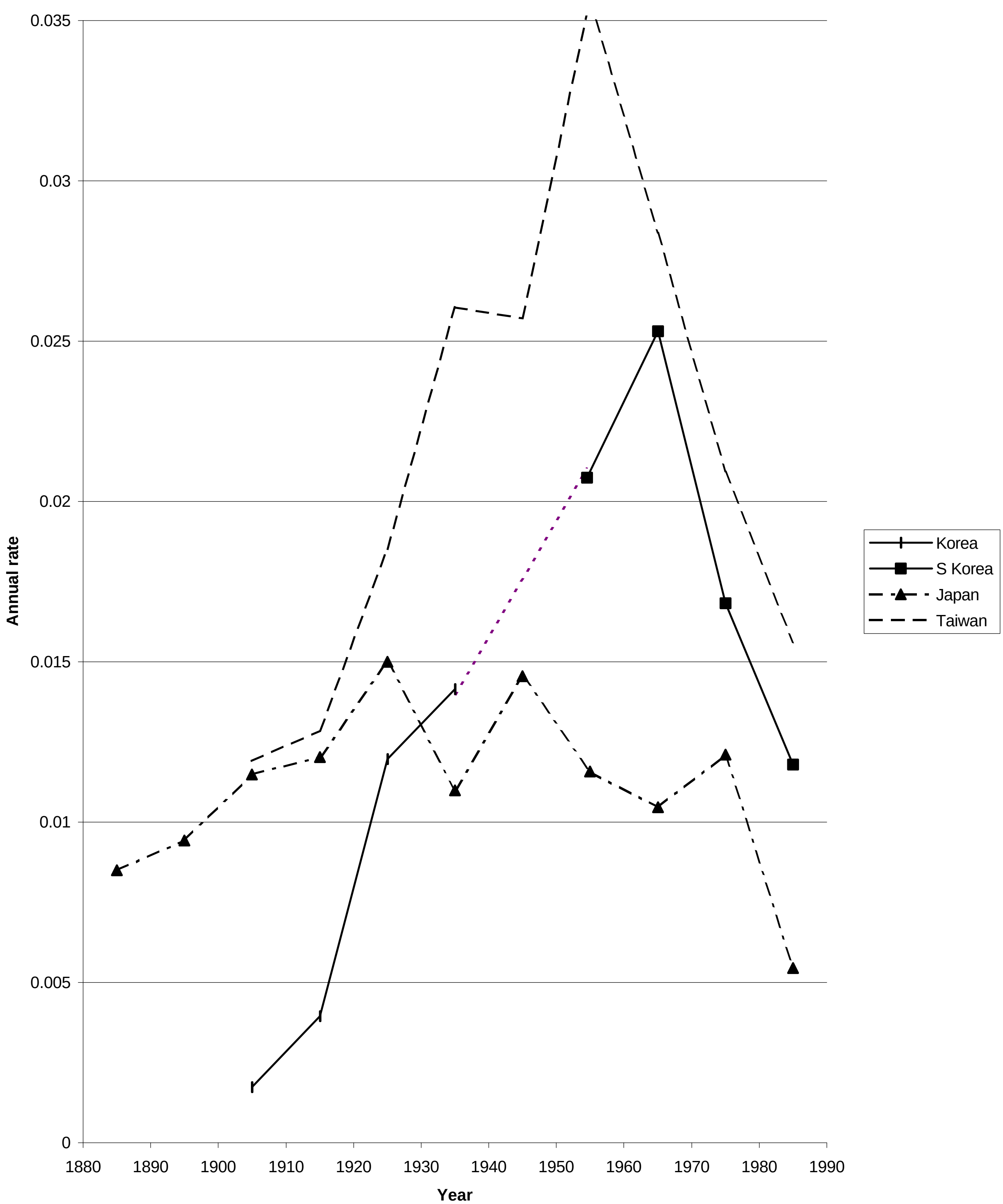
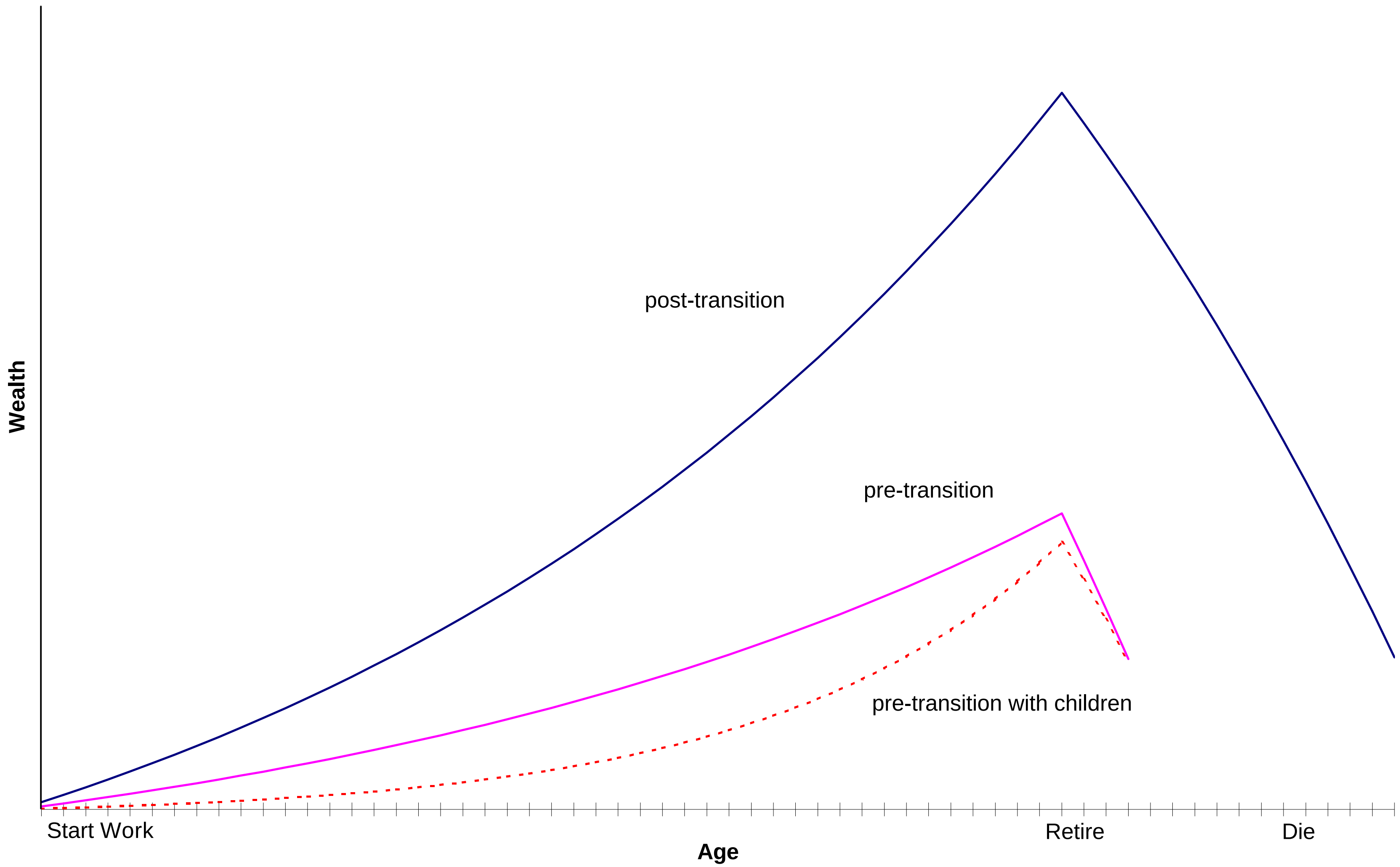


Figure 4. Wealth Profiles



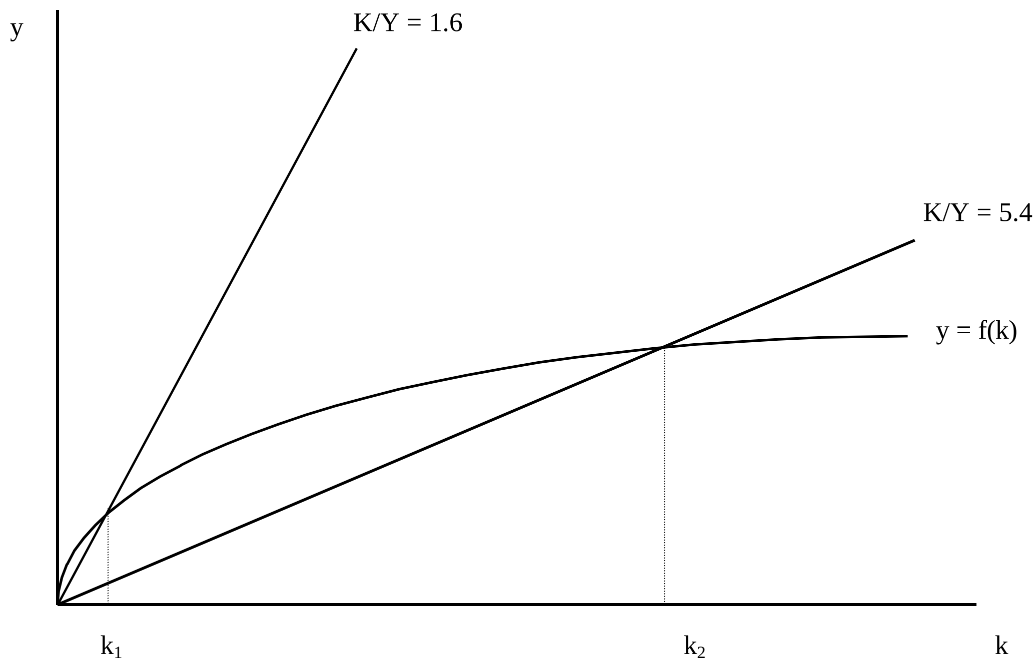


Figure 5. Closed Economy Equilibria

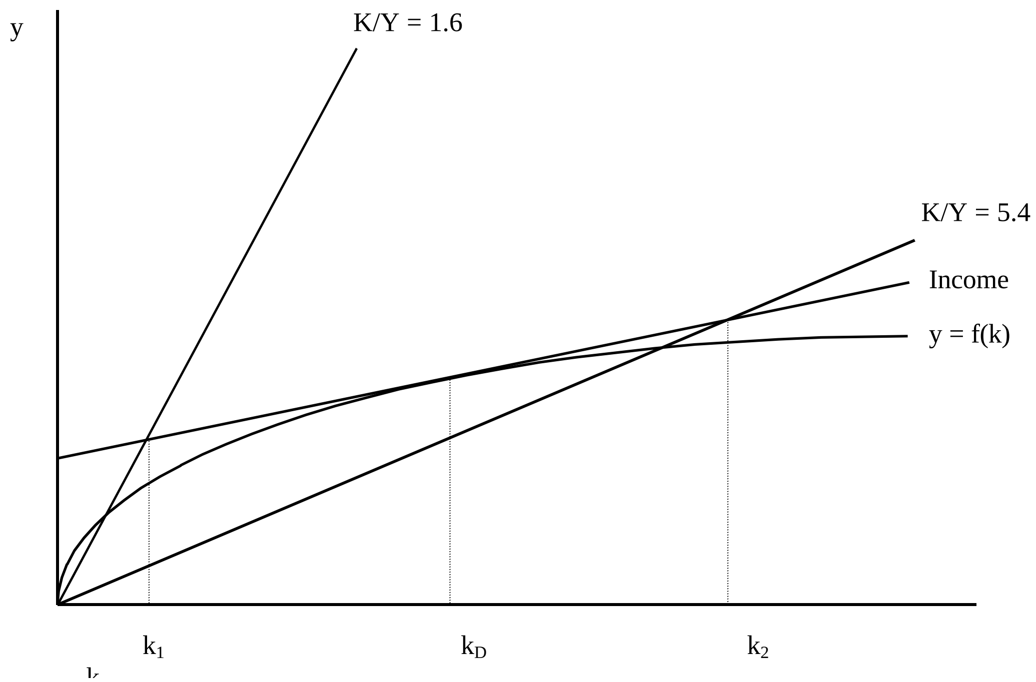


Figure 6. Open Economy Equilibria

Figure 7. Savings Rate: Taiwan, 1900-2050

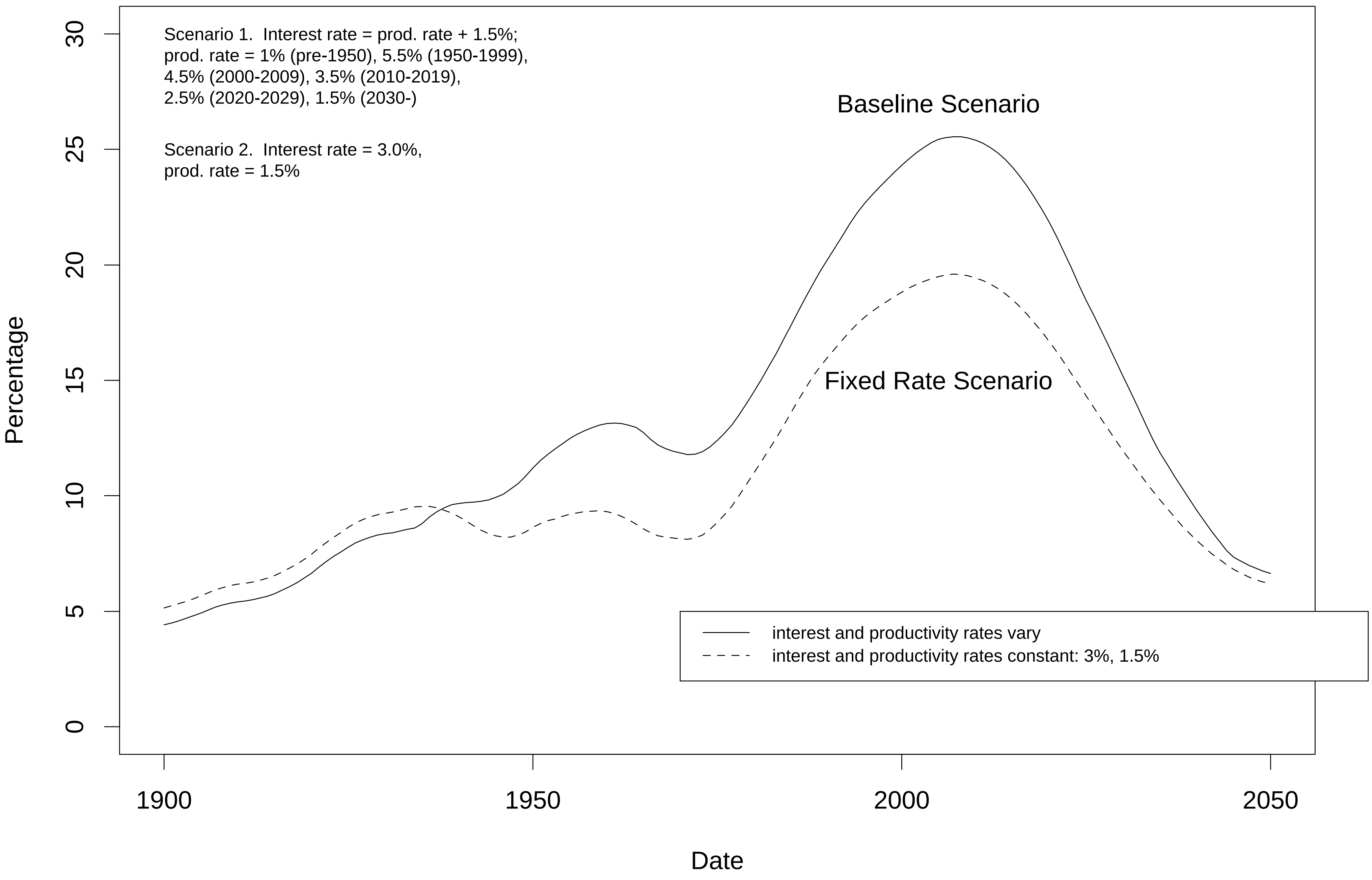


Figure 8. Wealth/Output Ratio: Taiwan, 1900-2050

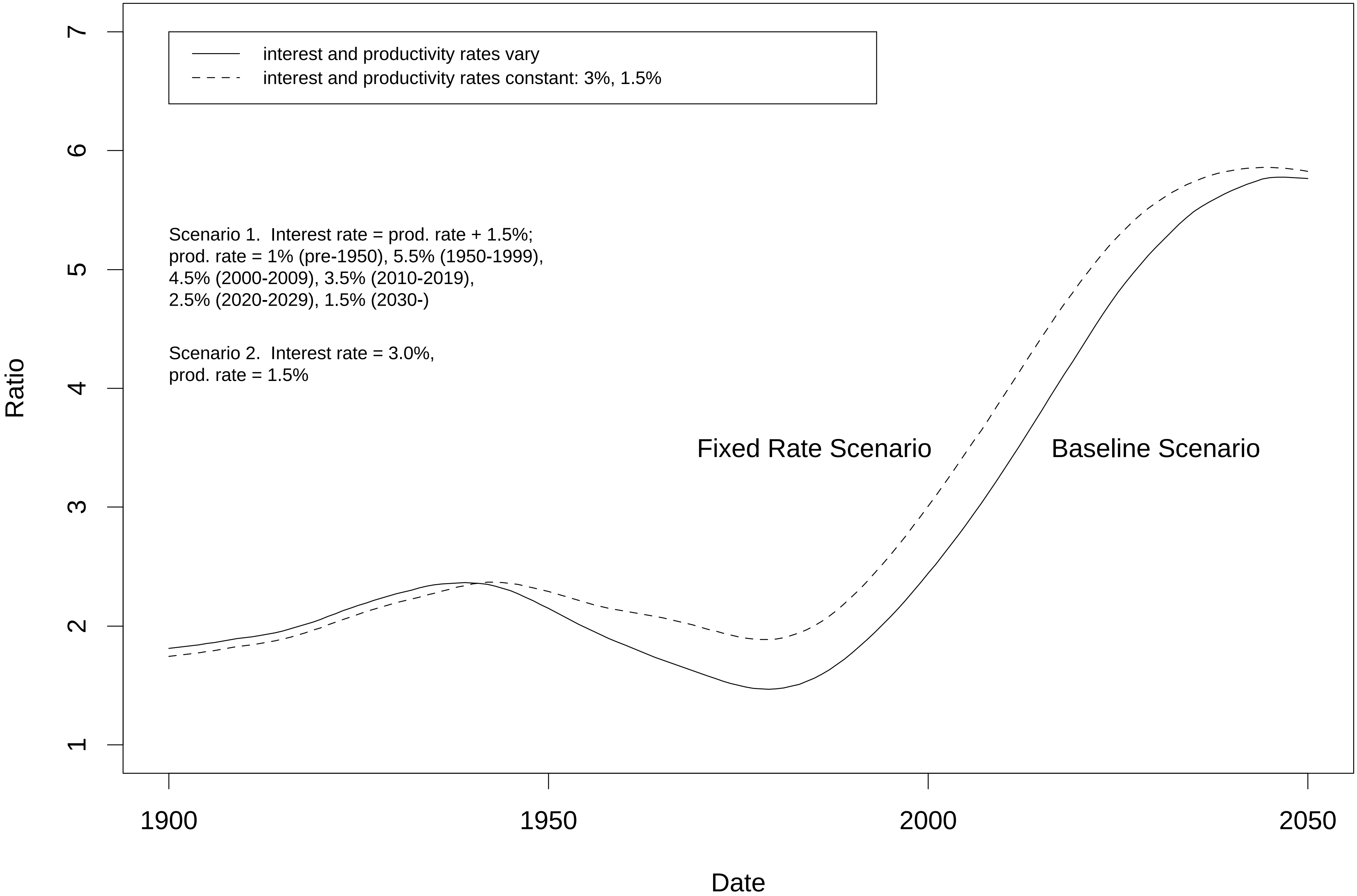


Figure 9. A Comparison of Predicted and Actual Saving Rates

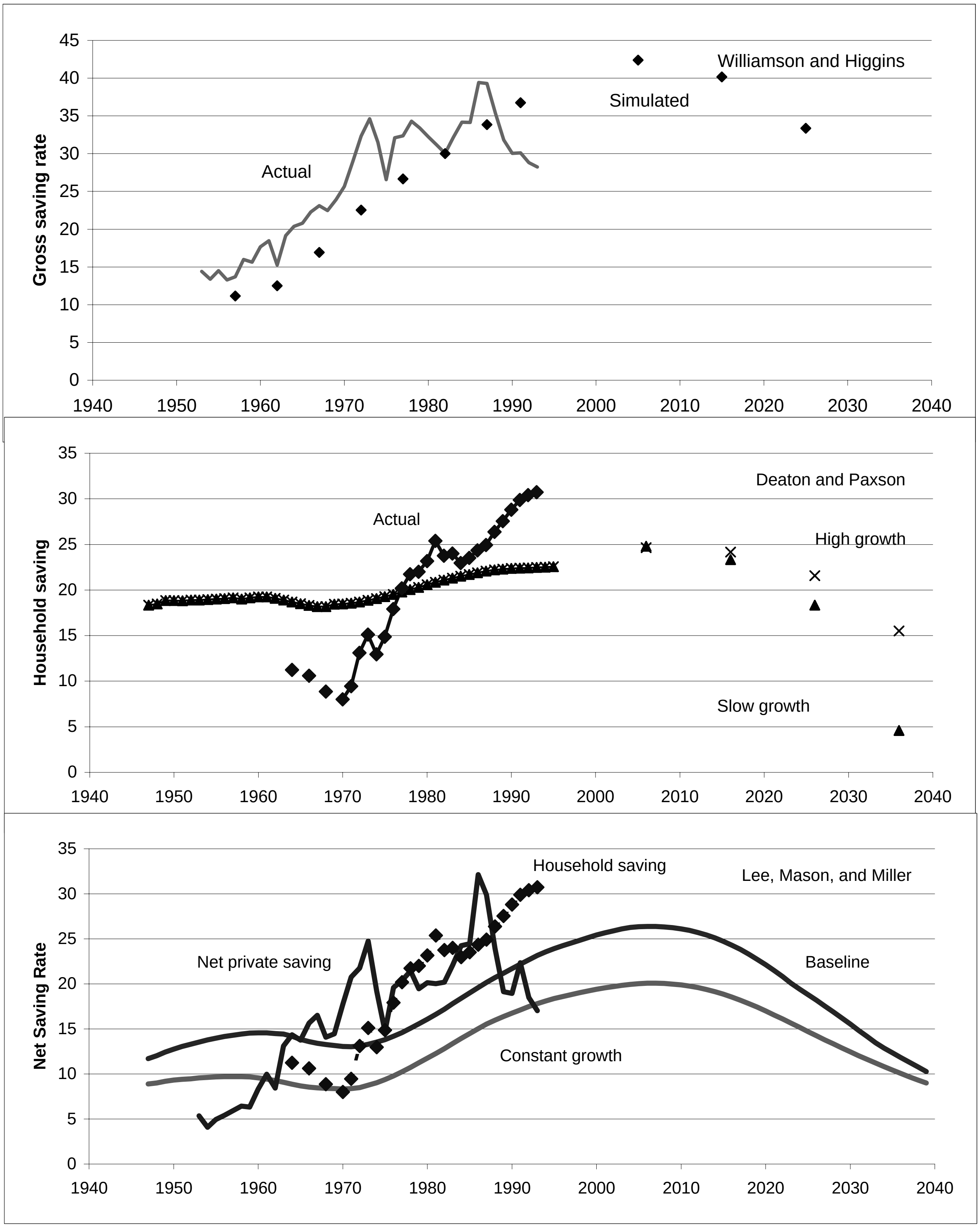


Figure 10. Savings Rate: Taiwan, 1850-2125

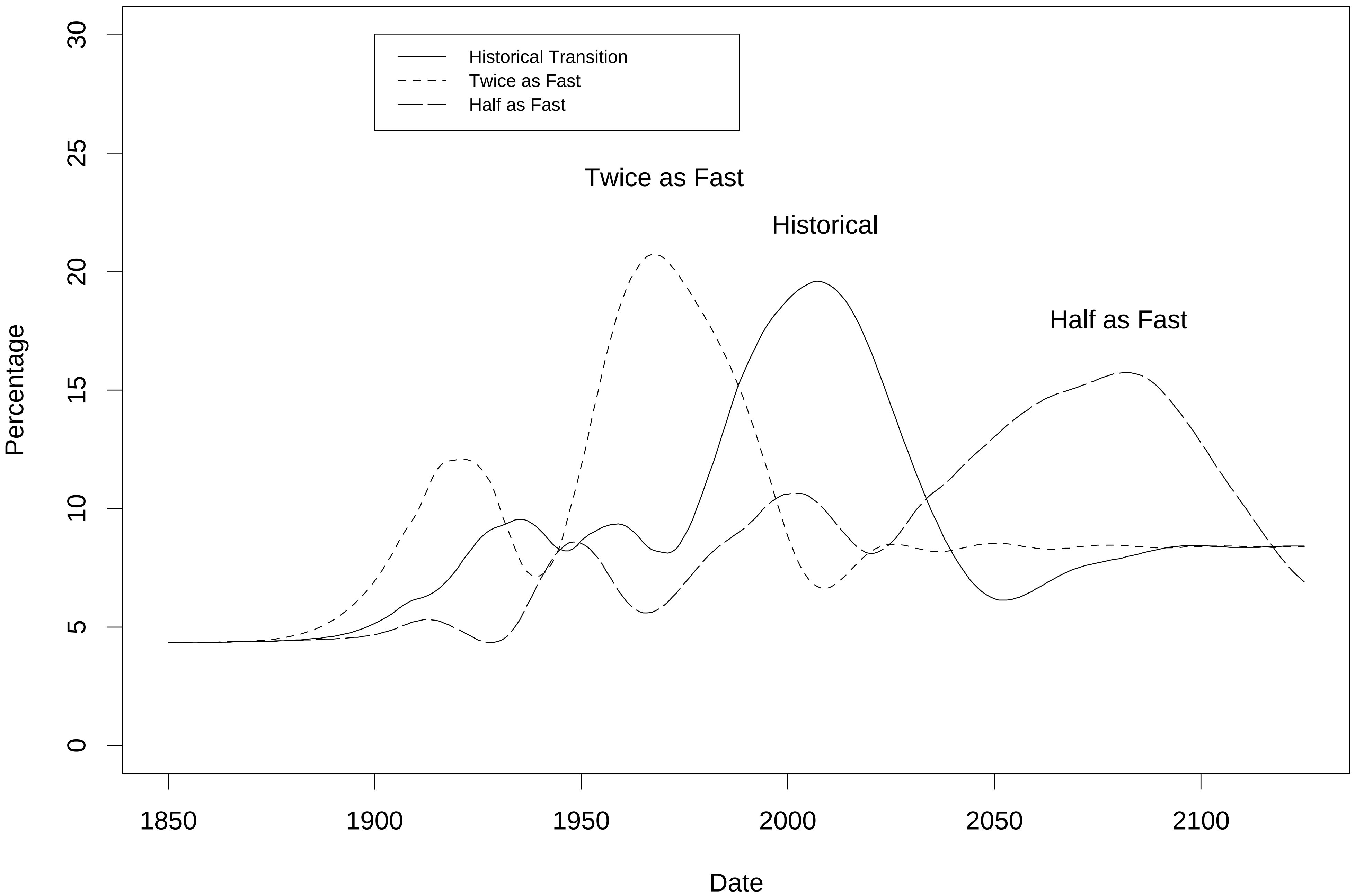


Figure 11. Wealth/Output: Taiwan, 1850-2125

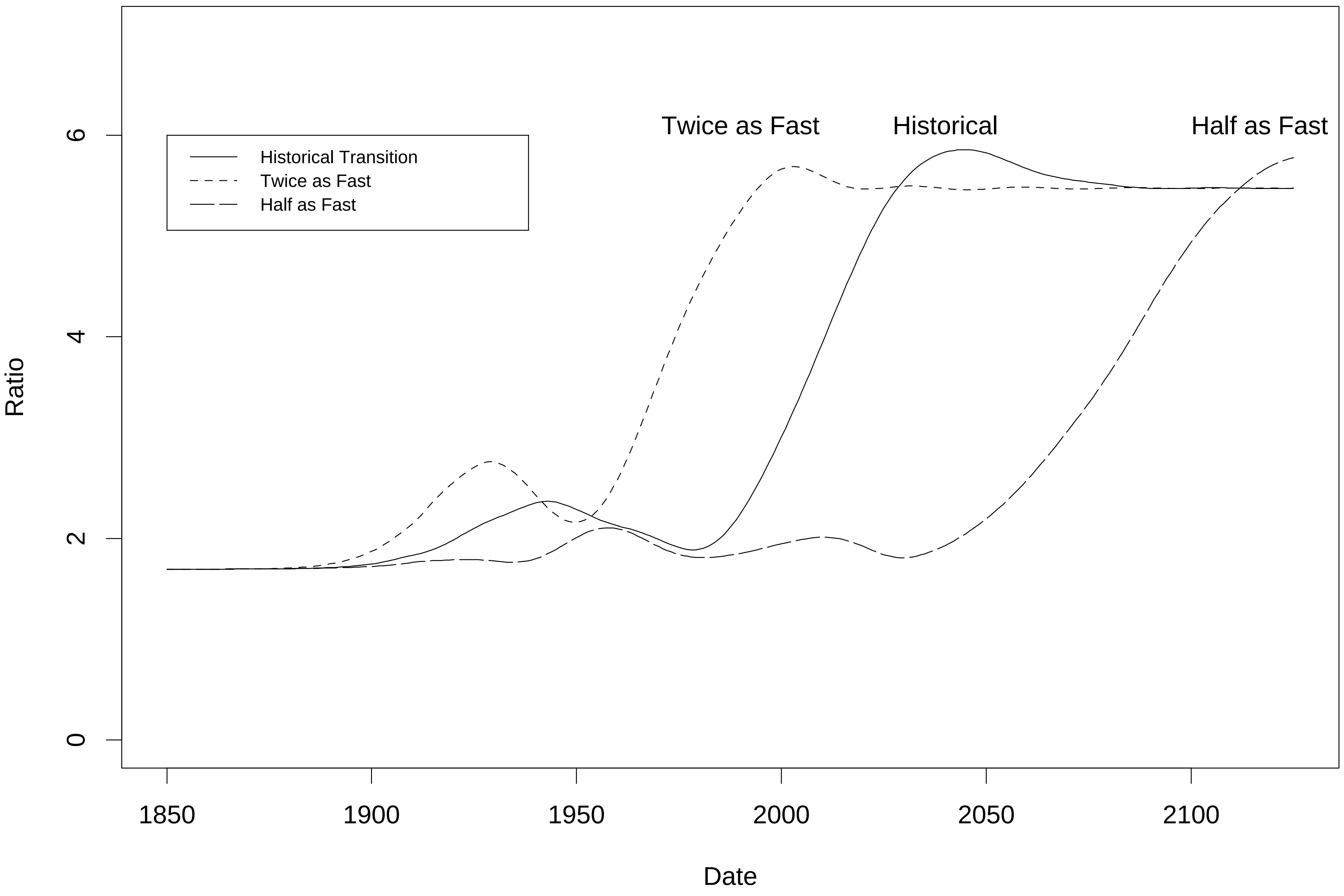


Figure 12. Savings Rate: Taiwan, US, & France, 1800-2100

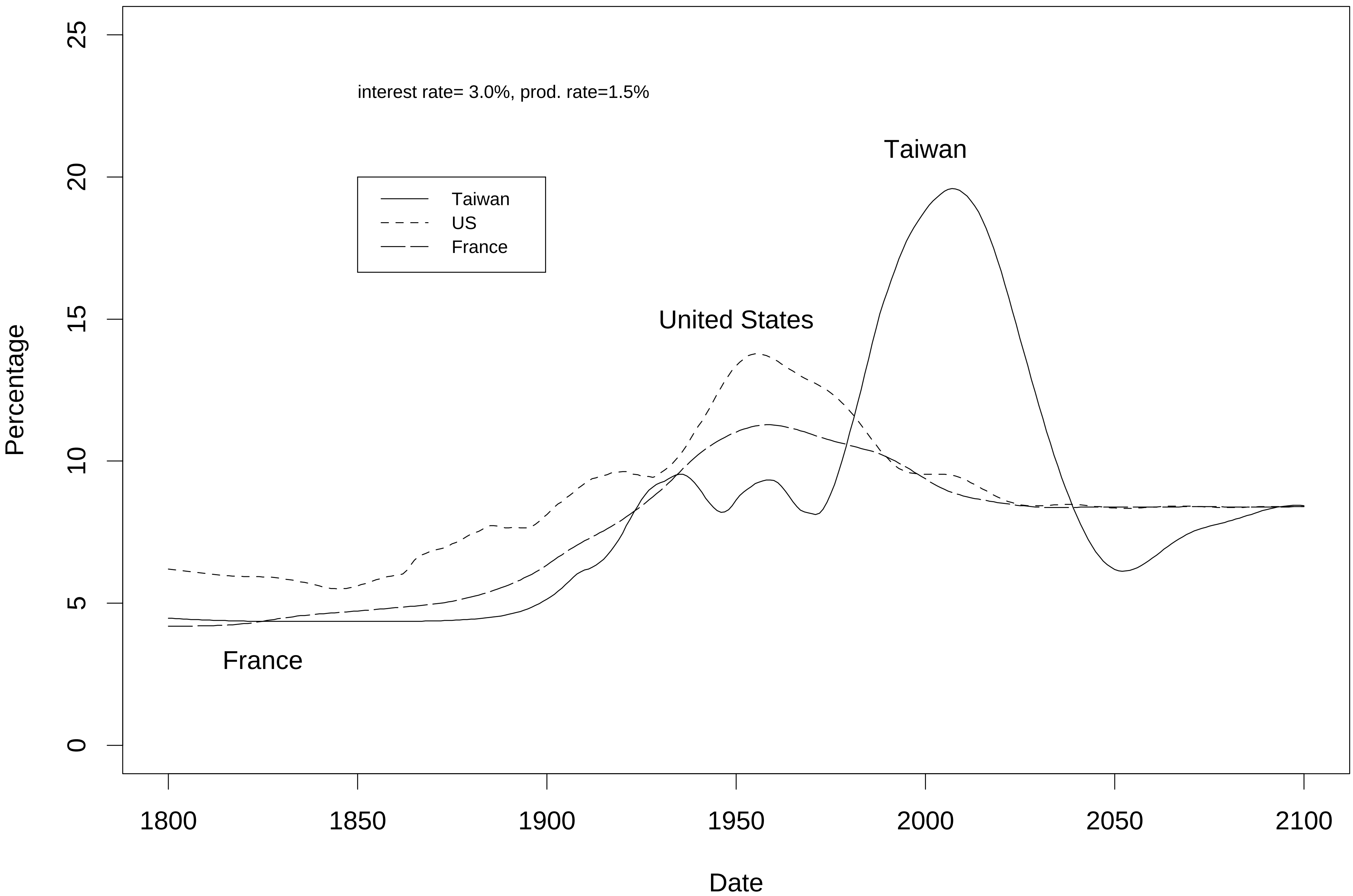


Figure 13. Wealth/Output : Taiwan, US, & France, 1800-2100

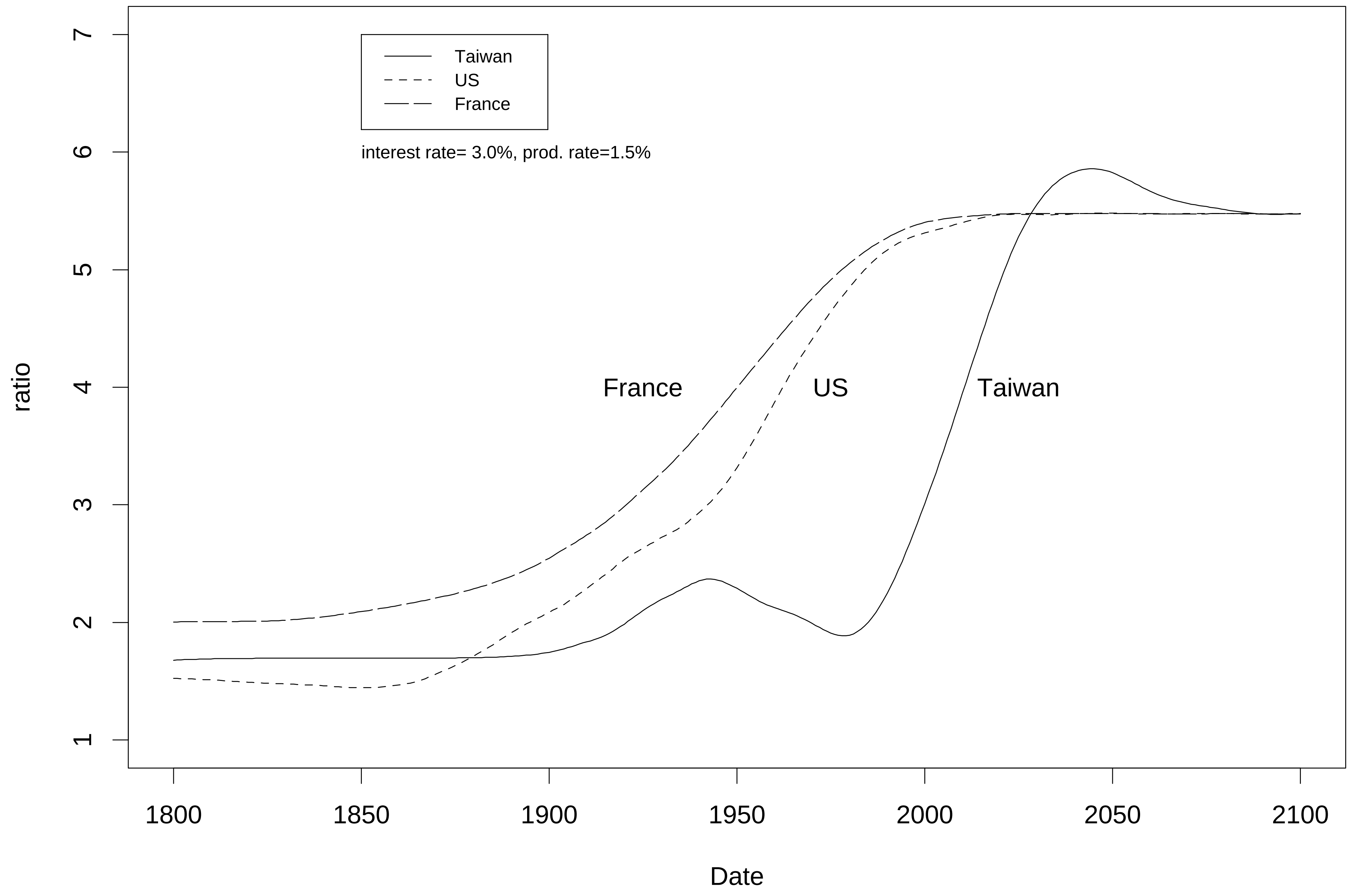


Figure 14. Savings Rate: Taiwan & Latin America, 1800-2100

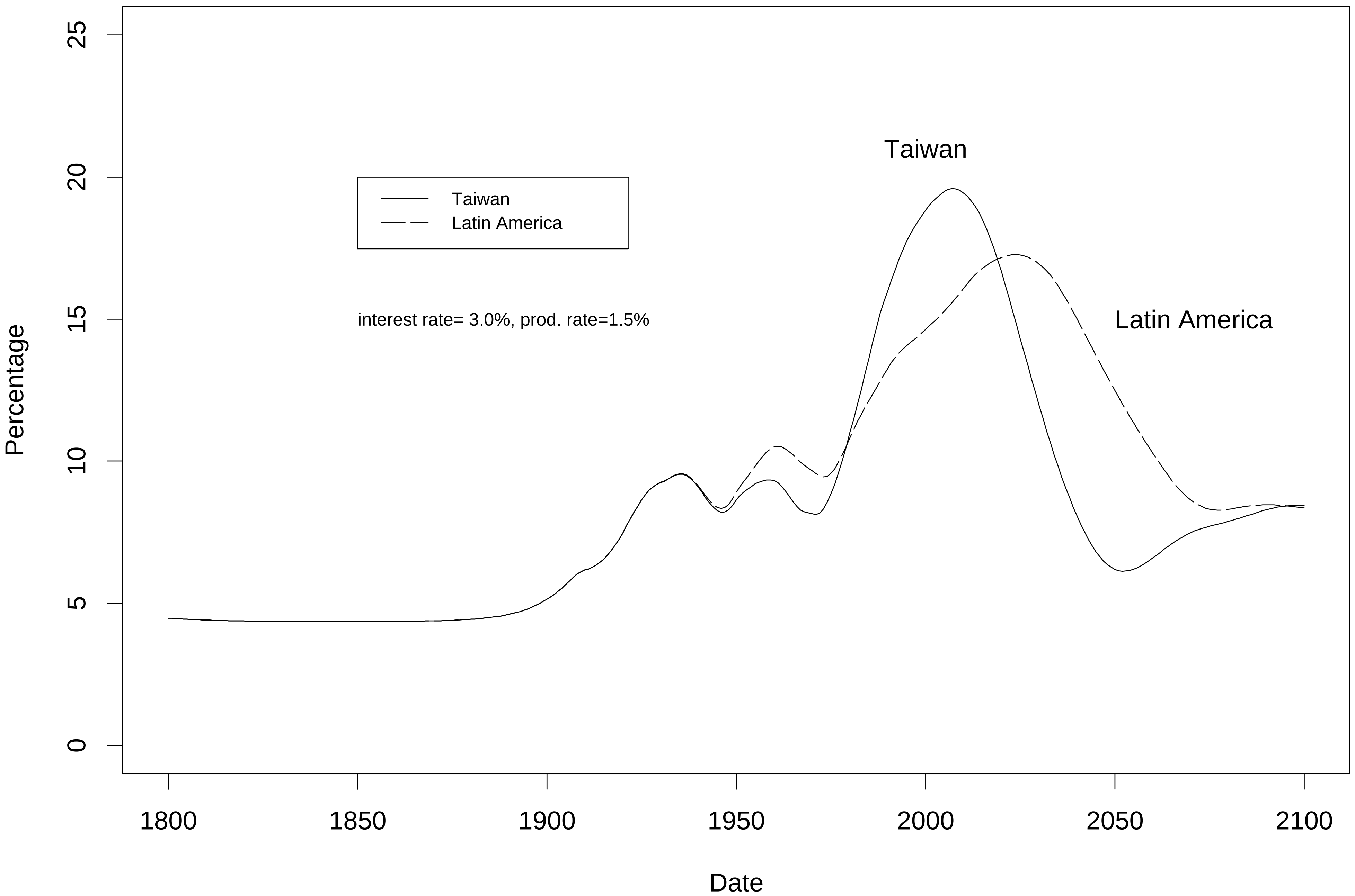


Figure 15. Wealth/Output : Taiwan & Latin America, 1800-2100