New Household Saving Behavior in the Dynamic GTAP model

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Abstract

In the dynamic GTAP model (GTAP-Dyn) saving is a fixed proportion of income in each region. There are two unwelcome implications of this. First, net foreign positions grow without bound in GTAP-Dyn simulations. The second problem is that as economies with high savings rates, like China, grow, there is a glut of global savings and, as a result, of investment and capital in the world. Because of excessive investment, rates of return to capital fall without bound. This paper documents new household saving behavior in the dynamic GTAP model. In this work we adopt very practical approach motivated by the stylized fact that gross foreign assets and liabilities do not diverge through time in reality nearly as much as in standard GTAP-Dyn. We modify the theoretical structure of the GTAP-Dyn so that the saving rate in each region is endogenous and is a function of the ratio of wealth to income. New theoretical structure supports balanced growth scenarios, stabilizes global rate of return to capital, and prevents net external assets or liabilities from growing implausibly large.

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1. Introduction

The GTAP-Dyn model (Ianchovichina and M^{c}Dougall, 2001) inherits from standard GTAP its specification of the regional household demand system, and, in particular, the treatment of saving. As in the standard GTAP model, there is a fixed average propensity to save; in other words, saving is a fixed proportion of income in each region.[2] There are two unwelcome implications of this. First, net foreign positions grow without bound in GTAP-Dyn simulations. "… the region's current account deficit can "blow out", implying that foreign claims on a region's domestic assets become large enough to create sustainability worries for some" (Tyers, 2005). In the real world, saving and investment are highly correlated across countries (Feldstein and Horioka, 1980), and net international capital flows and, as a result, net foreign positions are much smaller. The second problem is that as economies with high savings rates, like China, grow, there is a glut of global savings and, as a result, of investment and capital in the world. Because of excessive investment, rates of return to capital fall without bound. This prevents us from running simulations with Dynamic GTAP over very long time horizons.

This paper documents new household saving behavior in the dynamic GTAP model. In forward-looking models, saving rates are determined by the tradeoff between utility from present consumption and utility from future consumption. But this approach cannot be implemented in a recursive model like GTAP-Dyn. In this work we adopt an approach that has no particular theoretical foundation, but is very practical and motivated by the stylized fact

[2] In fact, the propensity to save is not quite fixed; see M^{c}Dougall (2002). But it is close enough to fixed for the present purpose.

that gross foreign assets and liabilities do not diverge through time in reality nearly as much as in standard GTAP-Dyn. We modify the theoretical structure of the GTAP-Dyn so that the saving rate in each region is endogenous and is a function of the ratio of wealth to income. Our approach is guided by the heuristic that it should support a balanced growth scenario in which regional income, wealth and saving have the same growth rate.

2. Theories of household saving behavior

There are several theories explaining people's desire to save. The most influential theory of household saving behavior is the life-cycle hypothesis developed in Modigliani and Brumberg (1954) and further tested in Ando and Modigliani (1963). This model starts from a consumer who maximizes his utility, which is a function of current and future consumption, subject to a resource constraint. "…As a result of this maximization the current consumption of the individual can be expressed as a function of his resources and the rate of return on capital with parameters depending on age" (Ando and Modigliani, 1963). This theory suggests that people try to smooth their consumption over their lifetime, saving little when they are young but much more in middle age, and dissaving in retirement.

Another theory of household saving behavior suggests that people save for precautionary reasons. If people are uncertain about their future income, and access to credit is limited, people tend to save more. At the same time, stock market and real estate capital gains reduce saving rates since people feel richer. Finally, people may adjust their saving in response to fiscal policies, whence the proposition of Ricardian equivalence.

Despite the fact that these different theories are supported by the data, more or less, in different regions, it would be difficult to implement them in a Computable General Equilibrium (CGE) model. In G-Cubed (McKibbin and Wilcoxen, 1995), forward-looking CGE model, household behavior is modeled by infinitely lived representative agent maximizing intertemporal utility subject to intertemporal budget constraint. However, only a portion of consumption – and as it follows saving – is determined by these intertemporally-optimizing consumers. The remainder is determined by after tax current income and fixed marginal propensity to save. Because at least part of the supply of savings in G-Cubed is determined by the tradeoff between utility from present consumption and utility from future consumption, current saving implausibly sensitive to remote future events. In forward-looking CGE model described in Benjamin (1994) households choose current consumption and saving based on income level, expected future price level and the interest arte. The household choice between present and future consumption is expressed with a Cobb-Douglas function, and thus, budget share spent on saving is fixed. In GREEN (Burneaux et al., 1992), recursively dynamic model, like in GTAP-Dyn, the saving enters atemporal Extended Linear Expenditure System utility function (Howe, 1975), and "…marginal propensity to save out of supernumerary income is constant and independent of the rate of reproduction of capital" (Burneaux et al., 1992).

The linkages between aging profiles and saving rates in a CGE model context are explored in Tyers (2005). To investiagate the economic implications of changes in population sizes and age profiles, determined by changes in fertility, mortality and migration, this work builds a demographic model into the dynamic GTAP model. Tyers (2005) relaxes the assumption of fixed propensity to save in GTAP-Dyn by introducing endogenous age-gender specific propensities to save, which depends on real disposable income and the real interest rate. These group-specific saving rates then determine regional saving rates in each period.

The solution that we develop in this paper does not have any particular theoretical foundation, but is very practical and based on the empirical observation that wealth to income ratios are stable over time for most of the countries and rising only in some fast growing countries.

3. Motivation

As in the standard GTAP model, regional households in GTAP-Dyn spend their income according to a Cobb-Douglas *per capita* utility function specified over three sources of utility: private consumption, government consumption, and real saving. Because the model is not forward-looking but recursively dynamic, the utility function is static: it represents utility from present but not future consumption. The practice of including saving in the static utility function derives from Howe (1975) (see Hertel (1997) for discussion) and allows regional households to value saving in atemporal settings. Because of the Cobb-Douglas functional form, the average propensity to save is fixed and saving is a fixed proportion of income in each region.

There are several unwelcome implications. Because propensities to save are fixed and incomes are rising over time, countries where saving substantially exceed investment, like Japan, accumulate unrealistically large stocks of foreign assets. If like China they also exhibit high rates of growth in income, in the end of long-run GTAP-Dyn simulations they may end up owning a large part of the wealth of the whole world. While such outcomes cannot altogether be ruled out *a priori*, they are very strong predictions resting on a very weak basis.

How large are gross and net foreign assets and liabilities in GTAP-Dyn simulations? Our basis for comparison is a country portfolio data base constructed by Kraay *et al*. (2000). The data base covers 68 countries, listed in table 1, including all industrial countries and many developing countries, for years ranging from 1966 to 1997. The data base contains estimates of domestic capital stock, domestic equity owned by foreign residents, foreign equity owned by domestic residents, loans issued by domestic residents and owned by foreign residents, and loans issued by foreign residents and owned by domestic residents. Gross assets abroad is foreign equity owned by domestic residents plus loans issued by foreign residents and owned by domestic residents. Gross foreign liabilities is domestic capital owned by foreigners and loans issued by domestic residents and owned by foreign residents.

We construct three indicators to evaluate foreign assets and liabilities in GTAP-Dyn simulations: foreign assets as a share of household wealth, foreign liabilities as a share of domestic capital, and the ratio of net foreign assets to GDP. The choice of the first two is driven by our interest in regional wealth allocation and the composition of capital in GTAP-Dyn. The third indicator is of more general interest and often used in discussion in the financial press and among policymakers about what size of net foreign liabilities is sustainable (see for example Kouparitsas, 2004).

We compare gross foreign assets as a share of household wealth, and foreign liabilities as a share of domestic capital, between GTAP-Dyn simulations and the Kraay *et al*. (2000) data base. Table 2 shows variation in historical gross foreign assets and liabilities across regions and over time. On average, gross foreign assets and liabilities are small. Claims on foreign assets represent only 4.3 percent of wealth in developing countries, while foreign claims on domestic assets comprise 11 percent of domestic capital. For industrial economies, claims on foreign assets and claims of foreigners on domestic assets are balanced and represent 14.8 percent of wealth and 14.9 percent of capital, respectively. For industrial countries, the shares of gross foreign assets and gross foreign liabilities in wealth rise over time, reflecting increasing integration of capital markets. On the other hand, the data for developing countries show no strong pattern.

Figures 1 and 2 show the distribution of gross foreign assets as a share of wealth and gross foreign liabilities as share of capital respectively, pooling the available 1717 observations with non-missing values for all countries and years in Kraay *et al*. (2000) data base. For 75 percent of the observations the share in wealth of gross foreign assets is less than 14 percent. Gross foreign liabilities as a share of capital are some what larger, but for 75 percent of the sample still represent less than 25 percent of capital. Gross foreign assets positions are small for most of the sample, but for some industrialized countries can be very large (see discussion below and figures 3 and 4). On both figures 1 and 2, observations with values greater than 1 represent Belgium-Luxemburg. Toward the end of the sample period, Belgium-Luxemburg keeps most of its wealth abroad, and at the same time owes more abroad than the size of its capital stock, which results in the observed gross foreign assets and liabilities shares greater than 1.

Next we compare the development through time of gross foreign positions in the Kraay *et al*. (2000) data base and GTAP-Dyn simulations. For this illustration, the v.5 GTAP data base was aggregated to 22 regions and 3 sectors.[3] To make the figures clear, we show results for just 11 of the 22 regions, representing 11 individual countries. Figure 3 shows gross foreign assets as a share of wealth in 1970 and 1997 from the Kraay *et al*. (2000) data base together with gross foreign assets as a share of wealth in 1997 and 2024 in GTAP-Dyn simulations. Years 1970 and 1997 from the Kraay *et al*. (2000) sample are chosen to capture changes over 27 years in gross foreign positions and because for some countries data are not available before 1970. For GTAP-Dyn simulations, the year 1997 is chosen because it is the initial year in our simulations, and it allows comparison of foreign positions in GTAP and Kraay *et al*. (2000) data bases. The 2024 is chosen to show changes in gross foreign assets in the 27 years of the simulation. Similarly, figure 4 shows gross foreign liabilities as a share of capital in 1970 and 1997 of Kraay *et al*. (2000) data base together with gross foreign liabilities as a share of wealth in 1997 and 2024 of GTAP-Dyn simulations.

First, there are differences in 1997 gross foreign positions between Kraay *et al*. (2000) and the initial GTAP-Dyn data base. This is because the approaches adopted in constructing

[3] The sectors are agriculture, manufacturing and services. The 22 regions are Australia, New Zealand, China, Japan, Korea, South Asia, Canada, United States, South America, Austria, Denmark, Finland, United Kingdom, France, Ireland, Italy, Netherlands, Portugal, Sweden, Turkey, Rest of Europe, Rest of World.

wealth and gross foreign positions are different. Kraay *et al*. use historical information on investment accumulation, while in GTAP-Dyn the starting point in the construction of wealth and its components is regional capital. The ownership shares in regional capital of domestic and foreign residents are then determined by foreign income receipts and payments. Though the differences between the initial starting point of simulation and the corresponding gross foreign positions recorded in Kraay *et al*. (2000) are important, they are not the focus of this discussion.

Figures 3 and 4 reveal important differences in the development of gross foreign positions over time between the historical data and the GTAP-Dyn simulation. First, note that while on average gross foreign positions are small, in some countries, like UK and Ireland, gross foreign positions can be large. Growth in gross foreign positions in UK and Ireland was very significant between 1970 and 1997 (figures 3 and 4). The large size of gross foreign positions in GTAP-Dyn simulations need not be of concern as long as their size is comparable with historical data.

Second, as can be seen from figures 3 and 4, if historical gross foreign assets and liabilities grow over time, they grow together, which results in small net foreign positions. In contrast, in GTAP-Dyn simulations, growth in gross foreign assets corresponds to decline in gross foreign liabilities, and *vice versa*. The faster the growth in gross foreign assets, the more rapid the decline in gross foreign liabilities, as in Korea and Japan. The faster the growth in gross foreign liabilities, the faster the decline in gross foreign assets, as in Turkey and US. This results in very large net foreign positions in GTAP-Dyn simulations. To further illustrate this statement, we compare historical and simulated ratios of net foreign positions to GDP.

The net foreign asset to GDP ratios calculated from the Kraay *et al*. (2000) data base are shown in figure 5. Kraay *et al*. (2000) provide detailed discussion and presentation of net foreign asset positions. To save space, we show ratios for just 12 of 68 countries. These 12 countries are chosen to represent all 6 regions in table 1 and to present extremes as well as common tendencies in the data base. Switzerland's net foreign assets and New Zealand's net foreign liabilities are two extreme cases among the industrialized countries (INDC). Net foreign position to GDP ratios of all countries in this group are in the range from -0.7 to 0.5. For the East Asia and Pacific (EAP) countries the net foreign assets to GDP ratio is in the range from -0.34 (Malaysia) to 0.86 (Singapore) with most observations in the range from -0.34 to 0.02. Among Latin American and Caribbean (LAC) countries, Jamaica is an outlier, with relatively large net foreign liabilities (see figure 5). Net foreign positions relative to GDP of other Latin American and Caribbean countries are in the range from -0.53 to 0.07. In the Middle East and North Africa (MENA) region, countries net foreign positions relative to GDP are in the range from -0.6 to 0.25 with Saudi Arabia net foreign positions as high as 1.34. In South Asia, net foreign assets to GDP ratios are in the range from -0.18 (Pakistan) to 0.02 (Bangladesh). Finally, net foreign position to GDP ratios of Sub-Saharan Africa (SSA) countries are in the range from -0.92 (Congo) to 0.15 (Lesotho). To summarize, historical net foreign assets are small.

Net foreign assets as a share of GDP in GTAP-Dyn simulations are shown in figure 6. For this simulation we use the same 22x3 aggregation. To make the figure clear, only 10 regions are shown. Net foreign position to GDP ratios of the other 12 regions of this aggregation are between the ratios of Japan and Turkey, which are the high and low extremes in this particular simulation. As can be seen from comparison of figures 5 and 6, net foreign positions in GTAP simulations are unrealistically large. In less than 10 years of the simulation, the ratios become outside the (-1, 1) range and continue to grow in absolute value.

Fixed propensities to save in the model coupled with rising incomes lead to unrealistically large international capital flows. They create too much saving, and, as a result, too much investment and capital in the world; they allow chronic rapid saving or dissaving, and, as a result, too great foreign assets or liabilities in individual regions. To overcome this problem we modify household saving behavior by endogenizing saving rates. The development of wealth of a region is determined by its saving behavior. The wealth of a region is its capital stock plus net foreign assets.

For illustrative purposes, consider a country where capital and income grow at the same rate. Rapid growth in net foreign liabilities relative to regional income will lead to a decrease in wealth relative to income, while fast growing net foreign assets relative to income increase regional wealth to income ratios. Our treatment is based on a simple historical observation that country wealth to income ratios are in a specific range and not changing rapidly over time. As an illustration, we compare historical wealth to income ratios calculated from the Kraay *et al*. (2000) data base with ratios in GTAP-Dyn simulations. Rapidly growing wealth to income ratios in GTAP-Dyn simulations are shown in figure 7. In comparison, the historical wealth to income ratios are very stable. To show this, we regress historical wealth to income ratios on a time trend. The regression results are reported in table 3. The time trend is not statistically significant in the majority of countries with exception of countries in East Asia and Pacific region and few Latin American and Caribbean countries. Figure 8 shows historical wealth to income ratio over time for selected countries and illustrates the regression result.

4. New household saving behavior in the Dynamic GTAP model

We assume that regional households try to maintain target wealth to income ratios *WYRT*(r). The actual wealth to income ratio,

$$WYRA(r) = \frac{WQHHLD(r)}{INCOME(r)}, \tag{1}$$

where *WQHHLD*(*r*) and *INCOME*(*r*) denote household wealth and income. Differentiating (1), we obtain the percentage change equation

$$wyra(r) = wqh(r) – y(r), \tag{2}$$

where *wyra*(*r*) denotes percentage change in the actual wealth to income ratio, *wqh*(*r*) percentage change in the wealth of the regional household, and *y*(*r*) percentage change in income. If the wealth to income ratio is too low or too high compared to the target wealth to income ratio in a region, then the regional household gradually adjusts its actual wealth to income ratio toward the target. Similar to the lagged adjustment mechanism in the rates of return in GTAP-Dyn model, we define a lagged adjustment mechanism for the wealth to income ratio:

$$RRG\_WYR(r) = LAMBWYR(r) * \log \frac{WYRT(r)}{WYRA(r)}, \tag{3}$$

where *RRG_RORG*(*r*) denotes the required rate of growth in the wealth to income ratio, and *LAMBWYR*(*r*) a coefficient of adjustment. Differentiating (3) we obtain

$$rrg\_wyr(r) = LAMBWYR(\mathrm{r})*(wyrt(r) – wyra(r)), \tag{4}$$

where *rrg_wyr*(*r*) denotes the (absolute) change in the required percentage point rate of growth in the wealth to income ratio *WYRA*(*r*), and *wyrt*(*r*) the percentage change in the target wealth to income ratio (typically exogenous and zero).

If the actual wealth to income ratio is higher or lower than the target ratio in a region, then the regional household increases or decreases its saving rate to move toward the target ratio. The actual rate of growth in the wealth to income ratio is defined as

$$ARG\_WYR(r) = \frac{dWYRA(r)/dTIME}{WYRA(r)} = \frac{dWQHHLD(r)/dTIME}{WQHHLD(r)} - \frac{dINCOME(r)/dTIME}{INCOME(r)} \tag{5}$$

The expression (5) says that the actual rate of growth in the wealth to income ratio is the difference between the rate of growth in household wealth and the rate of growth in income. Change in household wealth is given in the model by equation (6):

$$WQHHLD(r)*wqh(r) = WQHFIRM(r)*pcgds(r) + WQHTRUST(r)*pqtrust(r) + 100*SAVE(r)*time \quad (6)$$

where *WQHFIRM*(*r*) denotes household equity in domestic firms, *pcgds*(*r*) percentage change in the price of equity in domestic firms, *WQHTRUST*(*r*) household equity in the global trust, *pqtrust*(*r*) percentage change in the price of equity in the global trust, and *SAVE*(*r*) the time rate of (net of depreciation) household saving. The expression (6) says that change in household wealth is determined by changes in the prices of old assets plus the rate of new saving both in domestic assets and abroad.

We assume that in forming its expectation of the rate of growth in its wealth, the regional household takes into account only changes in wealth that are due to new saving, ignoring current changes in asset prices (or, equivalently, assuming that asset prices are constant). Under this assumption, expected change in household wealth is

$$dWQHHLD(r) = SAVE(r)*dTIME. \quad (7)$$

From (7), the expected rate of growth in household wealth,

$$\frac{dWQHHLD(r)/dTIME}{WQHHLD(r)} = \frac{SAVE(r)}{WQHHLD(r)} \quad (8)$$

In estimating the rate of growth in the wealth to income ratio, the regional household takes the perceived long run economic growth of its own region into account. The normal rate of growth in income, which we denote *YHAT*(*r*), is a long run concept and is different from the actual percent change in income in every period of simulation. Using (8) and *YHAT*(*r*) we now can define *expected* rate of growth in the wealth to income ratio:

$$ERG\_WYR(r) = \frac{SAVE(r)}{WQHHLD(r)} - YHAT(r) \tag{9}$$

When the long run steady state is known, we can set *YHAT*(*r*) to its actual long run value at the beginning of simulation. For example, if an experiment is characterized by the static steady state (no growth in endowments and no technological progress in the long run), then we can set *YHAT*(*r*) equal to zero in the initial period and keep it equal to zero during the simulation. In scenarios where the long run economic growth is not known precisely, the household is allowed to adjust *YHAT*(*r*) so that as the economy converges toward a steady growth equilibrium *YHAT*(*r*) converges toward the actual steady equilibrium growth rate. We postulate a gradual adjustment mechanism in *YHAT*(*r*):

$$DYHAT(r) = LAMBYHAT(r)*(y(r) - 100*YHAT(r)*time), \tag{10}$$

where *DYHAT*(*r*) denotes absolute percentage point change in *YHAT*(*r*), and *LAMBYHAT*(*r*) a coefficient of adjustment.

Totally differentiating (10), we obtain:

$$erg\_wyr(r) = \frac{SAVE(r)}{WQHHLD(r)}(psave(r) + qsave(r) - wqh(r)) - DYHAT(r), \tag{11}$$

where *erg_wyr*(*r*) denotes absolute percentage point change in the expected rate of growth in wealth to income ratio, *psave*(*r*) percentage change in the price of saving, and *qsave*(*r*) percentage change in real saving. To achieve the required rate of growth in wealth to income ratio *RRG_WYR*(*r*), the regional household should make appropriate savings decision. Each period, the regional household decides how much of its income should be saved to achieve the required rate of growth in the wealth to income ratio. When making the decision, the regional household adjusts its propensity to save through the variable *dpsave*(*r*), which is exogenous in the standard GTAP treatment of regional household demand, but endogenous with the new structure. The expected rate of growth in the wealth to income ratio is equal to the required wealth-to-income ratio, both in levels:

$$ERG\_RORG(r) = RRG\_RORG(r) \tag{12}$$

and in differentials:

$$erg\_wyr(r) = rrg\_wyr(r). \tag{13}$$

Substituting (3) and (9) into (13), we see that the rate of saving is given by the condition that the expected rate of growth be equal to the required rate of growth in wealth to income ratio:

$$\frac{SAVE(r)}{WQHHLD(r)} - YHAT(r) = LAMBWYR(r) * \log \frac{WYRT(r)}{WYRA(r)} \ . \tag{14}$$

The four equations in the box below comprise the new savings module in the model.

$$wyra(\mathrm{r}) = wqh(\mathrm{r}) - y(\mathrm{r}) \tag{2}$$

$$erg\_wyr(r) = LAMBWYR(r) * (wyrt(r) - wyra(r)) \tag{4}$$

$$DYHAT(r) = LAMBYHAT(r)*(y(r) - 100*YHAT(r)*time) \tag{10}$$

$$\frac{WQHHLD(r)}{SAVE(r)}(erg\_wyr(r) + DYHAT(r)) = psave(r) + qsave(r) - wqh(r) \tag{11}$$

We have one new exogenous variable, *wyrt*(*r*), percentage change in the target wealth to income ratio. New endogenous variables include percentage change in the actual wealth to income ratio, *wyra*(*r*), determined by equation (2); percentage change in the propensity to save, *dpsave*(*r*), determined by equation (11); and change in the expected percentage point rate of growth in the wealth to income ratio, *erg_wyr*(*r*) determined by equation (4). We also add a variable representing absolute change in the normal percentage point rate of income growth, *DYHAT*(*r*), determined by equation (10).

5. Data and parameters

To implement the new household saving treatment in the model, we need to set the initial value of the coefficient *YHAT*(*r*), the parameters *LAMBWYR*(*r*) and *LAMBYHAT*(*r*), and the target wealth to income ratio *WYRT*(*r*). We set the initial perceived long-run economic growth rate *YHAT*(*r*) equal to a geometric average of historical annual growth rates. Time series data for gross national income (GNI) at constant local currency units are obtained from the World Development Indicators data base, which covers period from 1960 to 2004. However, we use just the last 15 years (1990–2004), because for many countries observations for earlier years are missing. Another reason to restrict the series to later years is to avoid incorporating past episodes of rapid economic growth into our current assessments. For example, annual growth rates in the Japanese economy between 1960 and 1973 were in the range from 6 to 13 per cent, but became much lower in recent years. Having the GNI time series from 1970 to 2004, we aggregate over countries according to our chosen aggregation scheme, and then calculate the geometric average GNI growth rate, which is our proxy for *YHAT*(*r*). Note that precision in estimating *YHAT*(*r*) is not very important since it is updatable. However, as we see below, the initial *YHAT*(*r*) setting plays a role in setting the regional target wealth to income ratios.

The parameter *LAMBWYR*(*r*) determines the initial distance between the target and actual wealth to income ratios, and how fast the actual wealth to income ratio moves toward the target ratio. From (14), the initial distance between wealth to income target and actual ratios is given by the formula

$$\frac{WYRT(r)}{WYRA(r)} = \exp\left(\frac{1}{LAMBWYR(r)}\left(\frac{SAVE(r)}{WQHHLD(r)} - YHAT(r)\right)\right). \tag{15}$$

Other things being equal, larger *LAMBWYR*(r) leads to a larger gap between target and actual wealth to income ratios in the initial data base. If growth in regional wealth is faster than perceived normal economic growth, then the expression in parentheses is positive and *WYRT*(*r*) is greater than *WYRA*(*r*). Similar, when growth in regional wealth is slower than perceived normal economic growth, then the expression in parentheses is negative and *WYRT*(*r*) is less than *WYRA*(*r*). To achieve desired wealth to income ratios, regions adjust their propensities to save. Consider a simple scenario with no growth in endowments and no technological progress over the long run. For such a scenario, we can set *YHAT*(*r*) equal to zero in the initial period and keep it equal to zero during the simulation, removing the adjustment mechanism equation (10). The region accumulates more wealth and increases its wealth to income ratio moving it closer to the target. As the distance between the target and actual wealth to income ratios diminishes, less growth in wealth is needed, and the saving rate declines. When *WYRA*(*r*) = *WYRT*(*r*), the regional household saves only to cover its capital depreciation, and the net saving rate *SAVE*(*r*) is zero.

How much adjustment should we allow in wealth to income ratios? An answer to this question will help us set parameter *LAMBWYR(r)*. As discussed in section 3 of this paper, and as shown by the insignificant time trends in wealth to income ratios in table 3, wealth to income ratios are very stable for most countries. This suggests that the target wealth to income ratios should be set close to the actual wealth to income ratios calculated in the initial data base.

The size of historical wealth to income ratios is also helpful in setting target wealth to income ratios. The ratio is larger for industrialized countries than for other countries in the sample. The ratios for industrialized countries in the period 1966–1997 are in the range from 1.5 to 5.5, with the exception of Switzerland's, which is in the range from 4.35 to 6.72.[4] For other countries the ratios are in the range from 0.65 to 4 in East Asia and Pacific region, from 0.5 to 3.7 in Latin American and Caribbean region, from 0.5 to 3.7 in Middle East and North Africa, from 0.5 to 1.6 in South America, and from 0.5 to 2.7 in Sub-Saharan Africa. From

[4] This range is for 1983-1996 since the data for Switzerland in Kraay *et al*. (2000) data base is available only for 1983-1996 period.

these observations, it appears, a reasonable upper bound on the target wealth to income ratio is 5.5.

We now present a specific example illustrating how we set *LAMBWYR*(*r*). We use the 22x3 aggregation of the version 5 GTAP data base mentioned in section 3 of this paper. Following equation (15), the target wealth to income,

$$WYRT(r) = WYRA(r) * \exp\left(\frac{1}{LAMBWYR(r)} * \left(\frac{SAVE(r)}{WQHHLD(r)} - YHAT(r)\right)\right). \qquad (16)$$

The inputs into the calculation, together with resulting target wealth to income ratios when *LAMBWYR*(*r*) = 0.05, are given in table 4. For most of the regions in this aggregation, the calculated target wealth to income ratios are within the plausible range. The exceptions are Japan, Korea and Netherlands. Here, unusually high target wealth to income ratios result from a combination of high initial ratios and rapid initial growth in the ratios. The later is driven by slow growth in income in Japan, rapid growth in wealth in Korea, and both slow growth in income and rapid growth in wealth in the Netherlands. It is possible that for these countries the 1997 savings to wealth ratio recorded in v. 5.4 of GTAP data base is abnormally high. But, what is really important that even these relatively high target wealth to income ratios impose an upper bound on actual wealth to income ratios in GTAP-Dyn simulations. And these bounds are much lower than the ratios that would be observed with fixed saving rates, as illustrated in figure 7.

How sensitive are the target ratios with respect to *LAMBWYR*(*r*)? As can be seen from equation (16), as *LAMBWYR*(*r*) becomes very small, *WYRT*(*r*) approaches infinity. Large *LAMBWYR*(*r*) leads to *WYRT*(*r*) = *WYRA*(*r*). This is supported by figures 9 and 10. With *LAMBWYR*(*r*) below 0.05 (figure 9), *WYRT*(*r*) becomes very large. On the other hand, with *LAMBWYR*(*r*) larger than 0.1 (figure 10), target wealth to income ratios are not sensitive to *LAMBWYR*(*r*), but remain very close to initial actual ratios *WTRA*(*r*). Taking into account the historical fact that wealth to income ratios are stable for most countries, setting *LAMBWYR*(*r*) to 0.1 or larger seems plausible. However, a high setting of the parameter would lead to rapid changes in savings rates in early years of the simulations, for example, rapid reductions in saving in Japan, Korea, China, and the Netherlands, and rapid increases in the residual "Rest of World" region. But while it is plausible that such changes will take eventually, there is little reason to expect them to take place rapidly and in the near future; we therefore prefer to avoid such obtrusive phenomena in our scenario results. It is also possible that, for some scenarios, too high a setting of the adjustment parameter may make the model unsolvable. From these considerations, we conclude that the acceptable range for *LAMBWYR*(*r*) is around 0.05 to 0.1.

Finally, we need to set *LAMBYHAT*(*r*). This plays the same role in the formation of expected growth in income in our new saving treatment as *LAMBKHAT*(*r*) plays for expected growth in the capital stock in the standard GTAP-Dyn investment theory (Ianchovichina and McDougall, 2001). Since *LAMBYHAT*(*r*) is similar in role to *LAMBKHAT*(*r*), we set *LAMBYHAT*(*r*) equal to *LAMBKHAT*(*r*), that is, to 0.2.

As noted above, the introduction of the adjustment mechanism for expected growth in income, equation (10), is for convenience only. In some cases, it may prove more convenient to delete the adjustment mechanism and provide a fixed expected growth rate. In particular, high settings of the adjustment parameter lead to faster adjustment toward equilibrium and larger changes in the model, and may make the model unsolvable. Specifically, large changes in saving may lead to negative utility from savings in the top level Cobb-Douglas regional household demand system. In such cases, the solution is to calibrate *YHAT*(*r*) for the specific experiment and set it consistent with long run trends in the scenario.

6. Conclusion

We conclude this paper with two illustrative simulations based on the 22x3 aggregation of the GTAP data base, and a discussion of directions for future research to improve the realism of the GTAP-Dyn model. In the first illustrative simulation there is no growth in endowments and productivity, and only the *time* variable is shocked. Here, we assume that the long-run steady state is static, that is, that there is no growth in productivity or endowments. Under these assumptions net saving tends toward zero over the long run, as does *YHAT*(*r*), resulting in relatively high target wealth to income ratios. In terms of saving rate adjustment, it is an extreme case since it requires large adjustment in such countries as China, Japan and Korea in this 90 year simulation. Figure 11 shows convergence of wealth to income ratios toward their targets in the long run simulation. Figure 12 contrasts these wealth to income ratios with the unbounded ratios when the saving rates are constant. Figure 13 shows endogenously declining saving rates. Figure 14, contrasted with figure 6, illustrates how ratios of net foreign assets to GDP are now bounded. These ratios are still high, however, compared to the historically observed ratios in figure 5.

In the second illustrative simulation, we use population, labor and GDP growth given in the standard GTAP baseline (Walmsley *et al*, 2000). In the long run we assume that GDP growth rates gradually converge to levels given in table 5 and labor and population growth rates remain after 2020 as in 2020. Saving rates, wealth to income ratios, and net foreign asset to GDP ratios in this simulation are shown in figures 15–17. Figure 18 shows global rate of return to capital in the long run GTAP-Dyn simulations at constant and endogenous saving rates. New household saving behavior allows reduction in the rate of growth in world capital and stabilization of the global rate of return to capital.

The proposed modification enforces long run stabilization in regional wealth to income ratios, which is critical to obtaining a sensible baseline in light of currently divergent savings rates across countries. As a direction for future research, it would be interesting to compare investment-saving correlations in the simulations from the model with and without new household saving behavior, and with correlations reported in the studies following Feldstein and Horioka (1980). Finally, it would be interesting to validate projections of the saving rates generated by the new mechanism against those tied to regional aging profiles and reported in Tyers (2005).

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Table 1. Kraay *et al*. (2000) data base: countries and period covered for each country.

Country	Code	Period	Obs.
East Asia and the Pacific (EAP)			
China	CHN	1981–1997	17
Indonesia	IDN	1966–1994	29
Korea	KOR	1969–1997	29
Malaysia	MYS	1976–1994	19
Philippines	PHL	1967–1997	31
Singapore	SGP	1966–1997	32
Thailand	THA	1969–1997	29
Industrial countries (INDC)			
Australia	AUS	1966 – 1997	32
Austria	AUT	1967 – 1997	31
Belgium-Luxembourg	BLX	1967–1977, 1986–1996	22
Canada	CAN	1966 – 1997	32
Switzerland	CHE	1983–1997	14
Germany	DEU	1968–1997	30
Denmark	DNK	1968–1996	29
Spain	ESP	1966–1997	32
Finland	FIN	1966–1997	32
France	FRA	1968–1997	30
United Kingdom	GBR	1966–1997	32
Greece	GRC	1966–1996	31
Ireland	IRL	1966–1997	32
Italy	ITA	1968–1997	30
Japan	JPN	1971–1986, 1991–1997	23
Netherlands	NLD	1966–1997	32
Norway	NOR	1975–1997	23
New Zealand	NZL	1973–1997	25
Portugal	PRT	1971–1997	27
Sweden	SWE	1966–1996	31
United States	USA	1969–1997	29
Sub-Saharan Africa (SSA)			
Cote d'Ivoire	CIV	1970–1985, 1987	17
Cameroon	CMR	1979, 1986–1993, 1995	10
Congo	COG	1993–1996	4
Lesotho	LSO	1980–1994	15
Mauritius	MUS	1974–1997	24
Senegal	SEN	1968–1970, 1972–1981	13
South Africa	ZAF	1968–1997	30
Latin American and the Caribbean (LAC)			
Argentina	ARG	1966–1974, 1976–1989, 1991–1997	30
Bolivia	BOL	1966–1985, 19871–997	31
Brazil	BRA	1966–1997	32
Chile	CHL	1967–1973, 1977–1979, 1981–1985	15
Colombia	COL	1967–1994	28
Costa Rica	CRI	1966–1995	30
Dominican Republic	DOM	1969–1984, 1986–1994	25
Ecuador	ECU	1966–1996	31
Guatemala	GTM	1966–1994	29
Honduras	HND	1966–1997	32
Jamaica	JAM	1968–1995	28
Mexico	MEX	1966–1997	32
Nicaragua	NIC	1966–1981, 1983	17
Peru	PER	1975–1993	19
El Salvador	SLV	1966–1997	32
Trinidad and Tobago	TTO	1974–1994	21
Uruguay	URY	1967–1973, 1980–1997	25
Venezuela	VEN	1974–1997	24
Middle East and North Africa (MENA)			
Algeria	DZA	1966–1991	26
Egypt	EGY	1988, 1989	2
Iran	IRN	1966–1982	17
Israel	ISR	1969–1997	29
Jordan	JOR	1966–1989	24
Morocco	MAR	1966–1982, 1988–1997	27
Oman	OMN	1973–1989	17
Saudi Arabia	SAU	1966–1969, 1981, 1985–1989	10
Syria	SYR	1966–1987	21
Tunisia	TUN	1966–1997	32
Turkey	TUR	1966–1998	32
South Asia (SA)			
Bangladesh	BGD	1972–1981, 1983	11
India	IND	1966–1997	32
Sri Lanka	LKA	1966-1975, 1980-1997	28
Pakistan	PAK	1966–1971, 1974–1997	30

Table 2. Foreign assets as share of wealth and foreign liabilities as share of capital, across regions and over time.

	1966–73	1974–81	1982–89	1990–97	1966–97
Gross foreign assets as a share of wealth					
Industrial countries	0.076	0.088	0.152	0.211	0.148
Developing countries	0.025	0.045	0.043	0.046	0.043
East Asia and the Pacific	0.044	0.046	0.035	0.050	0.045
Latin America and the Caribbean	0.018	0.032	0.038	0.049	0.038
Middle East and North Africa	0.043	0.114	0.130	0.065	0.098
South Asia	0.007	0.011	0.008	0.012	0.010
Sub-Saharan Africa	0.096	0.061	0.054	0.056	0.061
Gross foreign liabilities as a share of capital					
Industrial countries	0.061	0.082	0.154	0.218	0.149
Developing countries	0.114	0.114	0.117	0.102	0.110
East Asia and the Pacific	0.130	0.125	0.082	0.080	0.086
Latin America and the Caribbean	0.102	0.122	0.161	0.134	0.135
Middle East and North Africa	0.186	0.136	0.171	0.161	0.160
South Asia	0.062	0.051	0.058	0.071	0.061
Sub-Saharan Africa	0.243	0.167	0.138	0.105	0.148

Weighted averages for each 8-year period are computed using unbalanced panel. For foreign assets share the weight is country wealth. For foreign liabilities share the weight is country capital.

Table 3. The wealth to income ratio regressed on time trend.

Country	Intercept	Time trend	First lag	Second lag	R-square	Obs.
1	2	3	4	5	6	7
INDC						
AUS	0.588**	-0.007	1.326***	-0.495***	0.895	30
AUT	0.902***	0.013	1.096***	-0.462**	0.788	29
CAN	0.558***	0.000	1.377***	-0.669***	0.819	30
CHE	2.231**	0.146***			0.666	14
DEU	0.501**	-0.001	1.051***	-0.200	0.909	28
DNK	0.979**	-0.010	1.173***	-0.425**	0.779	27
ESP	0.661**	0.008	1.163***	-0.442**	0.792	30
FIN	1.026**	-0.000	1.270***	-0.528***	0.781	30
FRA	0.900**	0.006	1.015***	-0.338*	0.713	28
GBR	0.796**	-0.004	1.161***	-0.470**	0.724	30
GRC	0.564**	-0.002	1.199***	-0.428**	0.771	29
IRL	0.688**	-0.002	1.155***	-0.451**	0.718	30
ITA	1.248***	-0.003	0.966***	-0.329*	0.610	28
JPN	1.655**	0.000	0.534**		0.356	15
NLD	0.845**	-0.000	1.165***	-0.412**	0.755	30
NOR	0.903	-0.005	0.754***		0.762	22
NZL	0.921*	-0.002	0.593***		0.361	24
PRT	1.472***	-0.010	0.878***	-0.432**	0.618	26
SWE	0.701**	-0.005	1.351***	-0.590***	0.843	29
USA	0.431**	-0.005***	0.855***		0.904	28
LAC						
BOL	0.909**	0.035**	0.428**		0.761	19
BRA	0.524***	0.024***	0.878***	-0.414**	0.822	30
COL	0.268	-0.002	1.055***	-0.243	0.763	26
CRI	0.514***	0.010**	0.425**		0.758	29
DOM	0.300***	0.067***			0.941	16
ECU	0.575**	-0.005	0.754***		0.653	30
GTM	0.307**	-0.002	0.687***		0.490	28
HND	0.312*	-0.002	0.749***		0.680	31
JAM	0.672**	0.003	0.621***		0.479	27
MEX	0.667***	0.007*	0.894***	-0.449**	0.646	30
NIC	0.694**	0.002	0.180		0.030	15
PER	0.692*	0.063***			0.393	19
SLV	0.197**	0.002	0.729***		0.680	31
TTO	0.576**	-0.004	0.568***		0.364	20
URY	0.125	0.021**	0.487**		0.708	16

Continued

Table 3. The wealth to income ratio regressed on time trend (Contd)

Country	Intercept	Time trend	First lag	Second lag	R-square	Obs.
1	2	3	4	5	6	7
EAP						
CHN	0.441	0.018**	0.330		0.533	16
IDN	0.305***	0.013**	1.019***	-0.464**	0.908	27
KOR	0.291***	0.018**	1.295***	-0.634***	0.965	27
MYS	0.703**	0.014*	0.410*		0.582	18
PHL	0.311**	0.010**	1.022***	-0.416*	0.883	29
SGP	0.332**	0.009*	1.378***	-0.554***	0.961	30
THA	0.175	0.003	1.232***	-0.384*	0.870	27
MENA						
DZA	0.518**	0.015	0.572***		0.762	25
IRN	-0.065	0.067*	0.960**	-0.414	0.917	15
ISR	0.710**	-0.003	0.681***		0.537	28
JOR	0.237*	-0.009***	0.870***		0.761	23
MAR	0.354**	0.001	0.842***	-0.365	0.447	23
OMN	0.370*	0.021	0.538**		0.814	16
SYR	-0.927**	0.019**	1.305***	0.384	0.816	19
TUN	0.315*	-0.007**	0.835***		0.865	31
TUR	0.400*	0.003	0.761***		0.662	31
SA						
IND	0.300**	-0.004**	1.196***	-0.396**	0.885	30
LKA	-0.034	0.019*	0.533**		0.946	17
PAK	0.151	-0.000	1.176***	-0.379**	0.834	22
SSA						
CIV	0.877***	0.006			0.013	16
MUS	0.218	-0.002	1.165***	-0.336	0.817	22
ZAF	0.543**	0.001	0.710		0.541	29

***, ** and * denote significance levels at 0.01, 0.05 and 0.1, respectively.
Number of lags is chosen to whiten the errors.

Table 4. Calculation of target wealth to income ratios for 22x3 aggregation of the v.5.4 GTAP data base. *LAMBWYR*(r) = 0.05.

Region	WYRA (wealth to income ratio, based on v. 5.4 GTAP data base)	YHAT (geometric average growth calculated using WDI data base)	SAVE/WQHHLD (wealth growth rate, based on v 5.4 GTAP data base)	SAVE/WQHHLD – YHAT	WYRT
Australia	2.842	0.037	0.031	-0.007	2.489
New Zealand	2.476	0.030	0.024	-0.006	2.187
China	2.657	0.073	0.100	0.027	4.548
Japan	4.013	0.013	0.051	0.039	8.688
Korea	3.296	0.053	0.081	0.028	5.737
South Asia	2.894	0.050	0.065	0.014	3.866
Canada	2.528	0.028	0.039	0.010	3.107
United States	2.626	0.032	0.028	-0.003	2.470
South America	3.013	0.029	0.022	-0.007	2.614
Austria	4.064	0.021	0.022	0.001	4.140
Denmark	2.356	0.025	0.046	0.021	3.588
Finland	3.325	0.019	0.027	0.009	3.942
France	3.531	0.020	0.027	0.007	4.099
United Kingdom	3.050	0.027	0.026	-0.002	2.946
Ireland	2.111	0.060	0.047	-0.013	1.632
Italy	3.534	0.015	0.021	0.006	3.973
Netherlands	3.593	0.024	0.051	0.027	6.179
Portugal	2.769	0.027	0.012	-0.014	2.077
Sweden	2.286	0.017	0.040	0.023	3.613
Europe	3.676	0.024	0.027	0.003	3.918
Turkey	3.075	0.030	0.031	0.001	3.132
ROW	3.770	0.034	0.013	-0.021	2.475

Table 5. Long run growth rates assumed in the second illustrative simulation.

Region	YHAT	Region	YHAT
Australia	0.031	Finland	0.032
New Zealand	0.030	France	0.024
China	0.035	Unite Kingdom	0.026
Japan	0.023	Ireland	0.035
Korea	0.035	Italy	0.025
South Asia	0.039	Netherlands	0.027
Canada	0.023	Portugal	0.027
US	0.026	Sweden	0.028
South America	0.035	Europe	0.026
Austria	0.028	Turkey	0.035
Denmark	0.025	ROW	0.036

Figure 1: Gross foreign assets as share of wealth.

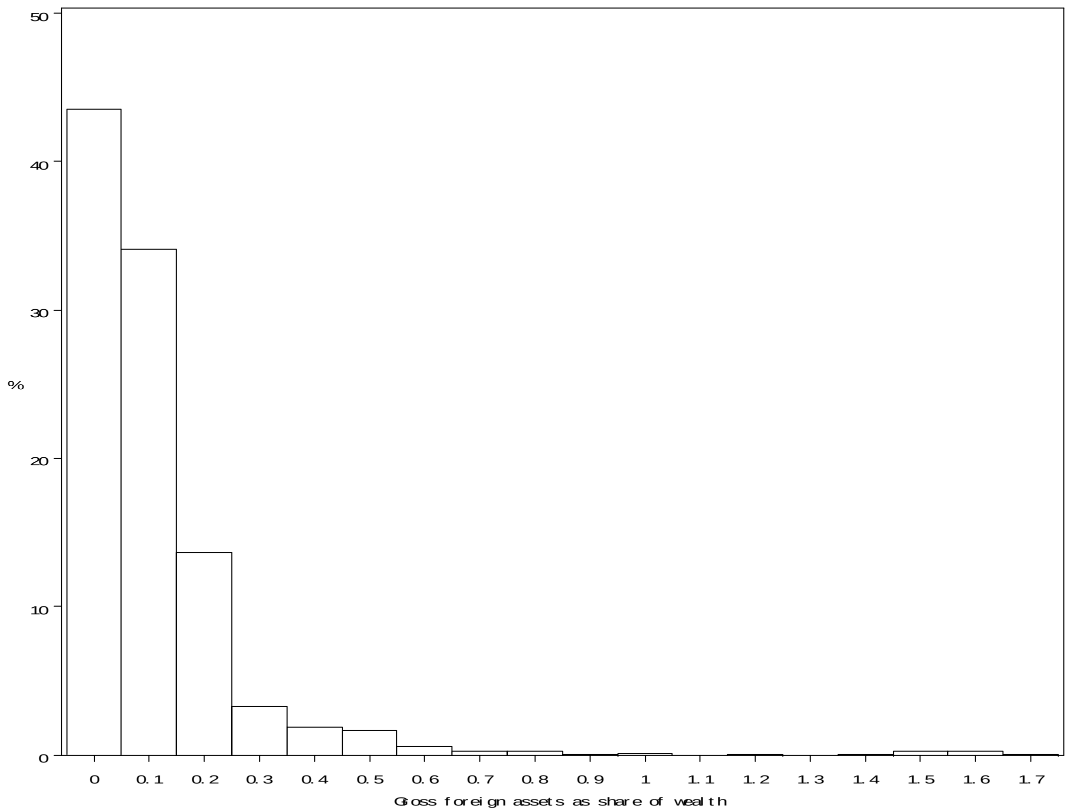


Figure 2. Gross foreign assets as share of capital.

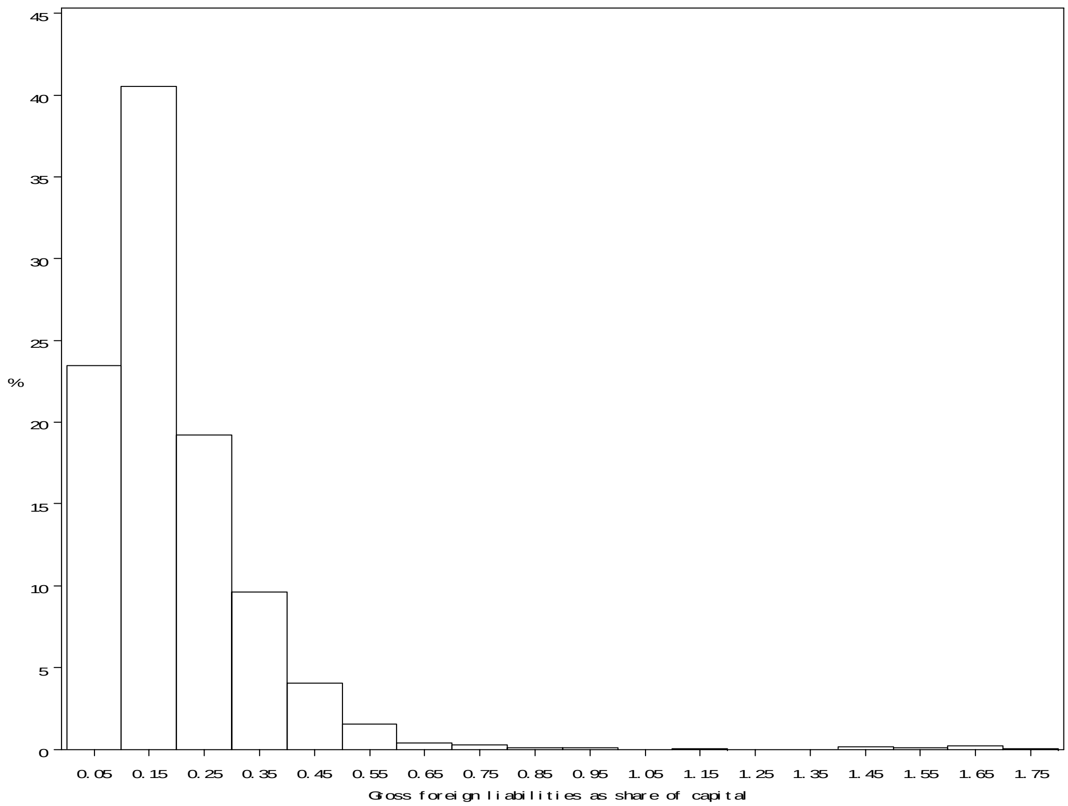
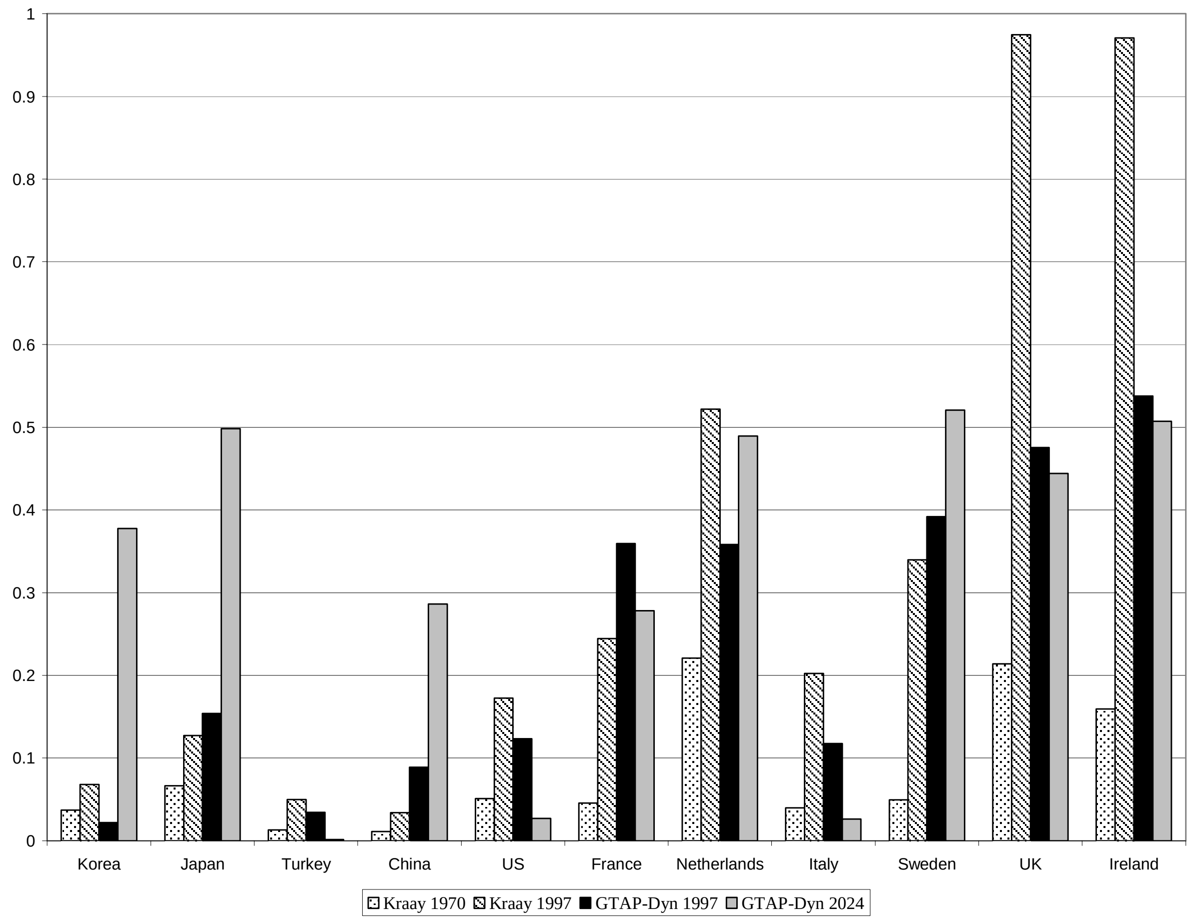
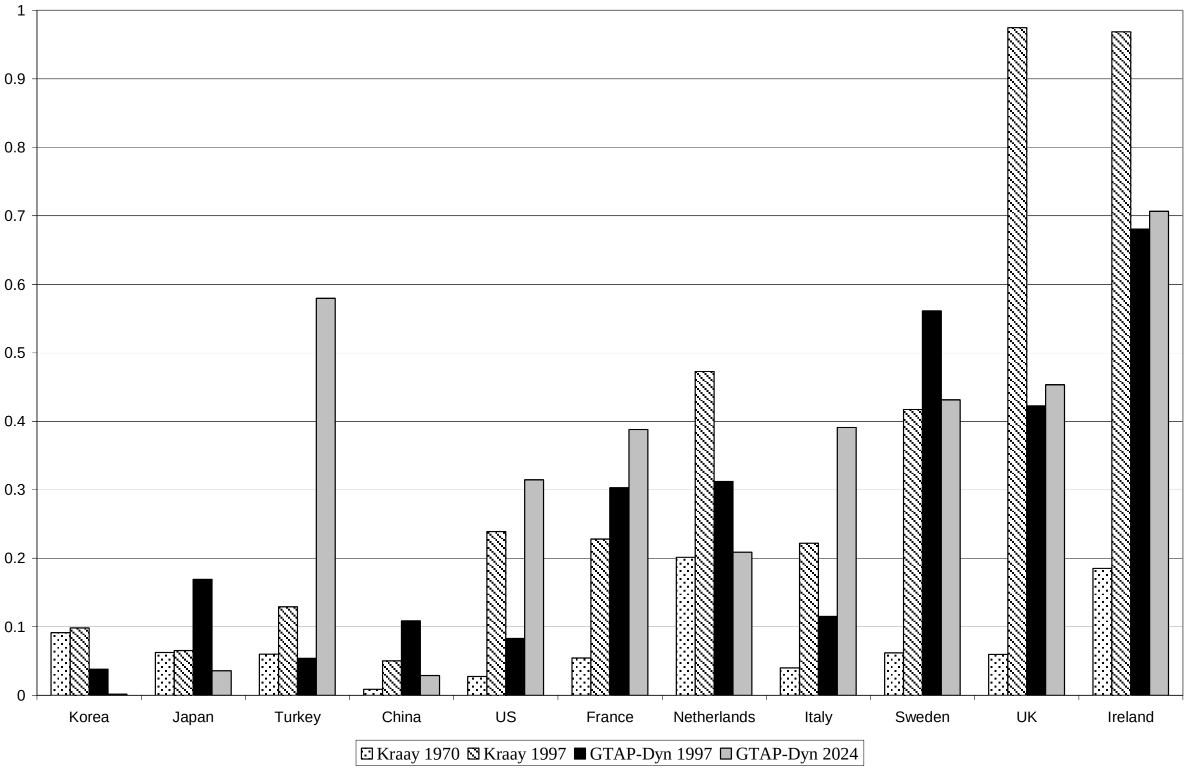


Figure 3. Gross foreign assets as share of wealth in 1970 and 1997 of Kraay *et al*. (2000) data base and in 1997 and 2024 of GTAP-Dyn simulations.



For Japan, the first observation in the Kraay *et al*. data base is for 1971. For Sweden, the last observation is for 1996. For Japan and Sweden, we show 1971 and 1996 gross foreign assets, respectively.

Figure 4. Gross foreign liabilities as share of capital in 1970 and 1997 in Kraay *et al*. (2000) and in 1997 and 2024 of GTAP-Dyn simulations.



For Japan, first observation in Kraay *et al*. data base is 1971. For Sweden, the last observation is in 1996. For Japan and Sweden, we show 1971 and 1996 gross foreign liabilities, respectively.

Figure 5. Net foreign position to GDP ratio for selected 12 countries from 1966 to 1967. Source: Kraay *et al*. (2000).

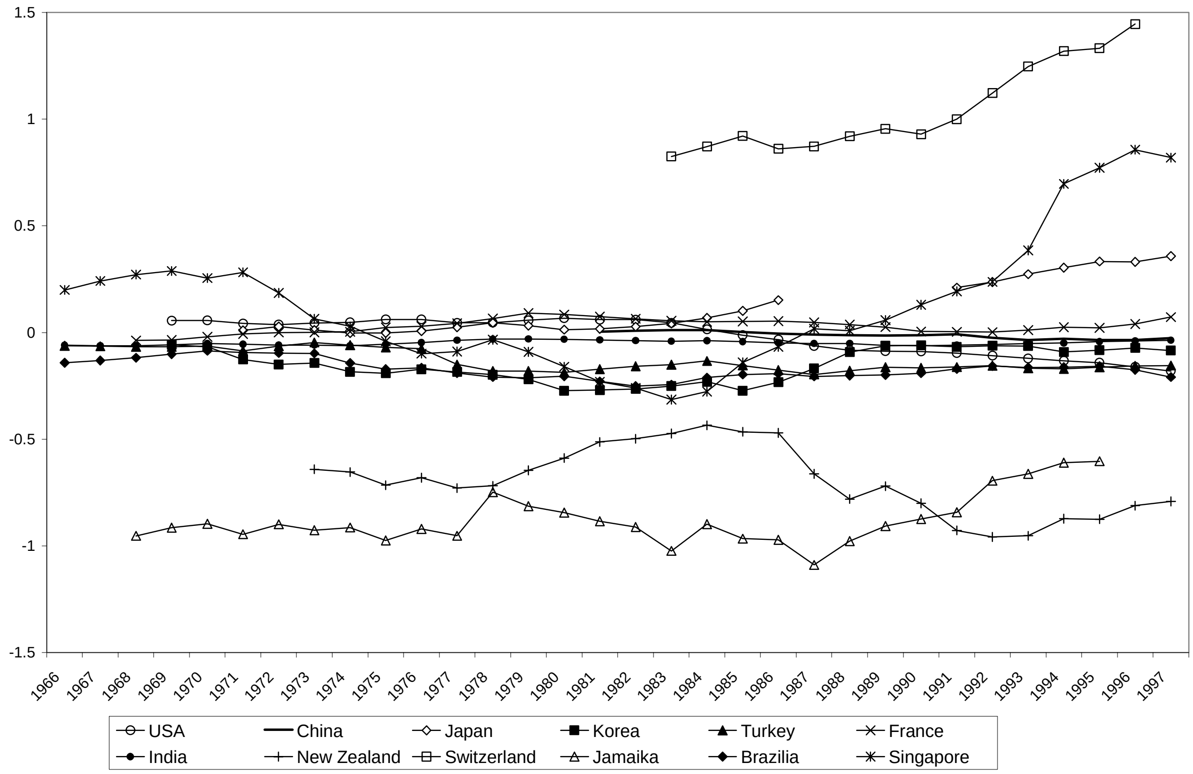
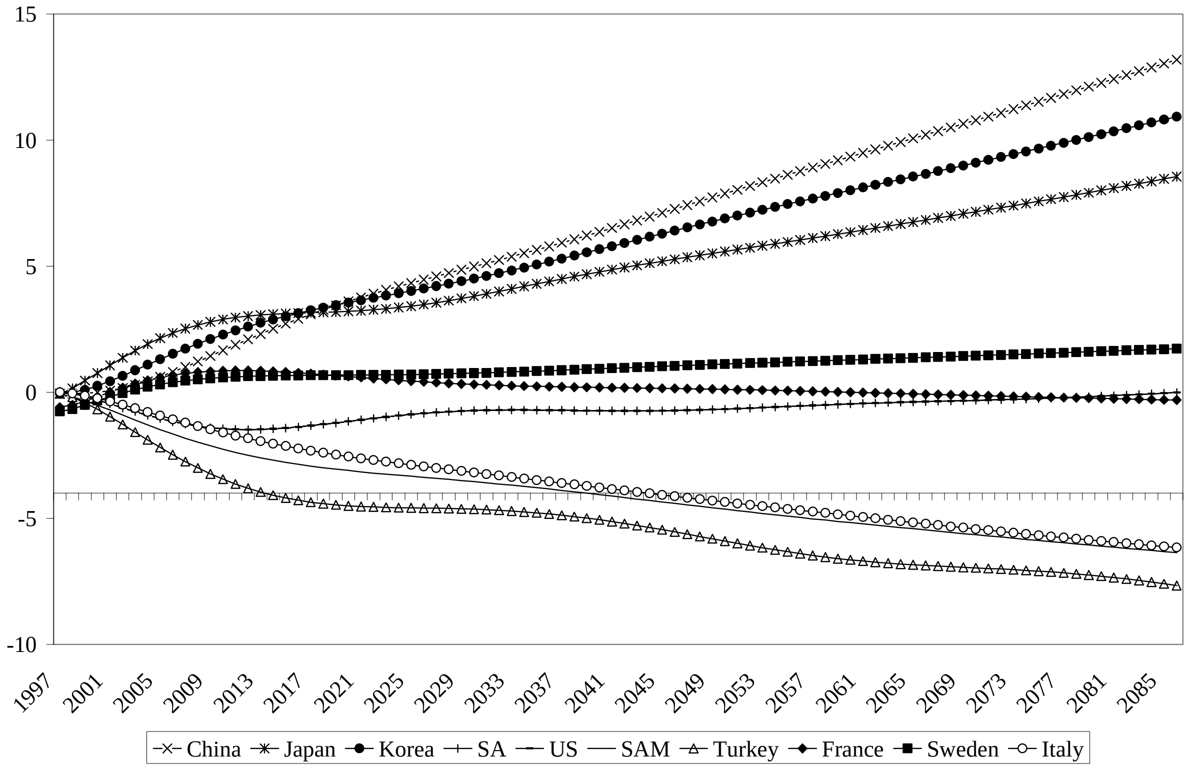


Figure 6. Net foreign position to GDP ratio in the long run GTAP-Dyn simulation.



For this simulation the v.5 GTAP data base was aggregated to 22 regions. To make the figure clear only 10 regions are shown. The ratios of other 12 regions are in the range between ratios of Japan and Turkey.

Figure 7. Wealth to income ratios in long run GTAP-Dyn simulations.

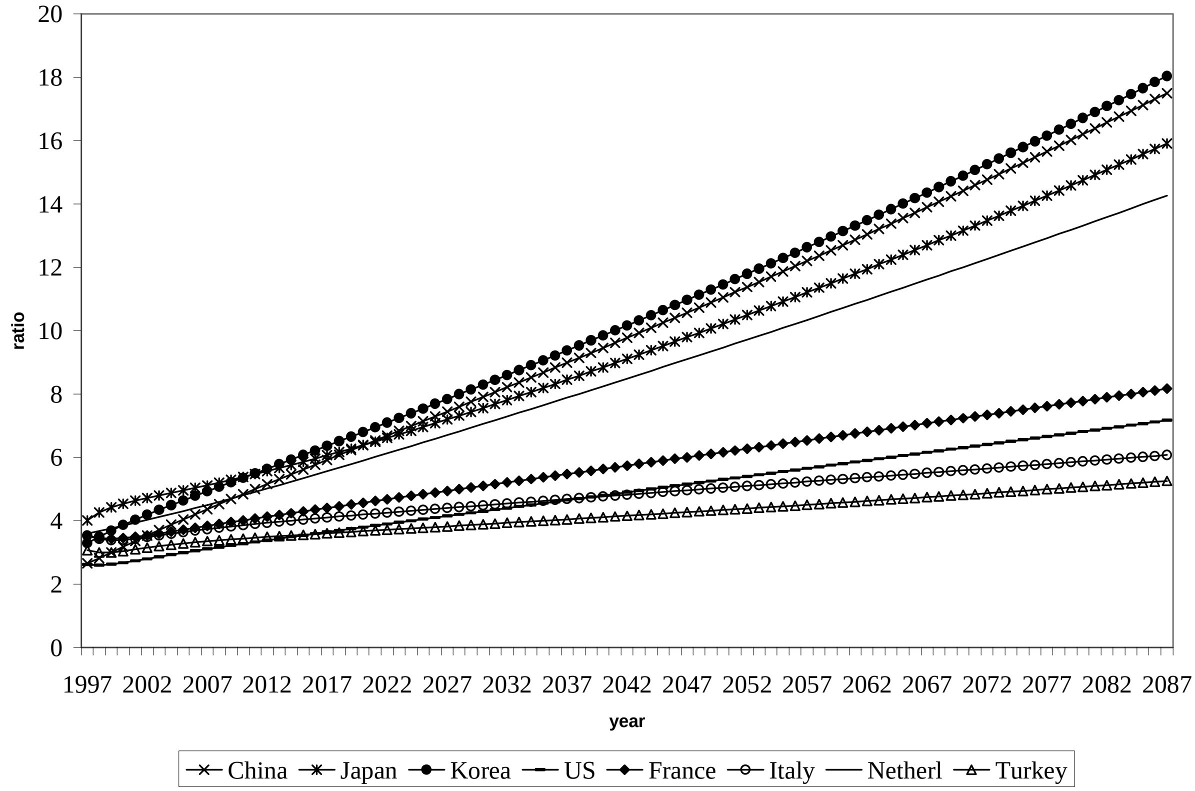


Figure 8. Historical wealth to income ratios of selected countries constructed using Kraay *et al.* (2000) data base.

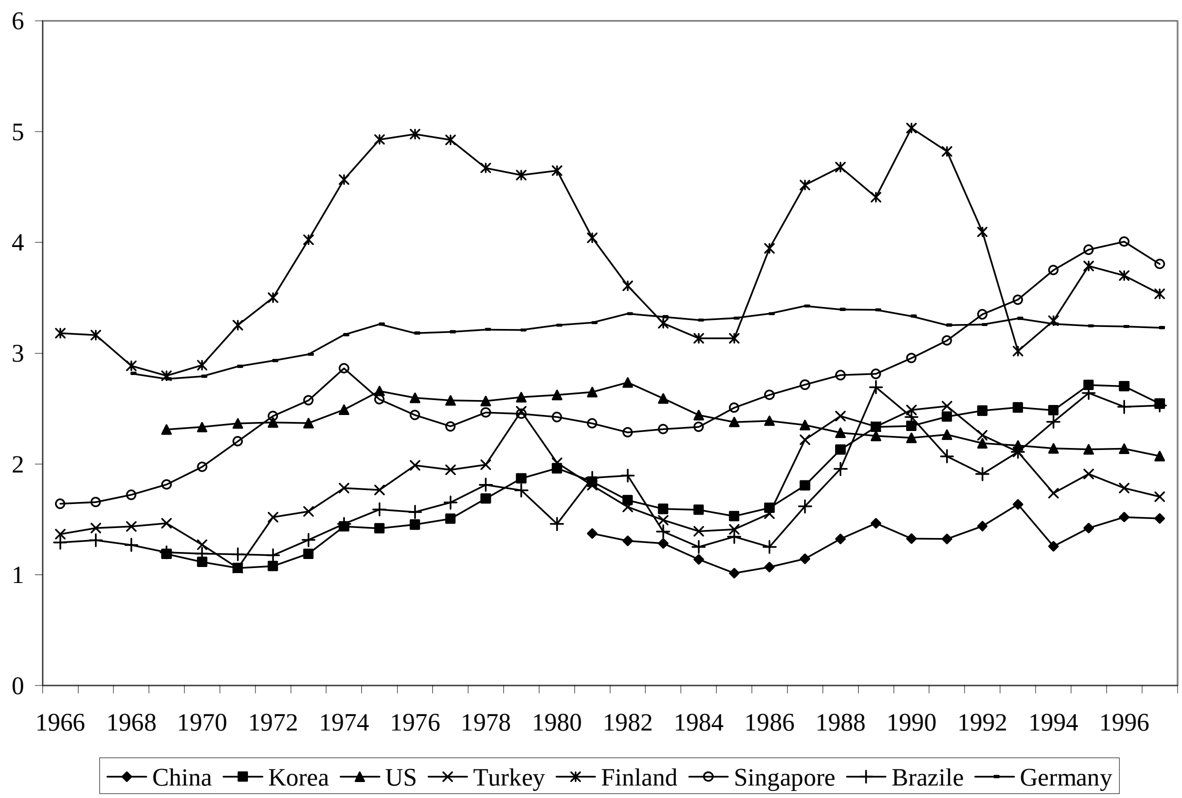


Figure 9. Target wealth to income ratios in GTAP-Dyn simulations when *LAMBWYR*(r) is relatively large.

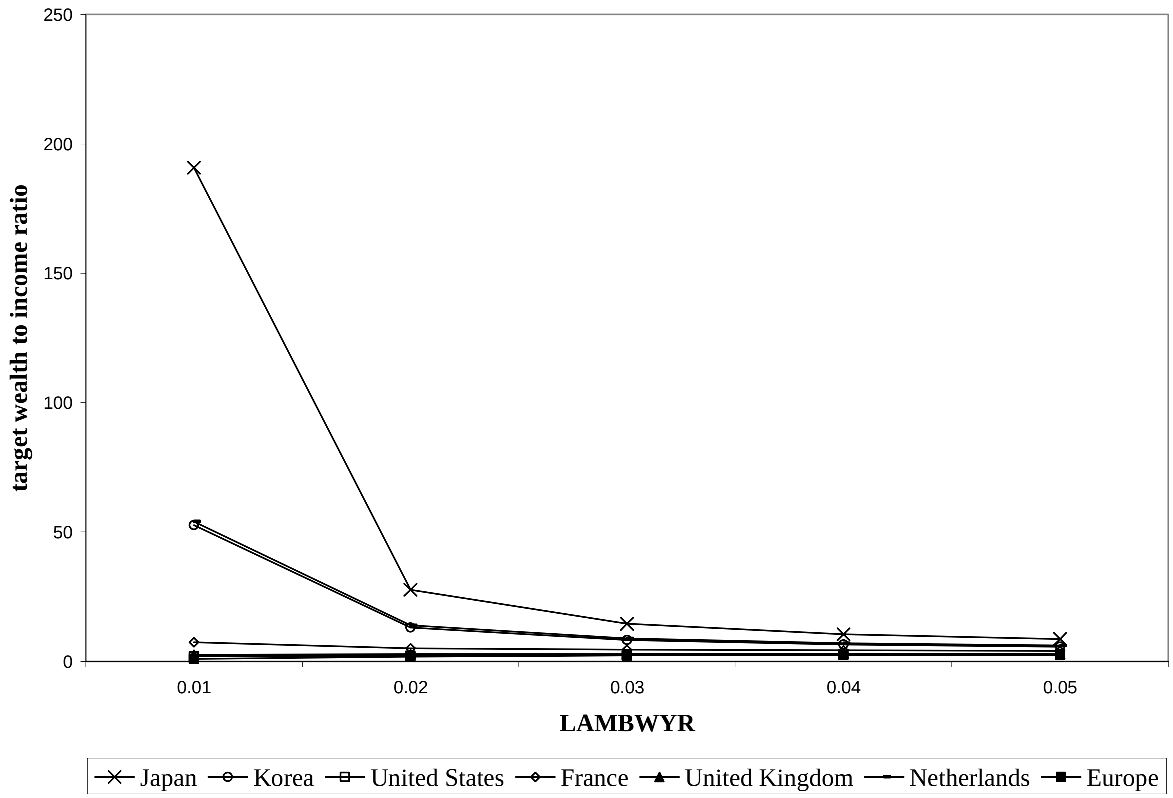


Figure 10. Target wealth to income ratios in GTAP-Dyn simulations when *LAMBWYR*(r) is relatively small.

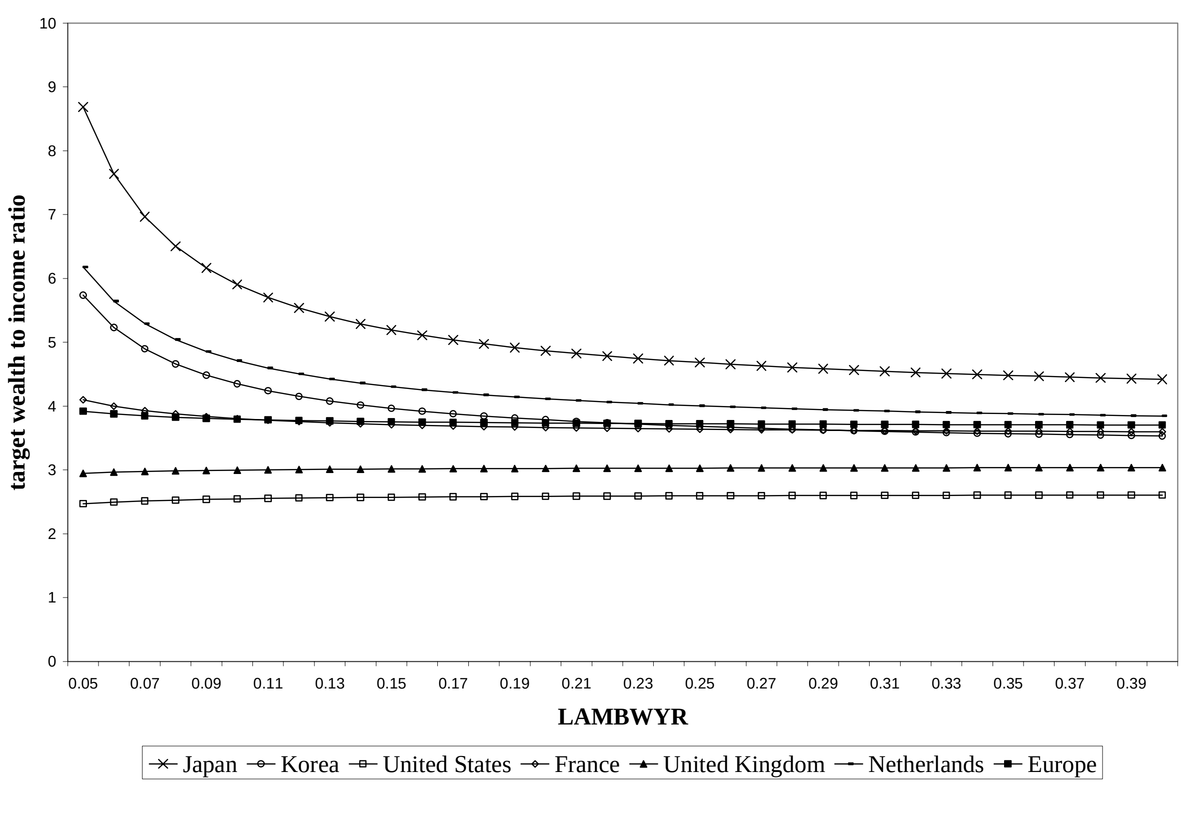


Figure 11. Wealth to income ratio in the long run GTAP-Dyn simulations with new household saving behavior, *LAMBWYR*(r) set to 0.1, long run growth assumed to be zero.

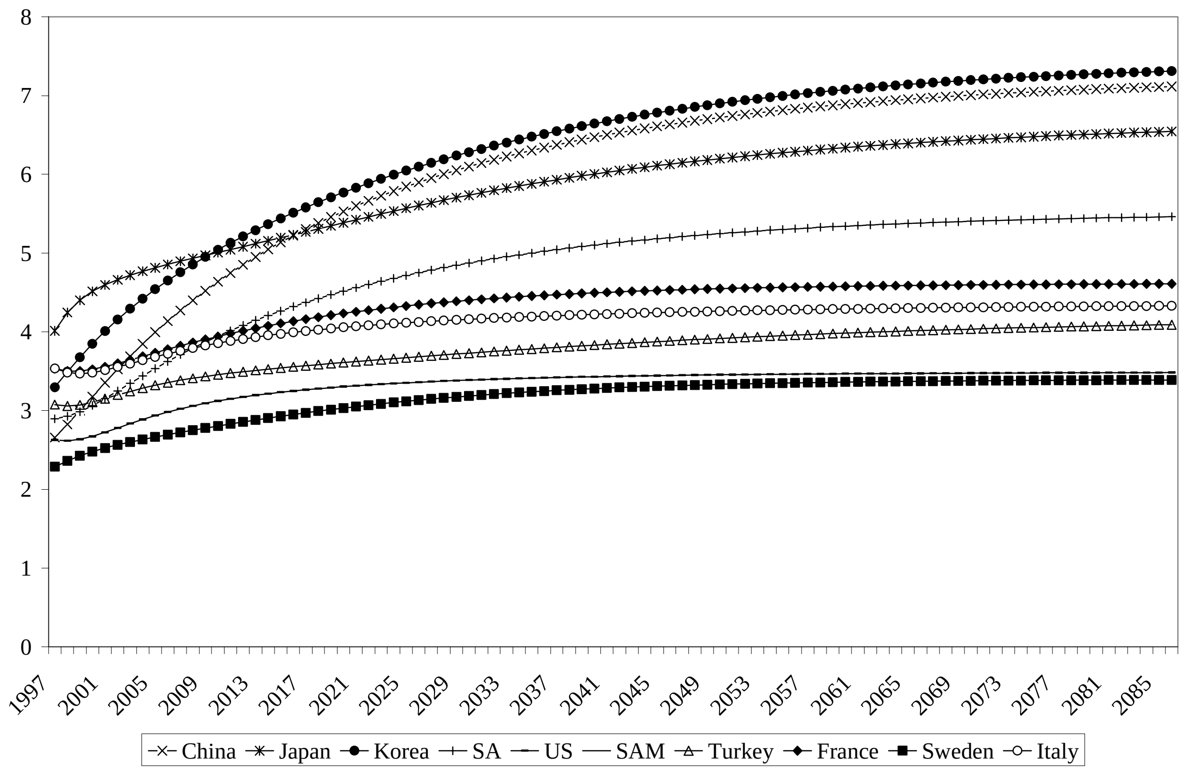


Figure 12. Comparison of wealth to income ratios in the end of GTAP-Dyn 90-year simulations with constant and endogenous saving rates.

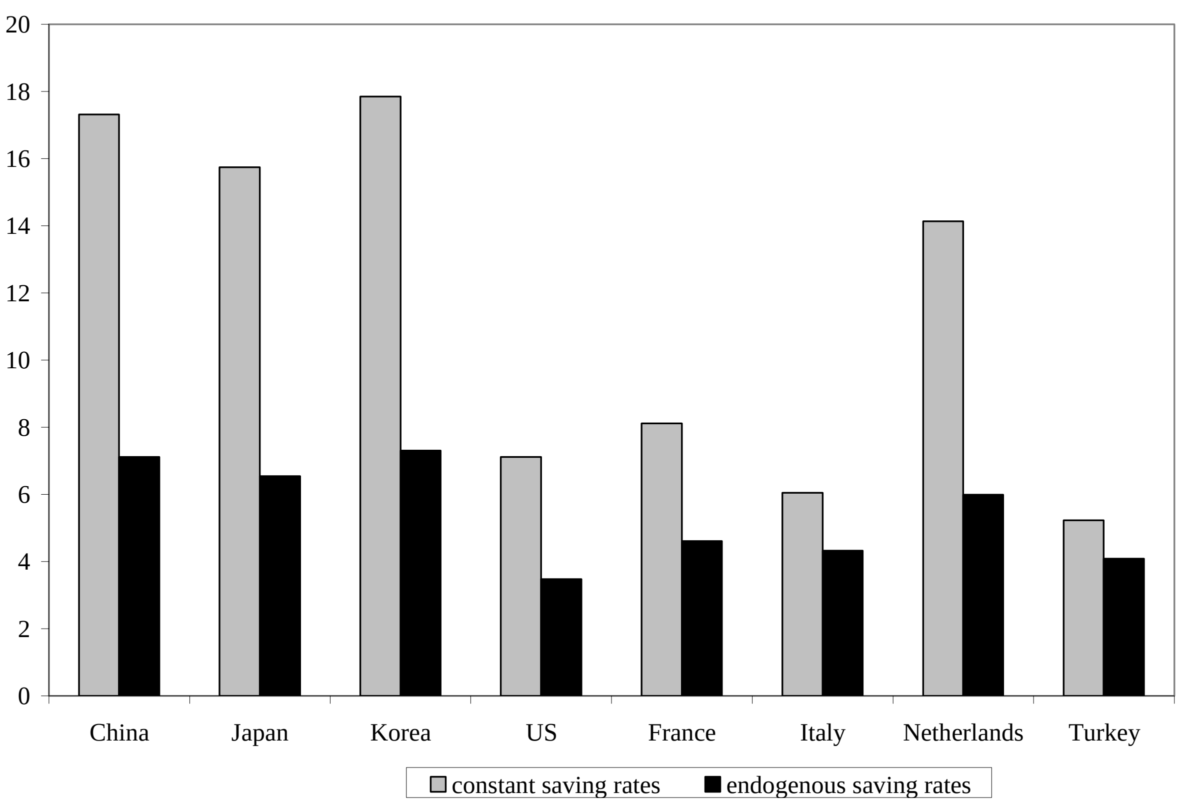


Figure 13. Saving rates in the long run GTAP-Dyn simulations with new household saving behavior, long run growth assumed to be zero.

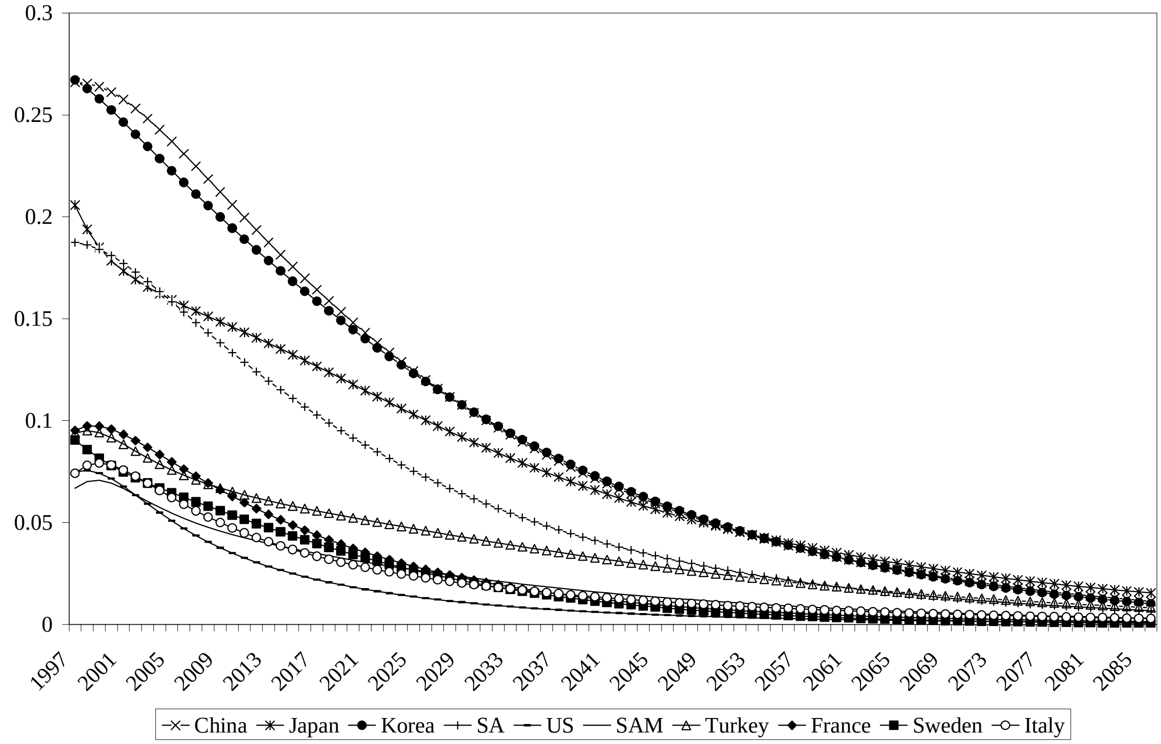


Figure 14. Net foreign assets to GDP ratio in the long run GTAP-Dyn simulations with new household saving behavior, long run growth assumed to be zero.

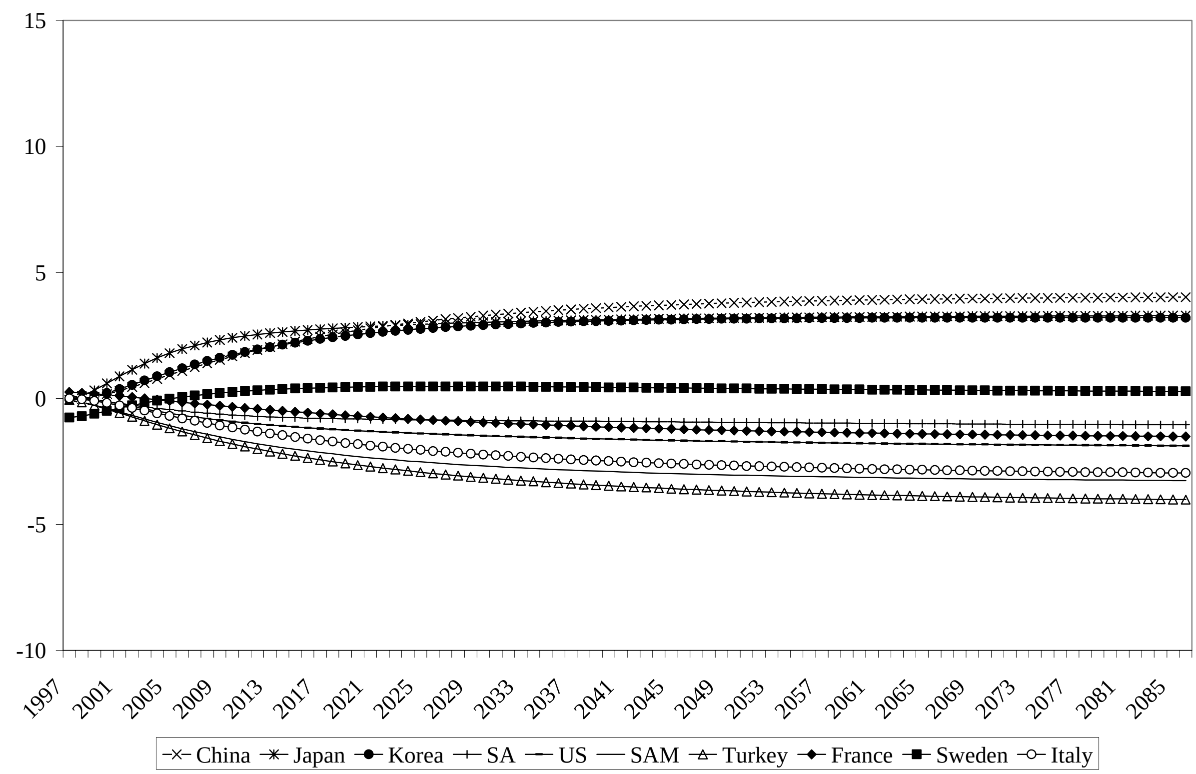


Figure 15. Wealth to income ratio in the long run GTAP-Dyn simulations with new household saving behavior, *LAMBWYR*(r) set to 0.1, long-run growth rates as given in table 5.

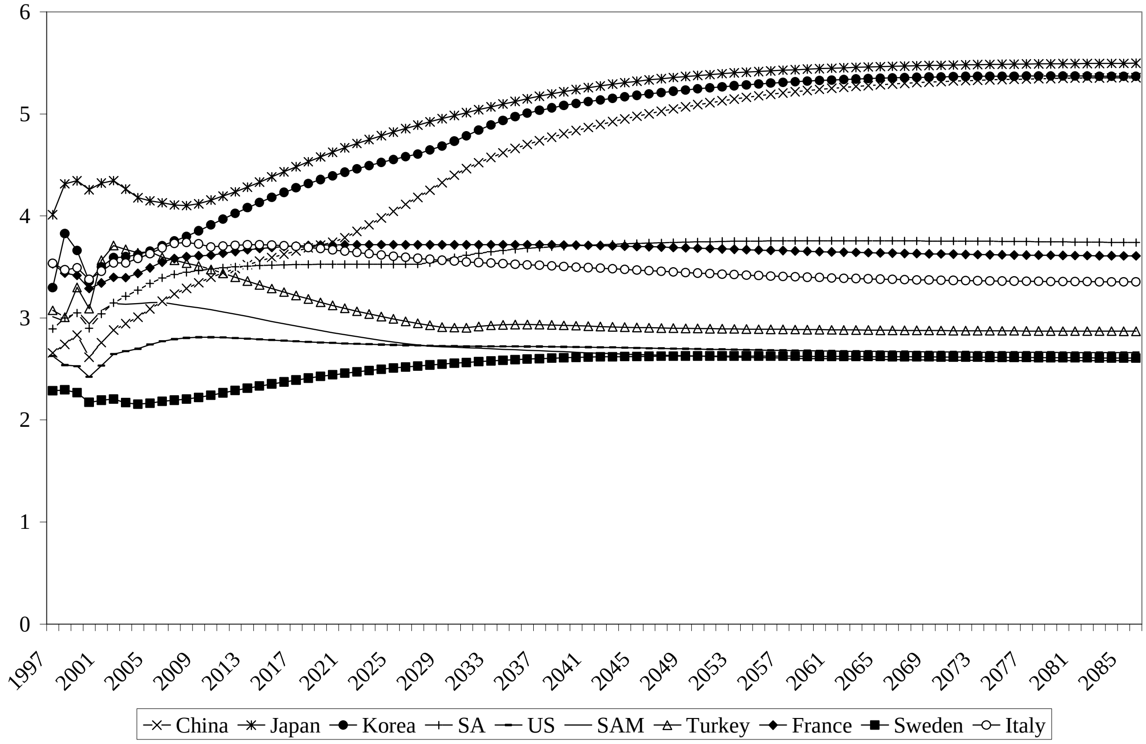


Figure 16. Saving rates in the long run GTAP-Dyn simulations with new household saving behavior, long run growth rates as in table 5.

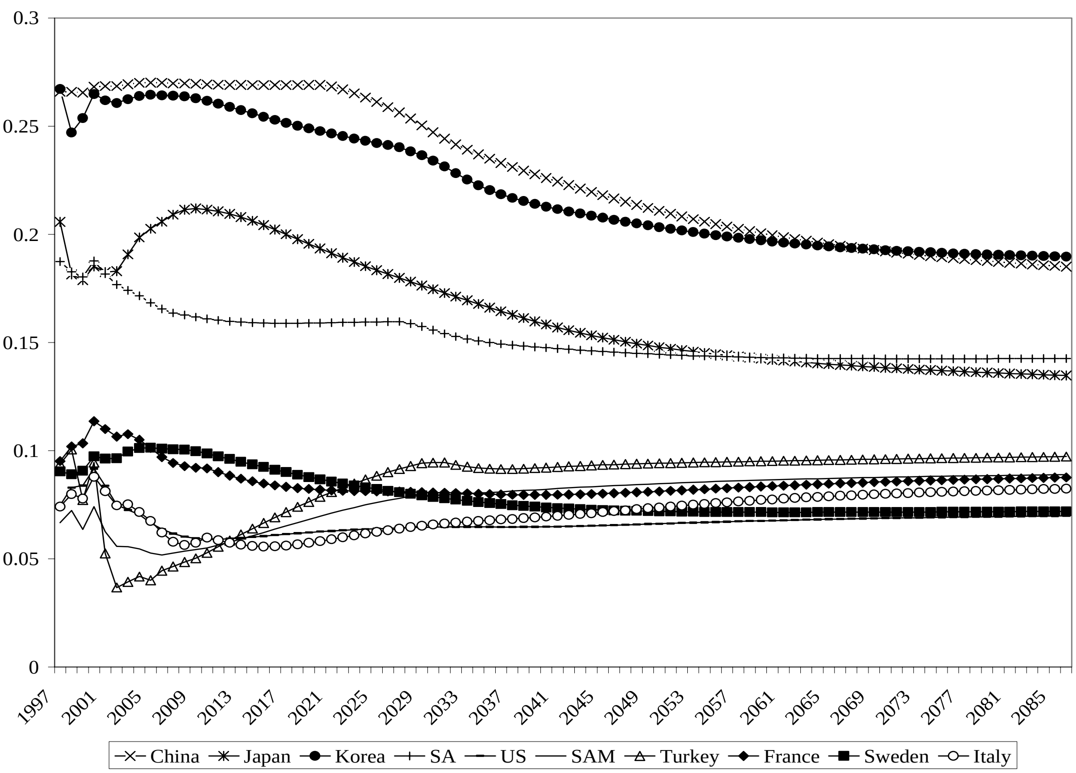


Figure 17. Net foreign assets to GDP ratio in the long run GTAP-Dyn simulations with new household saving behavior, long run growth rates as in table 5.

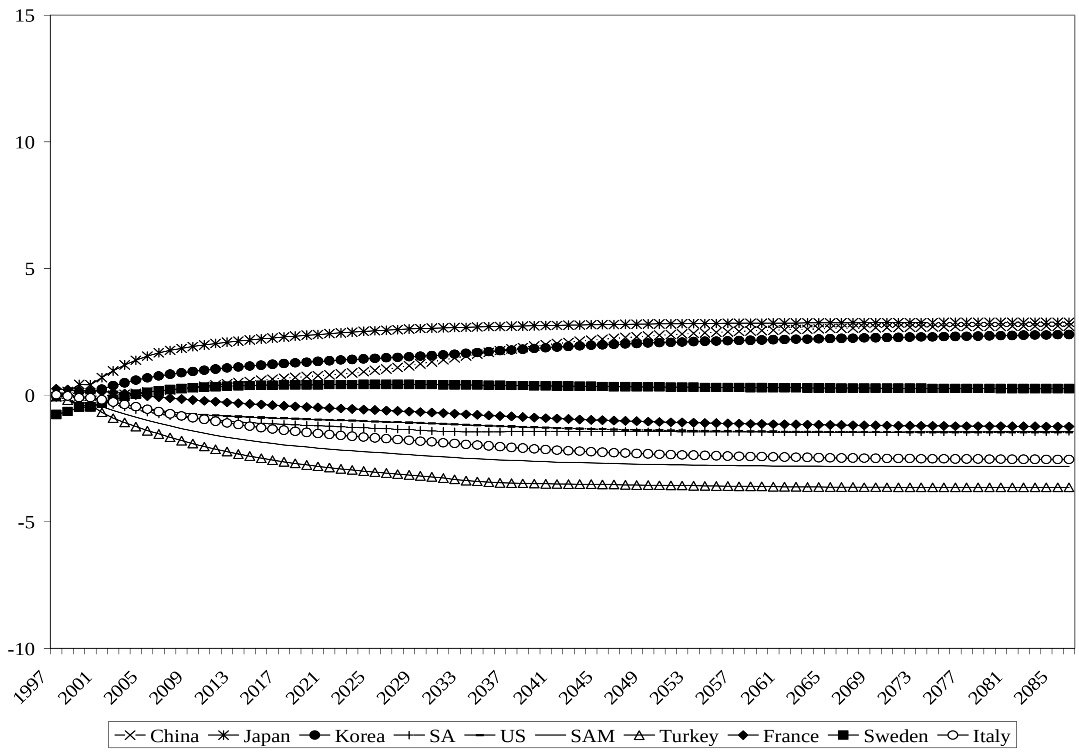


Figure 18. **Global net rate of return to capital at constant and endogenous saving rates in the long run GTAP-Dyn simulations.**