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ABSTRACT

We consider the causes of international capital flows. Since capital flows are extremely persistent, we argue that their drivers must be persistent, too. We think the most compelling candidates are demographic trends, tfp differences and financial frictions. In this paper we focus primarily on the role of demography in a multi-country overlapping generations model in which saving decisions are tied to agents' life expectancy. Capital flows reflect differences between saving and investment across countries. Demographic changes affect the aggregate accumulation of assets in two ways: by changing life expectancy which changes individual household saving behavior, and by changing the age distribution of the population by which individual household decisions are aggregated. The most important drivers turn out to be increases in life expectancy caused by decreases in adult mortality. We use a quantitative version of the model to illustrate the impact of demography on capital flows and net foreign assets in China, Germany, Japan, and the United States.

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1 Introduction

The movement of capital from less productive to more productive uses is a story repeated over and over again throughout history and around the world. Whether capital moves within a country — say from Massachusetts to North Carolina — or between countries — say from the US to Mexico — its flow addresses imbalances between local sources of funds (savings) and uses (investment). Certainly capital could flow for other reasons, but it's not hard to believe that market forces could account for substantial flows on their own. The period from 1880 to 1913 is often described as the golden era of capital mobility. Michael Bordo (2002) describes this earlier period: “The fifty years before World War I saw massive flows of capital from Western Europe to (mainly) the Americas and Australasia. At its peak, the outflow from Britain reached nine percent of GNP and was almost as high in France, Germany, and the Netherlands.” Over this period, Great Britain accumulated claims on the rest of the world equal to about one year's GDP. Among the recipients were Australia, Canada, Sweden, and the United States.

Through much of history, the major capital flows were from rich countries to poorer ones. A narrow view of these flows is that capital should flow from rich countries to poor countries because the returns to capital should be higher in the latter. But, this view is challenged by the evidence. Ohanian and Wright (2010) have shown that the direction of capital flows was not always consistent with the pursuit of higher returns as they measured them.

The recent history of capital flows also challenges the traditional view. The most notable importer of capital has been the richest country, the United States. Australia, and the UK have also been importers of capital. Germany, Japan, and China, have been significant exporters of capital. Moreover, these capital flows have been persistent - countries experiencing capital flows, in or out, are likely to be do so for long periods of time. These low frequency net capital flows are collectively referred to as “global imbalances.”

If capital flows are persistent, the question is why. One possibility is that market institutions, which evolve slowly, might be expected to lead to similarly slow-moving flows of capital. Another is tax rates, which change infrequently. In this paper we highlight the role of demography, and in particular increases in life expectancy and the associated aging of populations. Demographic trends are persistent are changes in demography are evident

worldwide. What is important, however, is that countries exhibit enough heterogeneity in these changes to make capital flows a plausible consequence. We will show that differences in the rate at which life expectancy is changing have a big impact on capital flows.

To study the connection between demography and capital flows we use a calibrated general equilibrium model with a rich set of demographics. We ask to what extent can net foreign asset positions be explained over time (and hence capital flows) by demography, and productivity differences. Differential demographic trends drive savings and investment differences as workers adapt to increased life expectancy and decreased fertility. In such a world capital flows to countries with more favorable demographics and these demographics explain well the differences in net foreign asset positions observed in the data. Differences in productivity explain some but not a lot of the movements in net foreign asset positions over time.

The idea of using an OG model to study the impact of demography on international capital flows isn't new. Attanasio, Kitao, and Violante (2007), Boersch-Supan, Ludwig, and Winter (2006), Brooks (2003), Domeij and Floden (2006), Feroli (2003), Ferrero (2010), Henriksen (2003), and Krueger and Ludwig (2007) all took this approach. Others before them expressed similar ideas without the formal structure of a model. A large literature also explores the impact of demography on aggregate saving rates.¹

We begin by relating some important facts about capital flows, demography, and capital output ratios for the subset of economies that we are focusing on. We then describe a one-good model and some equilibrium concepts that we use to explore the role of demography. In each country, households have power utility and firms have identical constant elasticity aggregate production functions. Countries differ only in their demography: the mortality rates and life expectancies faced by households and the age distribution of their populations. The question is how much variation in capital flows we can generate across countries and over time from these differences alone.² We show, using steady state calculations, that

¹The challenge with this kind of model are the dozens of decisions we must make about details, far more than we would have in a representative agent model. Did households foresee the large drop in mortality we've seen around the world? How do they deal with uncertain lifetimes? Bequests? Are pensions substitutes for private saving or something more?

²One thing we think is important is the time interval. Most of the data, and most of the work based on it, uses five-year intervals. We use an interval of one year to get more precise control over the effects of mortality on life expectancy. This also brings the model closer to other work in macroeconomics, where annual or even quarterly frequencies are typical.

changes in life expectancy can, in principle, have large effects on capital outflows or inflows and thus on net foreign asset positions. We go on to simulate paths for capital flows for China, Germany, Japan, and the United States, countries with large capital flows, both in or out.

2 Facts

We start with some facts about international capital flows and stocks, facts about demography, and facts about capital-output ratios. In describing these facts, we look at four countries: China (ISO country code CHN), Germany (DEU), Japan (JPN), and the United States (USA). These countries account for a substantial fraction of net capital flows in the world, and they have striking, and different, demographics. We show — for these countries anyway — that capital flows are persistent. If the ratio of the current account balance to GDP has a tendency to revert to zero, as it does in most multi-country business cycle models, it's well hidden in the data. The same holds for net foreign assets. Demography, of course, is inherently persistent. We describe changes in the age distribution of the population, in life expectancy, in old-age dependency, and in retirement ages. All but the retirement age have changed dramatically over the last few decades. Finally, we look at capital-output ratios, a central component of the modeling exercise that follows.

2.1 Capital flows and stocks

Global capital flows are most often depicted by plotting the current account — aggregate investment minus aggregate savings — as a fraction of GDP. Figure 1 is a plot of current account balances for a number of countries.³

What is striking about this picture is the persistence of current account flows. Countries like the US that tend to have current account deficits, have them for a long time as do countries that have current account surpluses - e.g. Germany, Japan and China. Although countries do reverse from surplus to deficit and vice versa they seem to do so infrequently.

³Current accounts are from the IMF's *World Economic Outlook* database for April 2013. Net foreign asset positions were computed by Lane and Milesi-Ferretti (2007).

The net foreign asset positions of these countries are shown in Figure 2 below. In principle these should represent the same phenomena and the Current Account should simply represent the change in Net Foreign Assets. In practice they don't line up and the difference is the subject of exploration. Ricardo Hausmann and Federico Sturzenegger (2006) have described this difference as "dark matter" that is explained by unmeasured flows of liquidity services, knowledge capital and insurance. They have argued that when this is taken into account the current account flows look very different. McGrattan and Prescott (2009) have argued that technology capital and plant specific intangible capital explain much of the difference between current account flows and net foreign asset positions and accounts for much of the measured differences in asset returns between countries. For our purposes the precise nature of "dark matter" is a secondary issue and we will focus primarily on Net Foreign Assets and will treat changes in Net Foreign Asset positions as the capital flows of interest.

Although much attention has been directed at the flows of capital as represented by the current account statistics, not enough has been directed at the question of why these data display the characteristics that they do. The features of the data belie the frequently voiced worry about sudden reversal of capital flows.

We see, for a start, that Japan has had persistent current account surpluses since the 1980s. These correspond to capital outflows and amounted to 50 percent of GDP in 2007, the last date in the available data. The US has had the opposite experience and now has a negative net foreign asset position. In both cases, the direction of net capital flows has been the same for almost three decades. Germany and China have had more variation, but there is a great deal of persistence in their capital flows as well. China, for example, has had capital inflows for almost twenty years. Germany has had the same for ten. Although there is a clear cyclical component in the current account, the bulk of current account fluctuations operate at a lower frequency. Henriksen and Lambert (2009) make the same argument more formally for a broader range of countries.

2.2 Demographics

Could demography play a role in these capital flows? The current account for a country is simply the difference between domestic savings and domestic investment. It is natural to

look at life-cycle considerations as primary drivers of domestic savings. For a given country the key drivers are fertility and mortality. The former determines how many workers there are over time while the latter determines how many years of post-employment consumption they have to save for. As fertility declines as it has in many of the most important economies, there are fewer workers saving over time. As mortality declines the number of years of retirement for each worker is likely to increase relative to the number of years of work. Certainly demography evolves slowly enough to produce persistent effects on the economy. It also differs across countries, a requirement for it to affect international capital flows.

Consider the evidence reported in the UN's *World Population Prospects*, the 2010 revision. We see in Figure 3 that UN data and projections for the future show significant aging of the populations of China, Germany, Japan, and the US. Japan's aging is the most pronounced in this group, with more than a third of the population expected to be over 70 by 2040. Germany is also aging quickly while the US, in this group, is aging the most slowly. This aging reflects, in part, a continuing increase in life expectancy; see Figure 4. The levels of life expectancy differ, but we see the same pattern of increase in all four countries. In each of them, life expectancy has increased almost a decade since 1970 and is projected to increase another decade by the end of the century.

The increase in life expectancy reflects a significant drop in mortality at all ages. We document this with data from the WHO's *Global Health Observatory*. Figure 5 shows how mortality has changed in the US: we plot the log of age-specific mortality rates for the years 1990, 2000, and 2011. We see a consistent drop at all ages. The drop at higher ages is larger in absolute terms, because the underlying rates are larger. In Figure 6 we see mortality rates for all four countries for the year 2011. The differences reflect those in life expectancy: Japan has the lowest mortality rates and China the highest.

The aging of the population and rise in life expectancy are projected to produce sharp increases in the old-age dependency ratio, measured here as the ratio of the population aged 65 and above to the population with ages between 20 and 64. See Figure 7. In Japan, the ratio was about 20% in 1990, is now about 40%, and is projected to be over 70% in 2050. Germany is only slightly less extreme. China exhibits a similar pattern somewhat latter, with a current dependency ratio of about 10% projected to increase to 60% by 2060. Aging in the US looks modest by comparison, with a projected dependency ratio of about 40% in 2050.

The other side of population dynamics is fertility, which we summarize in Figure 8. The numbers come from the UN's *World Population Prospects* and refer to the period 2005-2010. We see that fertility rates in Germany and Japan have been low, lower even than in China with its one-child policy. The lower input of young people into the population reinforces the impact of reduced mortality on the aging of their populations. The US has the highest fertility of the four countries, with 414 births per thousand women. The same number for China is 328, for Germany 271, and for Japan 264. [NB: Numbers are labeled as in the source, but the units seem to be off by ten.]

We see, in short, gradual but significant aging of the populations of all four countries, but also significant differences among them. We conclude with one last fact about demographic trends. We show in Figure 9 how the retirement age has changed with time. The retirement age comes from the OECD's *Statistics on average effective age of retirement* and is computed from labor market participation rates of older workers. We see in the figure that retirement ages differ across countries but show little variation over time over the period 1980-2011. Evidently, increases in life expectancy are leading to longer periods of retirement.

None of these facts are new. Bongaarts (2004) provides a more comprehensive analysis and a good summary of related work.

2.2.1 A Model of Demographic Flows

We capture these demographic facts in a model of overlapping generations of ex ante identical agents who are assumed to live up to I periods, with ages denoted by $i \in \mathcal{I} \equiv \{1, \dots, I\}$. At every point in time, there are I different cohorts alive. Individuals remain children for I_0 periods. As children they neither consume, accumulate capital nor supply labor. After I_0 periods the agents enter the economy as autonomous decision makers.

The survival probability between age i and $i + 1$ is denoted $s_{i,t}$ and varies with ages i and time. The unconditional probability of reaching age i is denoted s^i and is the product of conditional survival probability rates; $s^i = \prod_{j=1}^{i-1} s_j$.

Let $x_t \in \mathbb{R}^I$ be the vector of number of members in each cohort in period t . The demographic structure of the population changes through changes in fertility, mortality and immigration. According to time and age specific fertility rates $\varphi_{i,t}$, in each period these

individuals give birth to a certain number of new individuals, and the number of newborns in period $t + 1$, $x_{1,t+1}$, is the product of x_t and the vector of fertility rates φ_t . Then the law of motion of a population with survival rates as given above, but deterministic fertility, can be described by a simple $(I \times I)$ matrix⁴:

$$\hat{\Gamma} = \begin{bmatrix} \varphi_1 & \varphi_2 & \varphi_3 & \cdots & \varphi_I \\ s_1 & 0 & 0 & \cdots & 0 \\ 0 & s_2 & 0 & \cdots & 0 \\ \vdots & \vdots & \ddots & \ddots & \vdots \\ 0 & 0 & \cdots & s_{I-1} & 0 \end{bmatrix}$$

where the diagonal elements (s_1, \dots, s_{I-1}) are the conditional survival probabilities.

Let $m_t \in \mathbb{R}^I$ be a vector with each element representing the cohort specific number of net immigrants at time t . Denoting $\hat{\Gamma}_t$ the matrix of deterministic fertility and mortality rates at time t , the law of motion for the population may be written

$$x_{t+1} = \hat{\Gamma}_t x_t + m_t. \tag{1}$$

2.3 Capital stocks

We look at one last variable, the capital-output ratio, which plays a central role in our model. We compute capital stocks by standard methods from the Penn World Table, version 7.1. We take data on investment, estimate an initial capital stock value from a steady state approximation, and update by the perpetual inventory method using an annual depreciation rate of 6 percent. Caselli (2005) is one of many to describe the approach.

We show in Figure 10 how the ratio has evolved in our four countries. Over the period 1980 to 2010, the capital-output ratio has been between two and three in the US and China, about three in Germany, and has risen above four in Japan. China is the most surprising. Between 1990 and 2010, its real investment share of GDP averaged 37 percent, significantly higher than the 22 percent experienced by the US, yet its capital-output ratio is similar.

⁴The largest eigenvalue of the matrix Γ is the rate of growth of the population in steady state regardless of the initial condition. The eigenvector corresponding to this eigenvalue describes the share of each age group in the steady state population.

The reason it's not higher, of course, is that output has been growing so quickly. Could our calculation be grossly wrong for China? Our guess is no: Holz (2006) constructs similar estimates directly from company balance sheets.

3 An overlapping generations model

We study the impact of demographic changes in a model with overlapping generations of agents who spread their consumption over their lifetimes and supply labor inelastically. There is a common technology for producing goods from capital and labor. Countries differ primarily in their demographics, including their age distribution and mortality rates.

~~In this world supply of capital is determined by the collective decisions of households who make savings-consumption decisions that determine the path of their net worth given interest rates and prices. The production decisions of firms, given interest rates and prices determines the demand for capital and the capital output ratio. Net foreign assets is the difference between the aggregate net worth of agents and capital used by firms. Flows such as saving, investment, and the current account can be computed from the laws of motion of the stocks.~~

3.1 Organizing framework

We use the structure of competitive equilibrium as the organizing framework to analyze the effects of demographic change. In particular:

1. Capital supply:
 - (a) Individuals at every age solve their optimization problems given aggregate prices and conditional life expectancy.
 - (b) The decisions of individuals of different ages are aggregated by the relative cohort sizes
2. Capital demand: Firms employ all individuals of working age in each country and choose optimal quantities of capital demanded given prices.

3. Prices are determined internationally.

If the supply of capital is greater than demand for capital given prices the country is a capital exporter, and vice versa

In the following sections we will consider variations on this definition of equilibrium that illustrate the role of differences in mortality in the steady state and the nature of capital flows given a path for interest rates and prices. Finally, we will compute a general equilibrium.

3.2 Households

Individual households take prices of labor and capital as given. Demographic changes affect households individual decision problems by changing their life expectancy at every age. They affect aggregate decisions through the change in the age composition of cohorts.

3.2.1 Individual households' decisions

We refer to households as agents or cohorts. Households work, save, and consume.

Consumption starts at age I_w and continues until death. Utility has a time-additive power form, which we express recursively by

$$U_{it} = c_{it}^{1-\sigma}/(1-\sigma) + \beta s_{it} U_{i+1,t+1} \quad (2)$$

for $i = I_w, \dots, I$. Here U_{it} is utility from date t forward for an agent of age i , c_{it} is date- t consumption for the same agent, and β is the discount factor. The intertemporal elasticity of substitution is $1/\sigma$. The limiting case $\sigma = 1$ corresponds to log utility. The use of the survival probability s_{it} follows the now-familiar application of expected utility to uncertain lifetimes proposed by Yaari (1965).

Labor is supplied inelastically once agents reach working age. Formally, the agent begins to work at age I_w (w for work), supplying one unit of labor every year until retirement. At age I_r (r for retirement), the household stops working.

We build productivity into labor. Each individual of working age supplies one unit of labor. For an agent of age i at date t , that unit has efficiency e_{it} . Efficiency is zero for children and retirees: $e_{it} = 0$ for $i < I_w$ and $i > I_r$. If the wage per efficiency unit is w_t , the agent earns labor income $e_{it}w_t$.

Differences in e_{it} across time and countries will lead to level effects on the economies but will not matter much for the dynamics of capital flows. They can however be used to capture differences in productivity levels across countries.

Consumption and income are connected to changes in net worth through the budget constraint. Let a_{it} be financial assets or net worth owned by agents of age i at the start of the period t . The sequence budget constraint for an agent of age i is

$$a_{i+1,t+1} = (1 + r_t)a_{it} + e_{it}w_t - c_{it} + b_{i+1,t+1},$$

where r_t is the real return between t and $t + 1$. We have one of these constraints for each age $i = I_w, \dots, I$, plus boundary conditions

$$a_{I_w,t} = a_{I+1,t} = 0. \tag{3}$$

Bequests b_{it} are a necessary ingredient here, because we need to distribute the accidental bequests of agents who die before age I . The simplest method is to spread the assets of those who die among the living of the same generation: $b_{i+1,t+1} = (1 - s_{it})a_{i+1,t+1}$.

$$s_{it}a_{i+1,t+1} = (1 + r_t)a_{it} + e_{it}w_t - c_{it}. \tag{4}$$

Other alternatives are to assume an annuity system, to distribute accidental bequests equally to all individuals, to distribute accidental bequests to individuals of the assumed offspring, or to let them be lost. ⁵ See, among many others, Hansen and Imrohorglu (2008), Rios-Rull (2001), and Yaari (1965).

$$c_{i,t}^{-\sigma} = \beta c_{i+1,t+1}^{-\sigma} (1 + r_t).$$

This tells us that the slope of the lifetime consumption profile is governed by the discount factor β , the interest rate r_t , and the preference parameter σ . The absence of s_{it} stems from the annuity. The asset profile depends on consumption and the profile for labor income.

⁵Since we are calibrating preference and technology parameters to match certain moments conditional on the system, how we treat accidental bequests is not that critical.

3.2.2 Aggregation of individual decisions

Each of these individual or cohort variables has an aggregate analog. Aggregate consumption is the sum across generations: $C_t = \sum_i c_{it}x_{it}$. Aggregate net worth is the same: $A_t = \sum_i a_{it}x_{it}$. The total supply of labor at date t is the sum over all agents of working age: $N_t = \sum_i e_{it}x_{it}$.

3.3 Firms

Firms in aggregate combine capital K_t and efficiency units of labor N_t to produce output Y_t . Demographic change affects firms' demand for capital through changes in changes in the number of efficiency units of labor supplied by the households.

We give their technology a constant elasticity form:

$$Y_t = F(K_t, N_t) = [\omega K_t^{1-\nu} + (1-\omega)N_t^{1-\nu}]^{1/(1-\nu)}. \quad (5)$$

The elasticity of substitution between capital and labor is $1/\nu$. The limiting case $\nu = 1$ corresponds to Cobb-Douglas. The law of motion for capital is the usual

$$K_{t+1} = (1-\delta)K_t + I_t, \quad (6)$$

where I_t is gross investment in new capital and δ is the rate of depreciation.

A representative firm with this technology facing prices (r_t, w_t) chooses capital and labor equate marginal products to prices:

$$\partial F(K_t, N_t)/\partial K_t = r_t + \delta \quad (7)$$

$$\partial F(K_t, N_t)/\partial N_t = w_t. \quad (8)$$

With the constant elasticity function (5), the marginal product of capital takes the form

$$\partial F(K_t, N_t)/\partial K_t = \omega(K_t/Y_t)^{-\nu},$$

a decreasing function of the capital-output ratio.

3.4 Equilibrium and capital flows

At any time t , each country takes the international rate of return on capital as given. For given prices of capital and labor, households make their capital-supply decisions and firms make their capital-demand decisions. If the supply of capital is larger than the demand for capital for given prices, a country is a capital exporter – and vice versa if demand is larger than supply.

International capital markets must clear and the rate of return be such that the sum of capital demanded across all countries equals the sum of capital supplied.

$$R_t : \sum_j K_{j,t}^d = \sum_j K_{j,t}^s$$

4 Demography and steady states

First we consider the impact of increased life expectancy in the steady state. The demographic inputs give us a stationary age distribution for each country. When we decrease mortality rates, this increases life expectancy at every age and changes the age distribution, making it older. Second, this change in the age distribution has consequences for all of the variables in the model: consumption, labor supply, aggregate net worth, the capital stock, the wage, and the interest rate. In our closed economy, an increase in life expectancy raises aggregate net worth and the stock of capital. This reduces the marginal product of capital and hence the interest rate. This is an important consequence of demographic change that has been discussed by others.⁶

In an open economy, with a fixed interest rate, the increase in aggregate net worth shows up as an increase in net foreign assets. We describe these effects in a supply and demand diagram, where the demand for capital comes from firms' first-order condition and the supply comes from households accumulation of assets.

4.1 Parameter values

We review the inputs to the model, starting with demography. We use stylized demographics to illustrate the impact of increases in life expectancy. We start with benchmark mortality

⁶See Henriksen(2002) and Geanakoplos, Magill and Quinzil

rates, adapted from WHO data, associated with a life expectancy at birth of 60 years:

$$\log(1 - s_i) = \mu_i.$$

The shape is evident from Figure 6, with mortality high for the young and old and low in between. Only the latter matters here, because agents do nothing until they reach working age. We then scale them up and down by some constant z ,

$$\log(1 - s_{it}) = \mu_i - z_t \tag{9}$$

to reproduce other life expectancies. Demographers will recognize this as a simplified version of Lee and Carter (1992). The larger is z_t , the lower are mortality rates and the longer is life expectancy. We see the results in Figure 11, where we plot the resulting survival probabilities. The logarithmic form of (9) means that the greatest impact is on the largest mortality rates: those of the young and old.

With these mortality rates, and one birth each period, we can compute the stationary age distribution. The result is pictured in Figure 12. We see that this mechanism gives us an older population, on average, when we reduce mortality rates to reproduce longer life expectancies.

The next input is the technology. We set $\delta = 0.06$, which we used to generate the data. We also set $\nu = 1$, which corresponds to an elasticity of substitution of one, and choose ω to set capital's share equal to one-third at a capital-output ratio of three. The capital share in general is

$$\partial F(K, N) / \partial K \cdot (K/Y) = \omega(K/Y)^{1-\nu}.$$

With $\nu = 1$, the capital share is one-third when $\omega = 1/3$. With other values of ν , we adjust ω appropriately. The interest rate is the marginal product of capital minus depreciation:

$$r_t = \omega(K_t/Y_t)^{-\nu} - \delta. \tag{10}$$

Evaluated at a steady state with $K_t/Y_t = 3$ and $\nu = 1$, we have $r = 0.0511$.

A typical household's problem includes the interest rate and labor income as inputs and generates paths for consumption and net worth. We choose labor efficiencies $e_{it} = 1$ for agents of working age and zero otherwise. Working age starts at age $I_w = 21$ and ends at retirement age $I_r = 65$. Finally, we set $\sigma = 1$ (log utility) and choose β to match the steady state ratio of aggregate net worth to output of three. Since net worth and the capital stock are the same, net foreign assets is zero in the benchmark case.

4.2 Steady states

The interaction between the supply of capital by households and the demand for it by firms takes its cleanest form in a steady state, where we can capture its properties in a supply-and-demand diagram.

Demand is relatively simple. The demand for capital comes from the first-order condition (7). If we express capital as a ratio to output, the inverse demand function is equation (10). This equation holds at every date, as well as in a steady state.

Supply requires calculations that go beyond what we can show in an equation or two. But suppose we have a steady state age distribution for the population. Then we can compute the ratio of aggregate net worth to output for any constant interest rate. The overlapping generations structure is essential here. In a representative agent model, supply in a steady state is horizontal at the discount rate $(1 - \beta)/\beta$. Here there is some slope, which depends on intertemporal elasticity.

The results of these two sets of calculations are pictured in Figure 13. The downward-sloping line is demand, the upward-sloping one is supply. They cross by design at our steady state point: $K/Y = A/Y = 3$ and $r = 0.0511$. We show two examples of each. The solid downward-sloping line is the demand curve for $\nu = 2/3$ and the dashed line the demand curve for $\nu = 3/2$. As we might guess from (10), the line is flatter when ν is smaller. The supply curves depend in a less obvious way on household decisions, but they have a similar form. The solid line corresponds to $\sigma = 1/2$ and the dashed line to $\sigma = 2$. Evidently the line gets flatter as we increase σ . In what follows, we compute steady states for the intermediate values $\nu = \sigma = 1$ (log utility and Cobb-Douglas production).

Now consider the impact of an increase in life expectancy on the steady state from 65 to 80. That doesn't change the demand for capital, because life expectancy has no impact on the marginal product of capital. It does change the supply of capital. As we see in Figure 14, an increase in life expectancy increases the supply of capital. In a closed economy, we get an increase in the capital-output ratio and a decline in the interest rate. These effects of aging are well-known features of OG models. Here the impact combines two effects. One is a composition effect - we have more households at ages associated with high net worth. The other is that households have more wealth at all ages. The mechanism is one noted by

Bloom, Canning, and Graham (2003): with longer life expectancy, households save more. We see this in Figure 15, where net worth rises at most ages. The dashed line in the figure shows the effect of the composition effect alone: we fix net worth at all ages but change the age distribution. We see that this is a small part — less than ten percent — of the shift in supply.

In an open economy facing a fixed interest rate, the impact of increased life expectancy falls entirely on aggregate net worth. The demand for capital, and therefore the capital-output ratio, doesn't change, but with aggregate net worth rising, the result is a positive steady state net foreign asset position. If we take a general equilibrium perspective, we might imagine a world with two countries, one with longer life expectancy than the other. The equilibrium interest rate will split the difference, leading the country with longer life expectancy to lend to the other — forever, if this situation continues.

There are two important insights to be derived from this way of modelling capital flows with demographic changes: First, the most important effect of demographic changes come from increases in life expectancy and not from changes in the composition of cohort. Second, it is differences in the change in life expectancy that drives persistent capital flows

5 Country dynamics

We now compute time paths for net foreign assets and other variables for our four countries. In each case, all firms and all households in each country take interest rates and wage rates as given at any time. The interest rate is computed endogenously as the rate that clears the capital market between the United States, Japan and Germany. We emphasize that this is not an implicit assumption that these three countries constitute the global capital market. There are other big players - China, the oil exporting countries - that are big contributors to capital flows. Here we study the evolution of capital flows for one reasonable endogenous interest rate path as an example to see how effective demographic differences might be in explaining observed capital flows.

The computed interest path is in line with the findings of other work: the interest rate declines steadily from about 2000 to 2020. That is, as we've seen, the likely impact of increases in life expectancy worldwide as households save more to compensate for increased life expectancy.

The other parameters are similar to those in our steady state calculations. We use log utility ($\sigma = 1$) and a Cobb-Douglas production function ($\nu = 1$). The discount factor is chosen to match steady state net worth for a benchmark economy and is the same in all countries.

The differences are in the demographics. We take mortality rates from the WHO's *Global Health Observatory* and update them using equation (9), with the shift z_t chosen to match reported life expectancy. This gives us the survival probabilities that enter household consumption and saving decisions. Since mortality rates change with time, every generation has different ones. The age distributions are adapted from the UN's *World Population Prospects*. They report distributions every five years from 1950 to 2100 for five-year cohorts. We interpolate them to get annual numbers.

The last input is the initial values of household asset positions. We compute initial asset positions from their steady state values. From that point on, asset positions are computed recursively, starting in 1950. We report capital stocks and flows starting in 1980, with the hope that the effect of the initial conditions has worn off.

5.1 Capital Flows

Figure 17, shows the change in net foreign assets as a percentage of GDP implied by the model with the endogenous interest rate path. This picture can be usefully compared to Figure 1 which plots the Current Account in the data for these four countries. The ratio of Net Foreign Assets to GDP implied by these flows is shown in Figure 18.

5.1.1 U.S. and Japan

It is useful to begin by looking at the flows between the U.S. and Japan, an exercise that mimics the work in Henricksen (2002). The paths are broadly similar to what we saw in Figure 1 for the last three decades, with the US experiencing capital inflows and Japan capital outflows. The difference between the two, in the model, is due entirely to demography largely the difference in the rate at which life expectancy is changing. Obviously other factors have an influence, too, but this suggests that demography is an important starting point.

We also see that Japan's three decades of capital outflows is projected to reverse course a bit over the next several years and then increase again.

One issue for Japan is that its capital-output ratio has risen significantly over the last twenty years; see Figure 10. That's inconsistent with our model unless either Japan has a different technology or faces, for some reason, a different interest rate than the other countries. This increase in capital tends to offset what would otherwise be an even larger increase in net foreign assets.

5.1.2 Germany and China

Figure 17 also shows the pattern of flows implied by the model for German and China. The pattern for Germany roughly fits German experience, with the exception of the 1990s, when the country was focused on unification of what was formerly East and West Germany.

Chinese demographics of course are striking and the changes in life expectancy are dramatic. These factors alone account for significant capital flows given world interest rates, but it is still a huge challenge to account for China's sky-high saving rate. Clearly, the simple overlapping generations structure cannot account for a lot of the Chinese experience and the role of state directed savings. We've seen that the capital-output ratio isn't out of line, but it strikes us as unlikely that a model of this sort will explain what others have failed to explain. But see, among others, Chamon and Prasad (2010), Coeurdacier, Guibaud, and Jin (2013), Wei and Zhang (2011), and Yang, Zhang, and Zhou (2010).

6 Concluding Comments

In recent years there has been significant angst expressed in the economics literature over the persistence in international capital flows. Many view these so called "global imbalances" as a threat to the stability of the international financial system. We argue that persistent phenomena have persistent causes and the one of the most important and neglected drivers is demographic change.

We have shown that the most important element of demographic change is the change in life expectancy or more precisely the difference in the change in life expectancy across

countries. These changes in life expectancy can explain much of the pattern of capital flows across countries. Moreover, these changes in life expectancy and the concomitant incentive to save more are quite consistent with the pattern of declining interest rates over the past two decades.

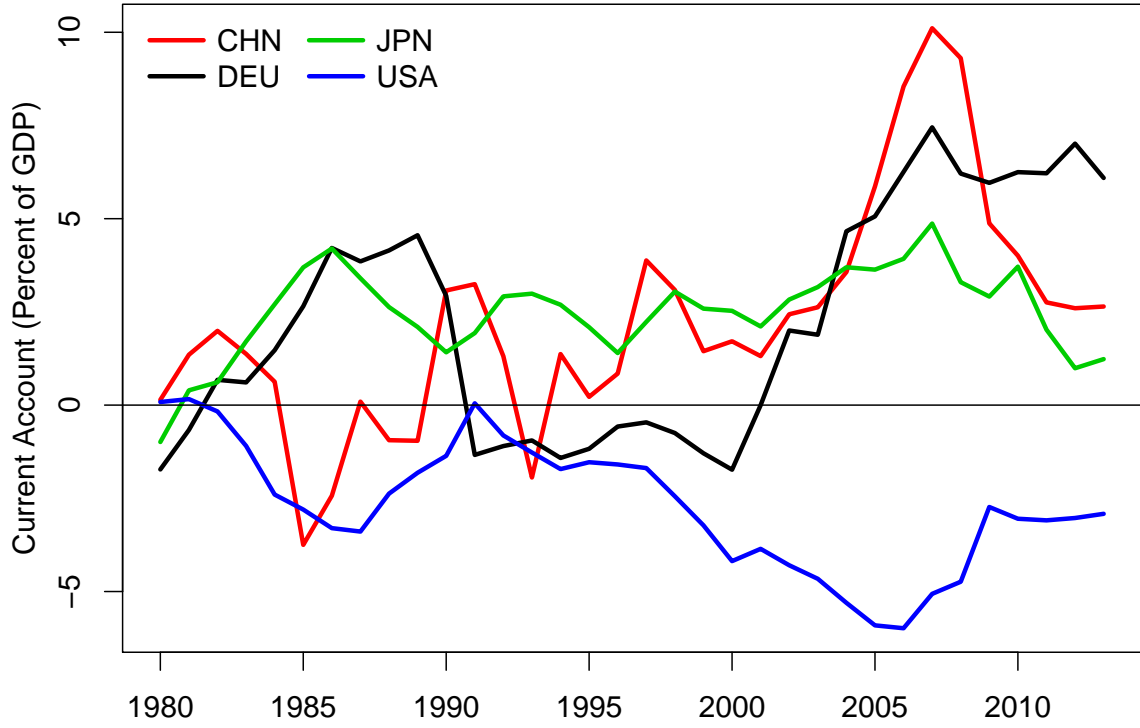
We have deliberately kept this model simple to highlight the important role of demographics for capital flows. Clearly there are other important differences across countries that drive capital flows - productivity differences, tax rates on capital and retirement policies that affect savings and investment. These are all candidates for inclusion in a richer model.

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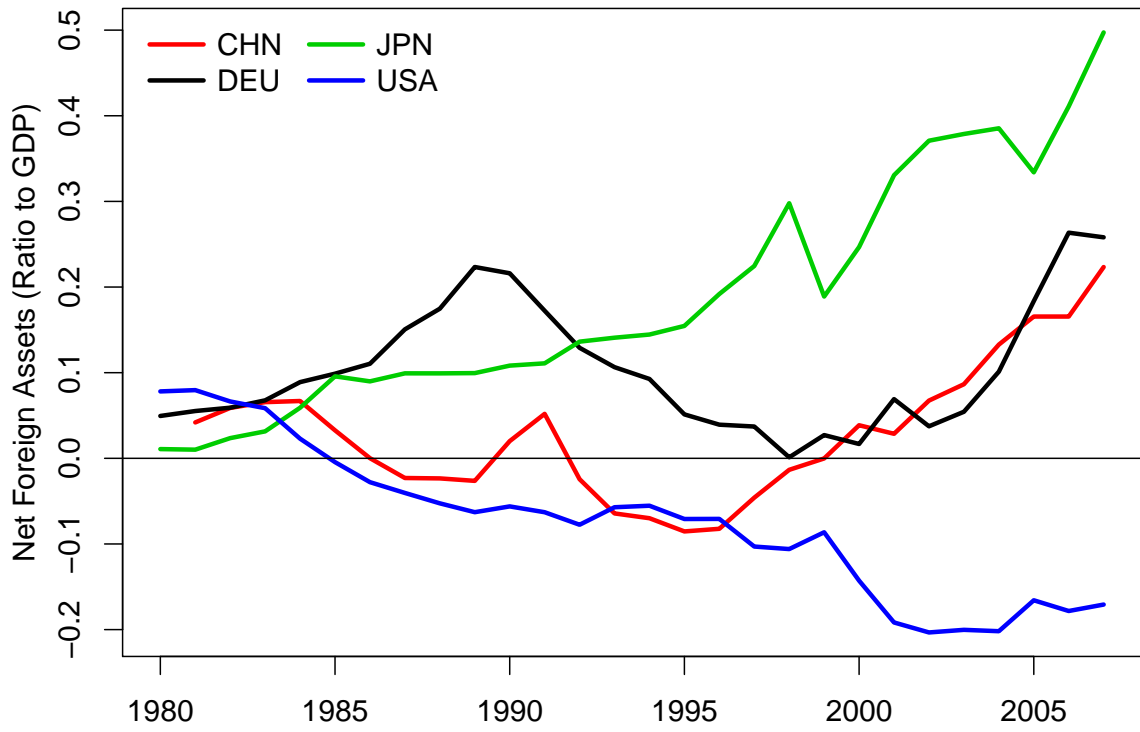
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Figure 1
Current account balances



Source: IMF, World Economic Outlook, April 2013

Figure 2
Net foreign asset positions



Source: Lane and Milesi-Ferretti

Figure 3
Age distributions of populations

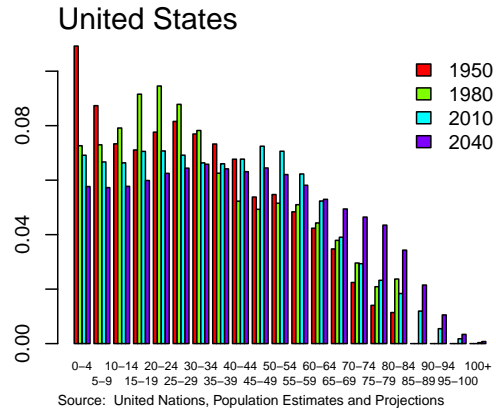
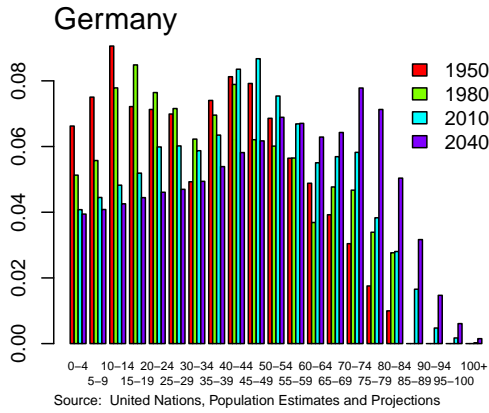
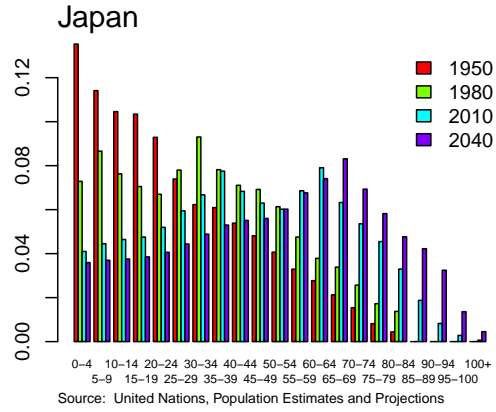
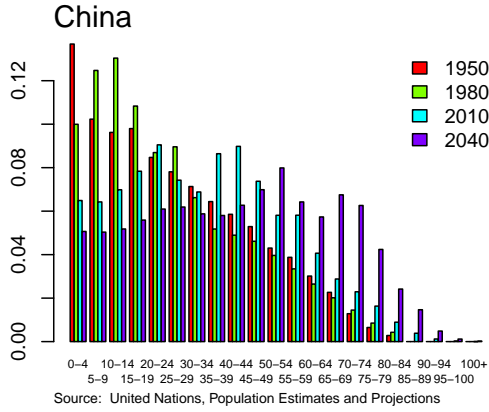
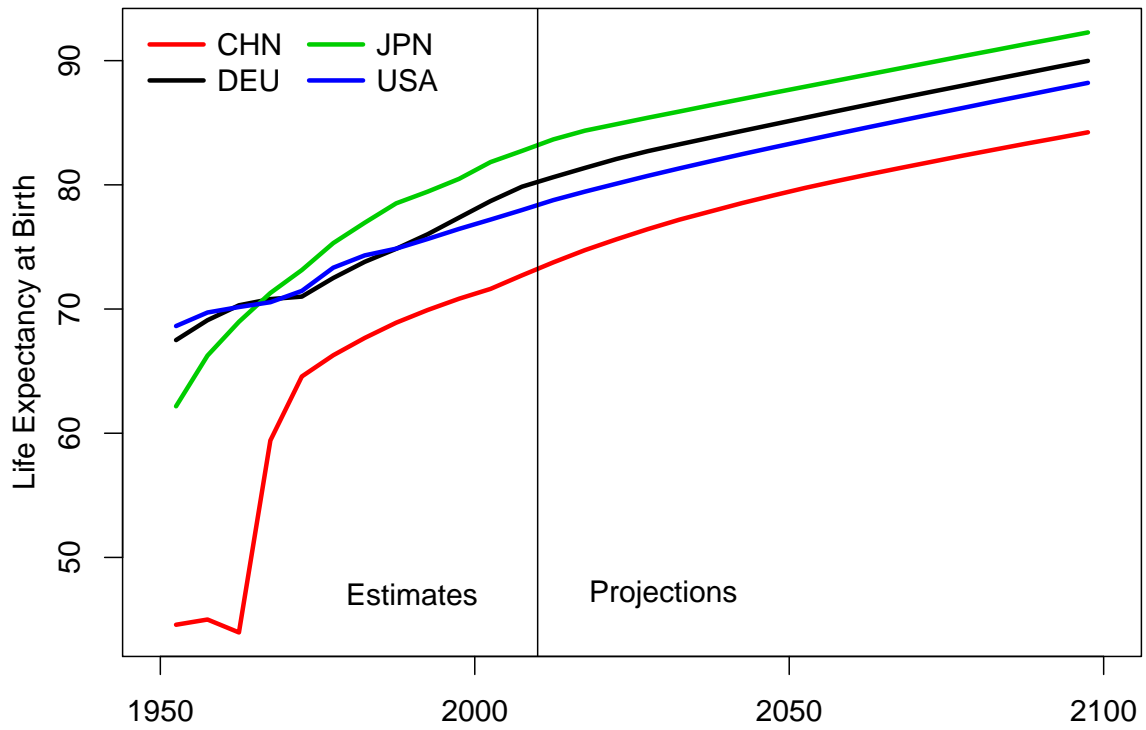
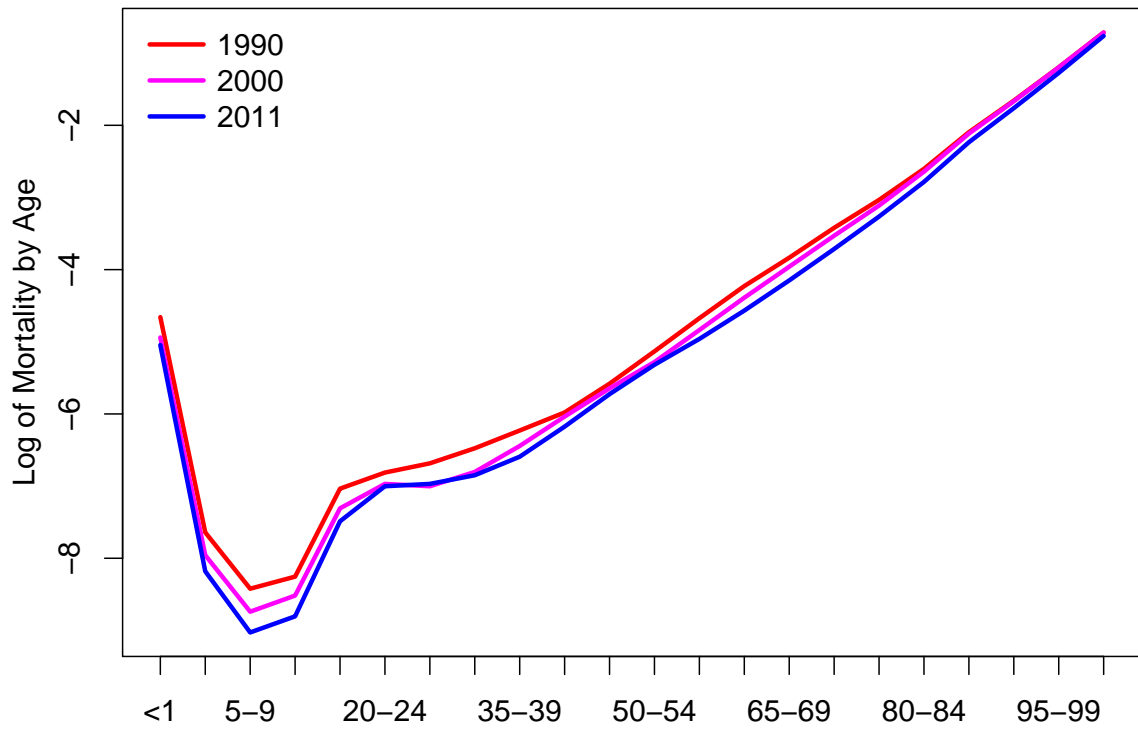


Figure 4
Life expectancy at birth



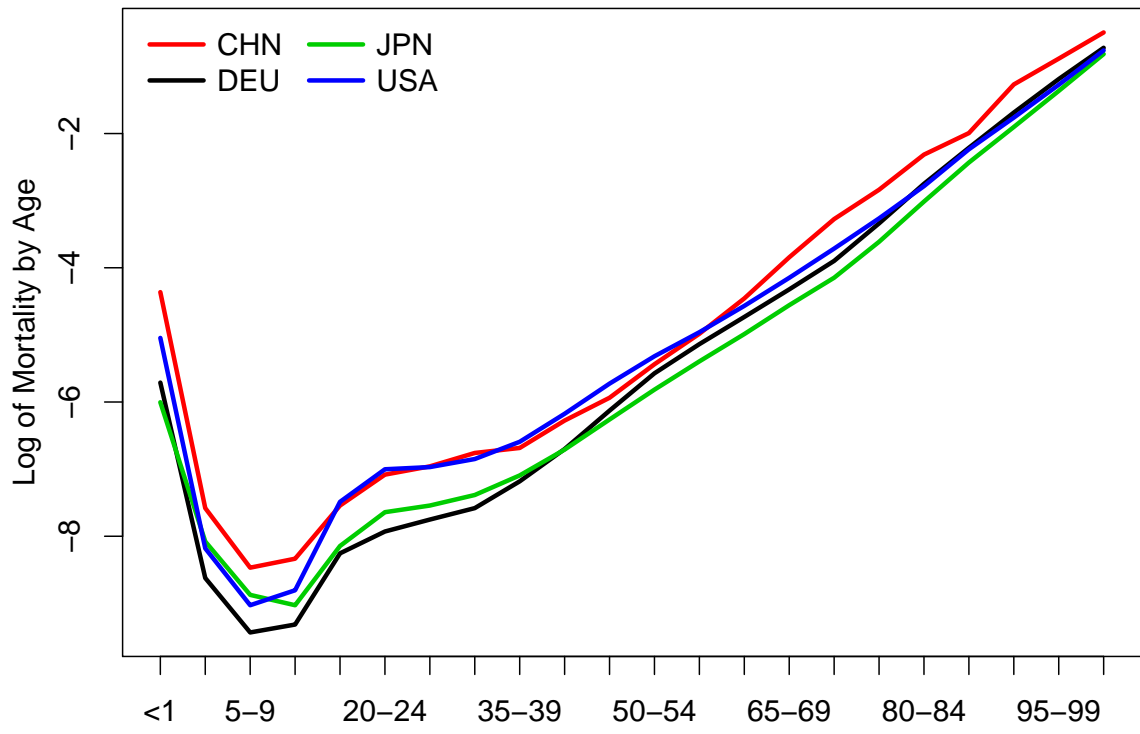
Source: UN, World Population Prospects, 2010 revision

Figure 5
Changes in mortality rates



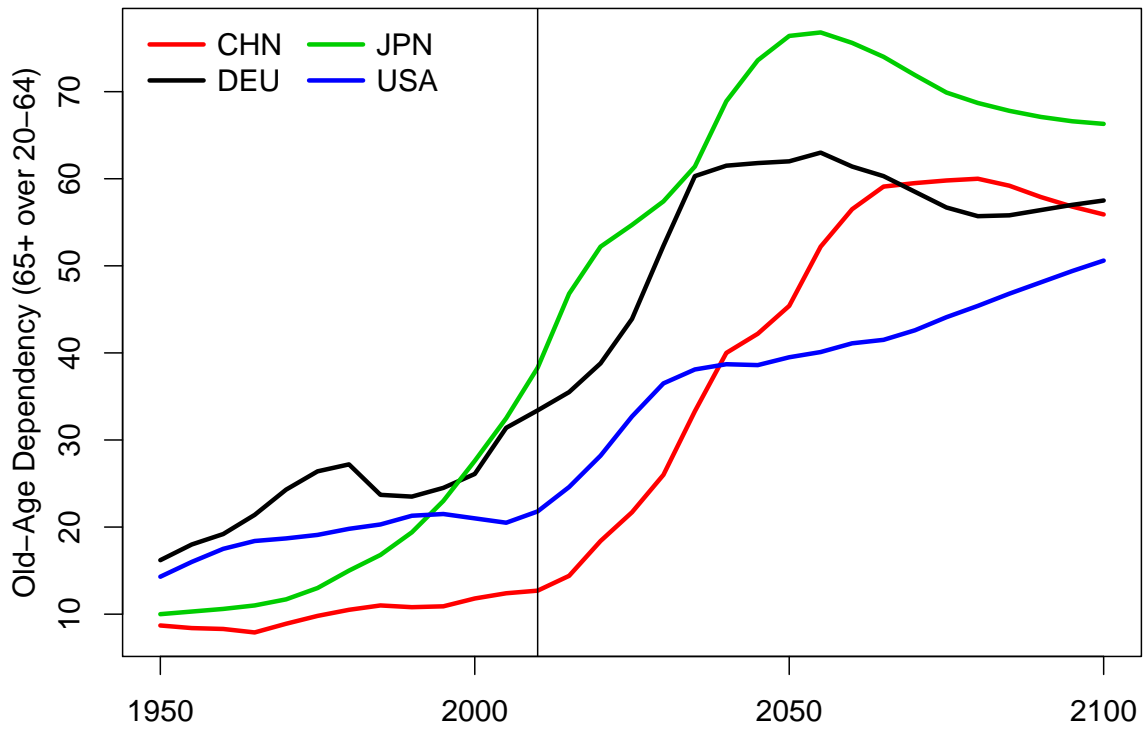
Source: WHO, Global Health Observatory

Figure 6
Mortality by age: estimates for 2011



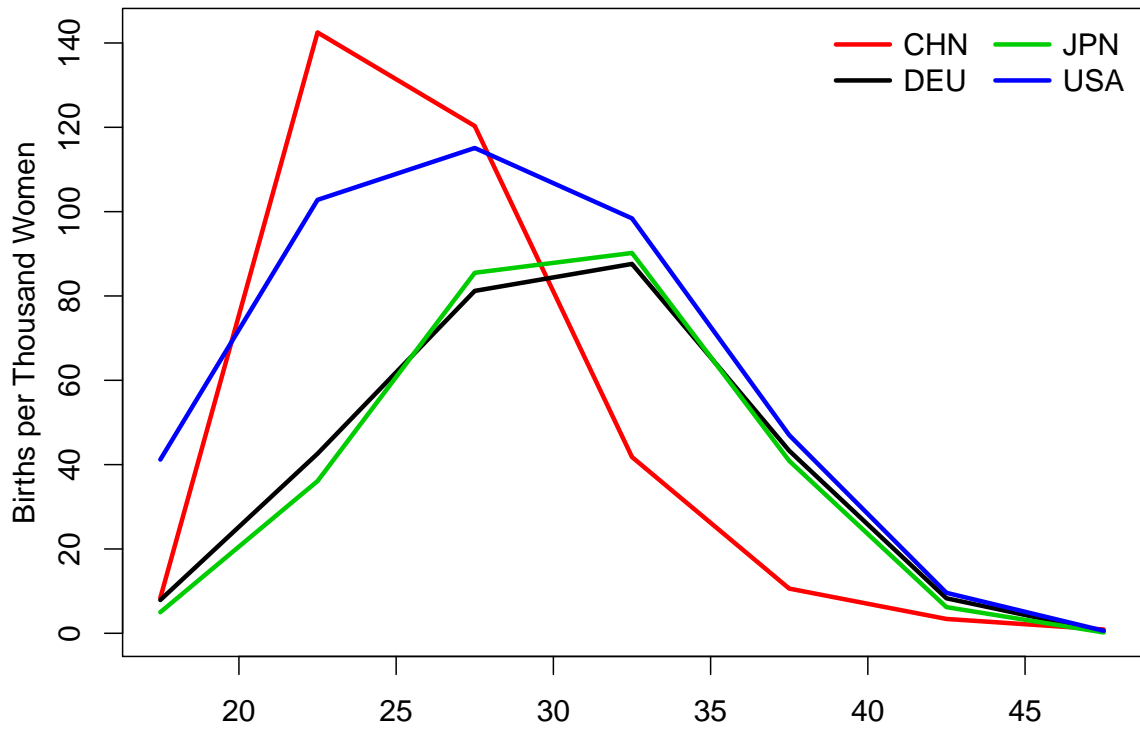
Source: WHO, Global Health Observatory

Figure 7
Old-age dependency: population 65 and over to 20-64



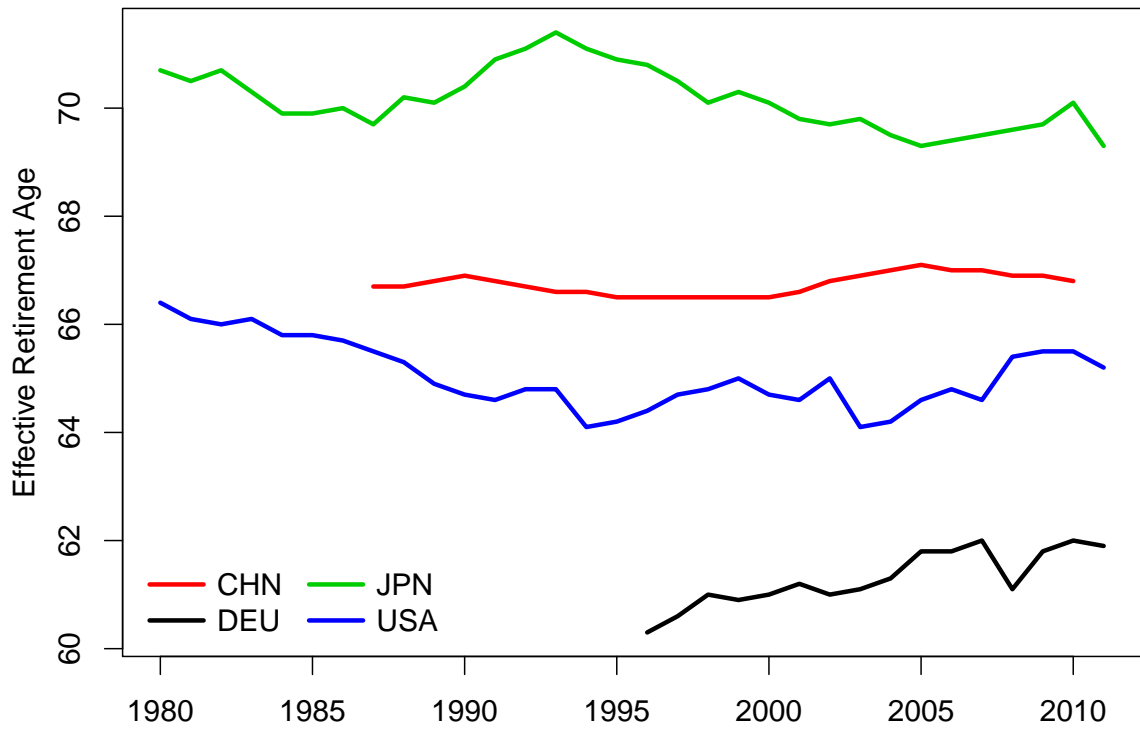
Source: UN, World Population Prospects, 2010 revision

Figure 8
Fertility by age: estimates for 2005-2010



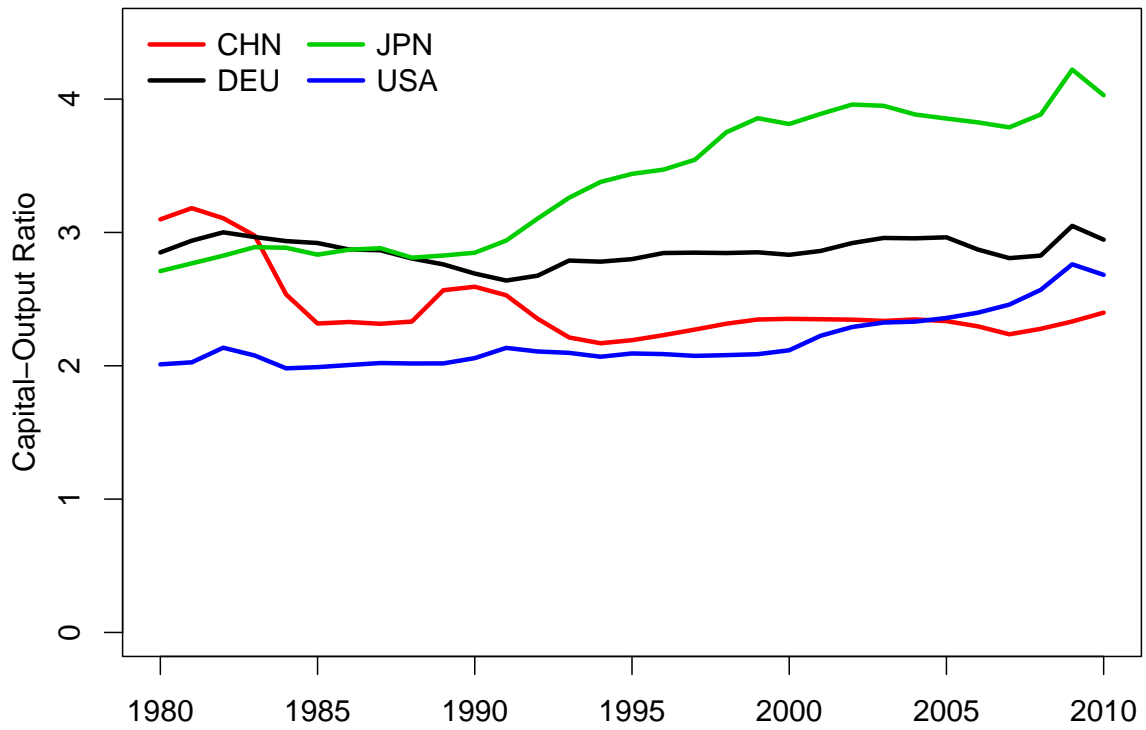
Source: UN, World Population Prospects, 2010 revision

Figure 9
Effective retirement ages



Source: OECD, Average Effective Age of Retirement

Figure 10
Capital-output ratios



Source: Penn World Table and authors calculations

Figure 11

Representative survival probabilities

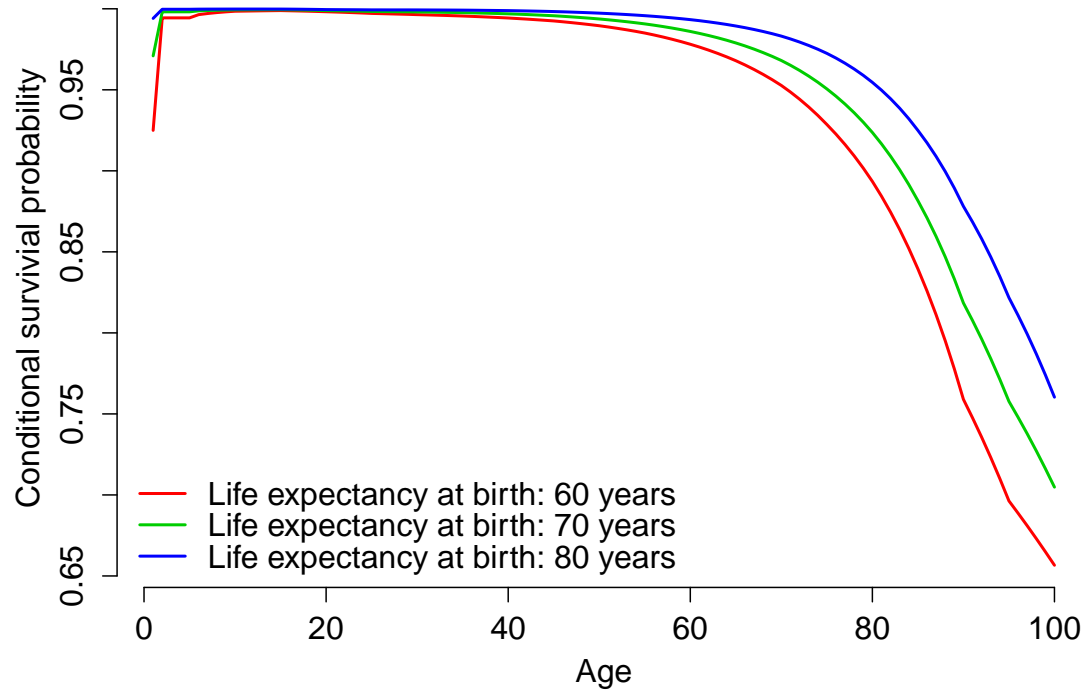


Figure 12
Representative stationary age distributions

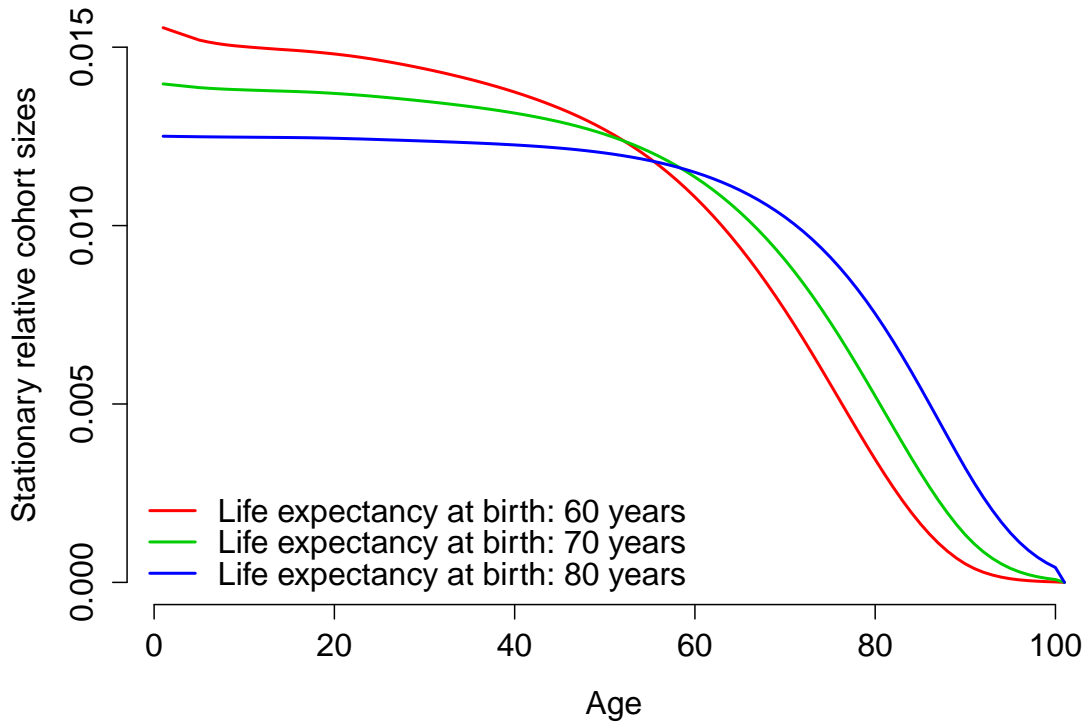


Figure 13
Steady state supply and demand for capital

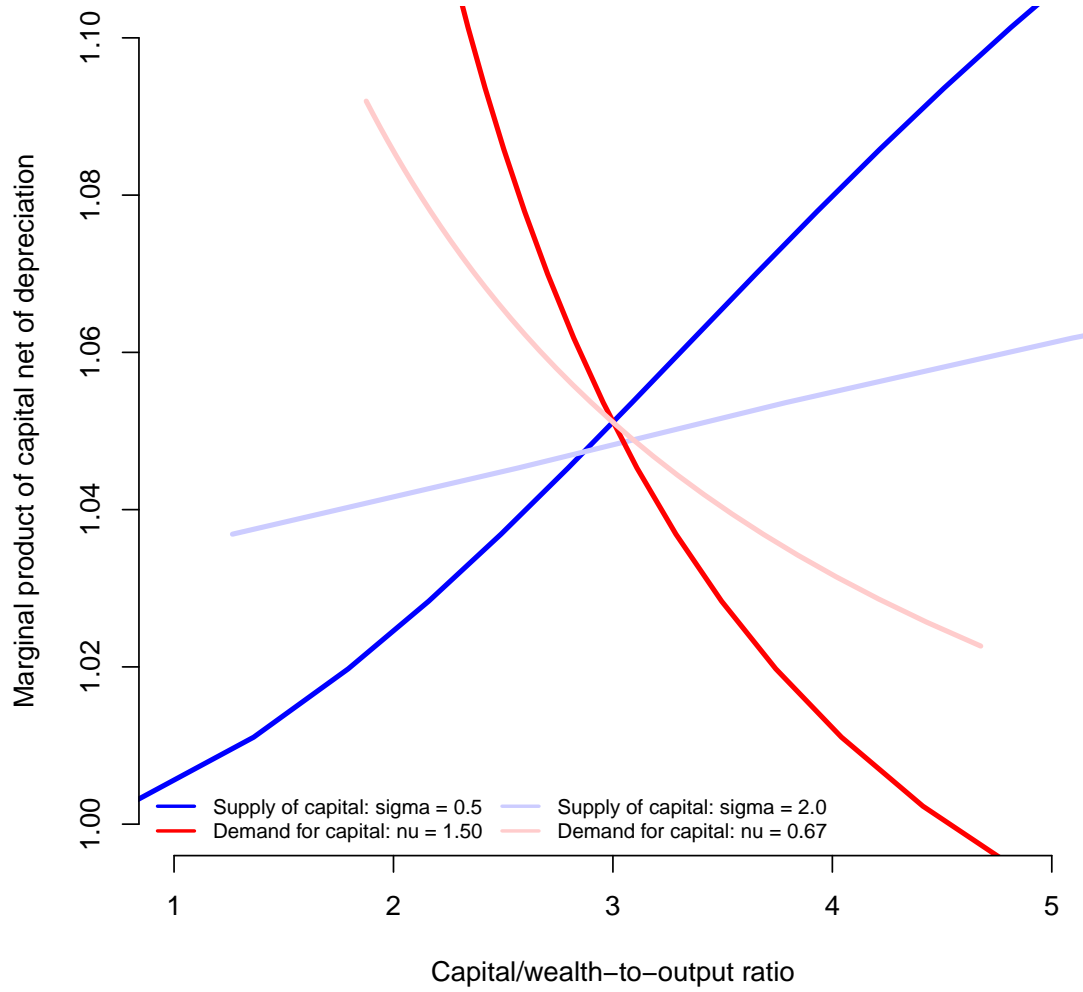


Figure 14
Life expectancy and the steady state supply and demand for capital

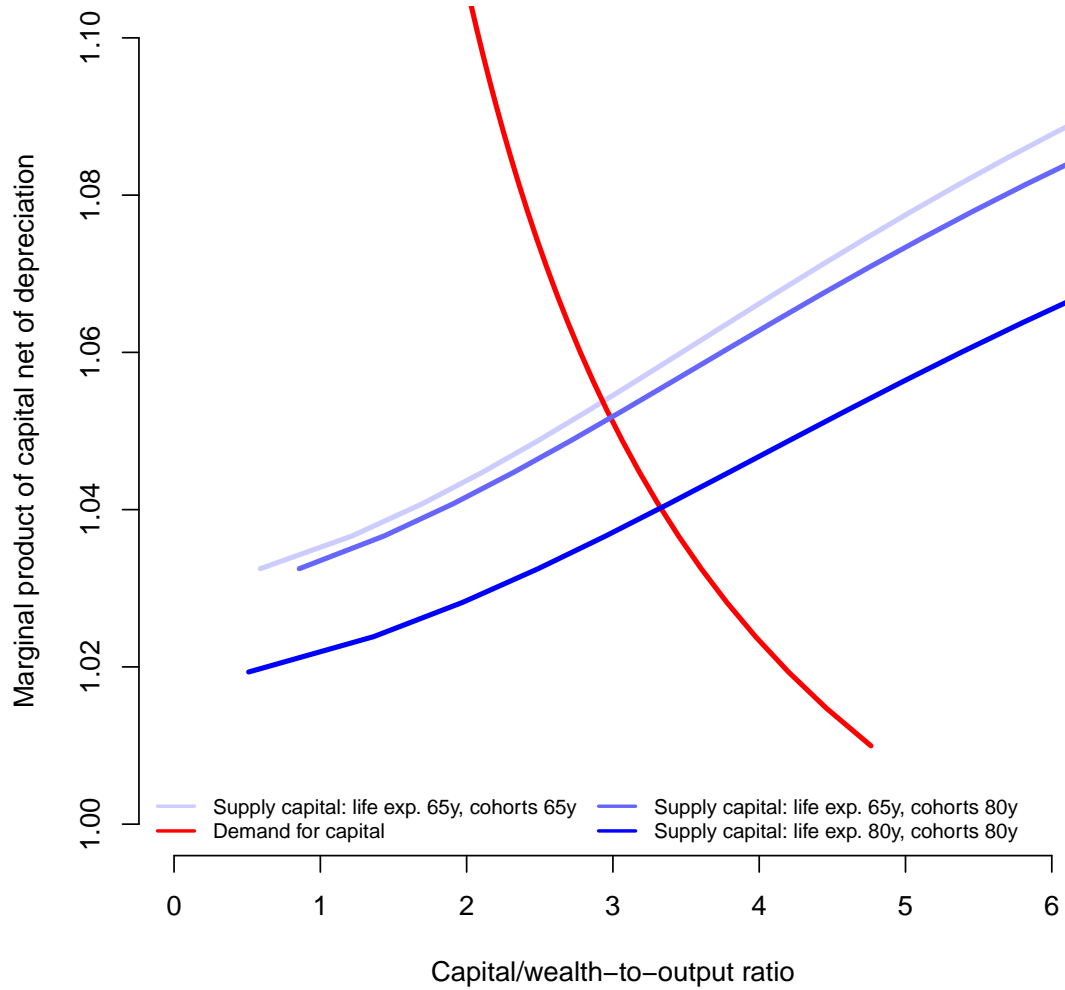


Figure 15
Steady state net worth by age



Figure 16
Dynamics of capital flows in the model with constant interest rates

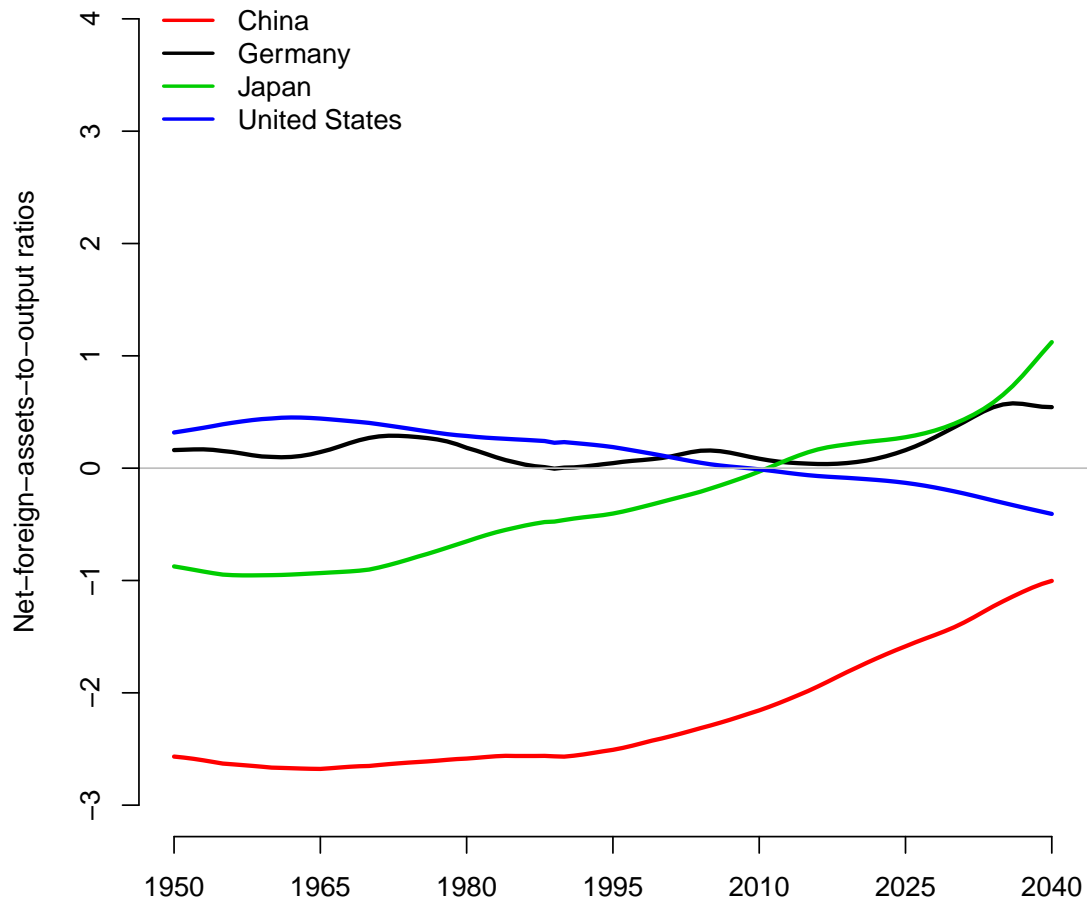


Figure 17
Dynamics of capital flows in the model

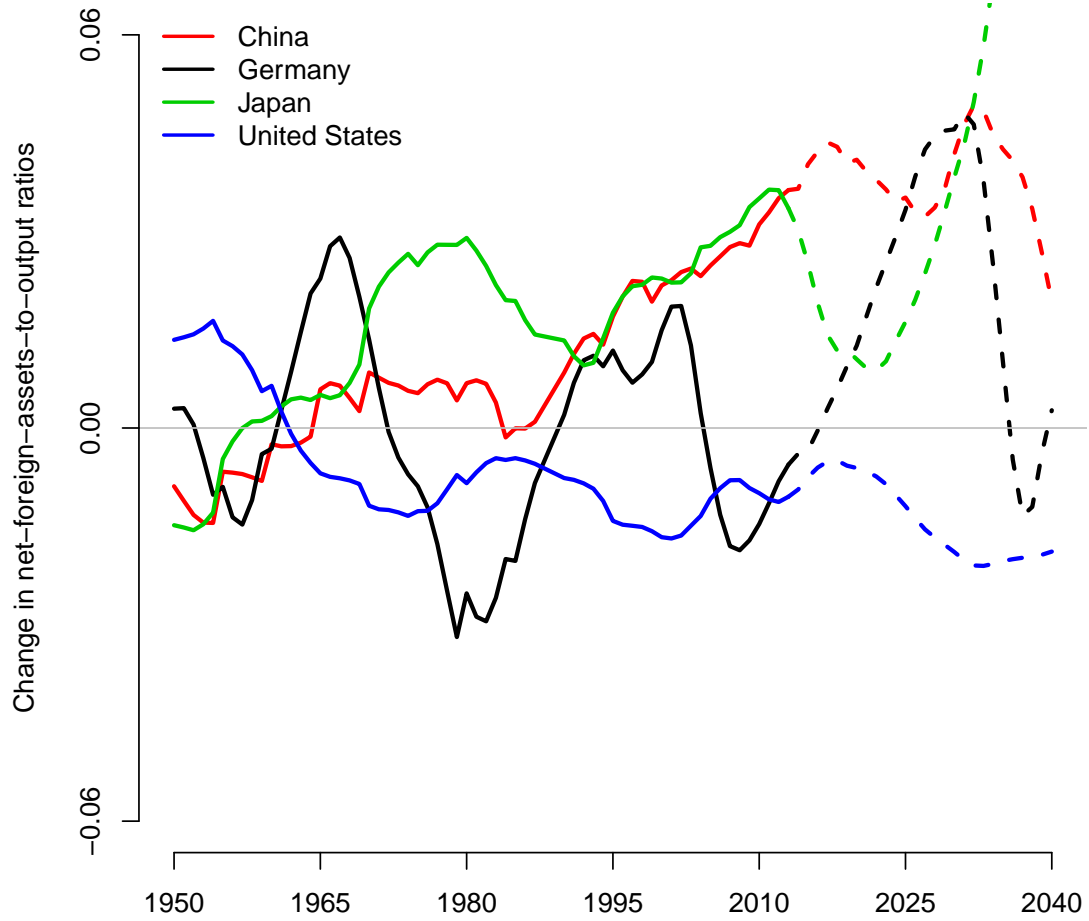


Figure 18
Implied Net Foreign Assets from the model

