Population Aging and International Capital Flows*

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Abstract

We use the neoclassical growth framework to model international capital flows in a world with exogenous demographic change. We compare model implications and actual current account data and find that the model explains a small but significant fraction of capital flows between OECD countries, in particular after 1985.

JEL classification: E22; F21; F41; F47

Keywords: current account; international capital mobility; demographics; Feldstein-Horioka puzzle

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1 Introduction

According to the life-cycle theory, consumption as a fraction of income varies with age. Taking this argument one step further, a country's saving rate depends on the age-structure of its population. This direct link between demographics and savings, investments, and capital flows has been addressed in a number of papers. Fair and Dominguez (1991) find mixed evidence for this story using quarterly U.S. data, while Higgins and Williamson (1997), Higgins (1998), and Lane and Milesi-Ferretti (2001) find strong support for the story using lower-frequency data for a large number of countries.

In this paper, we use another approach to examine the same link from demographics to savings, investment, and international capital flows. Rather than directly testing for correlations between a country's age-structure and these macroeconomic variables, we use a standard neoclassical model that is consistent with the life-cycle theory. We calibrate this model with population data and projections for a large number of countries, and examine if the data generated by the model can explain real-world capital flows.

In addition to controlling for the domestic age-distribution this approach allows us to control for a changing demographic structure in the world economy. In the coming decades, most developed countries will face aging populations and smaller fractions of prime-age workers in the population. Theory and the empirical results found by for example Higgins (1998) then predict that current account balances will fall. It is not possible, however, that all countries simultaneously run current account deficits. The correlations between age-structure and capital flows will then not be robust.[1] We get around this problem by using a general equilibrium model, where we force the sum of current accounts in the world economy to balance in each period.

Many studies (see the survey below) have used calibrated models similar to ours to examine the consequences of population aging. These studies have typically not tested the model's ability to explain historical data. Our paper therefore also contributes by providing a test of the standard model used frequently in the literature.

We find that the model generates data that can explain a small but significant fraction of capital flows between countries. This finding both reinforces the results in previous empirical studies documenting a correlation between age-distributions and capital flows, and supports the use of calibrated life-cycle models to study the effects of demographic change.

The model performs better when we restrict attention to data from 1985 and onwards. This result is consistent with the low mobility of capital documented by

[1] Higgins (1998) was well aware of this problem. For example, he argued that "out-of-sample projections cannot capture the general equilibrium effects of a novel pattern of global demographic change" (p. 366)

Feldstein and Horioka (1980), and Blanchard and Giavazzi's (2002) finding that capital has become more mobile in the last two decades.

As already mentioned, a number of studies use calibrated life-cycle models to examine how population aging will affect saving and capital flows. Much of this work either treat economies as closed (following Auerbach and Kotlikoff, 1987), or as small open economies facing exogenous and constant factor prices (following Auerbach et al., 1989). Exceptions exist, though. Cutler et al. (1990) use a two-region model for the United States and the non-U.S. OECD countries and find that the U.S. demographic transition is affected by capital inflows from the other OECD countries. Attanasio and Violante (2000) examine how the Latin American demographic transition would be affected by capital mobility and Brooks (2003), Flodén (2003), Feroli (2002), and Henriksen (2002) all look at capital flows in multi-region models. All these papers suggest that demographic change can have a substantial impact on capital flows, and that international capital mobility can affect macroeconomic effects of the demographic transition. Brooks, Feroli and Henriksen also find that their model implications are broadly consistent with historical capital flows, although they do not perform any formal testing as in the present paper.

The paper is organized as follows. We present the model in Section 2. In Section 3 we describe how we calibrate and solve the model. In Section 4 we compare capital flows implied by the model with real-world data. Finally, in Section 5 we examine the model's implications for future capital flows.

2 The Model

We consider a model of a world economy. Each country is populated by overlapping generations of households that solve a standard life-cycle consumption problem. The demographic development is exogenous and the production technology is identical across countries, except that we allow for permanent differences in factor productivity. We assume that labor is immobile but that capital can move freely between countries.

2.1 The household's optimization problem

Households enter the labor market at age 20, raise an exogenous number of children between ages 20 and 49, and die at age N or earlier. Survival between periods is stochastic and there are domestic annuity markets for savings. Households maximize adult life-time utility,

$$\max_{\{c_s, a_{s+1}\}_{s=20}^{N}, b} \sum_{s=20}^{N} \beta^s \Phi_s \frac{(c_s/\psi_s)^{1-\mu}}{1-\mu} + \Theta \beta^{N_b} \Phi_{N_b} \frac{b^{1-\mu}}{1-\mu} \tag{1}$$

subject to

$$a_{s+1} = \begin{cases} \frac{(1+r_s)a_s}{\phi_{s-1,s}} + y_s - c_s & \text{if } s \neq N_b \\ \frac{(1+r_s)a_s}{\phi_{s-1,s}} + y_s - c_s - b & \text{if } s = N_b \end{cases}$$

$$y_s = w_s h_s$$

$$a_{N+1} \geq 0$$

and

$$a_{20} \text{ given.}$$

Here β is the discount factor, $\phi_{s-1,s}$ denotes the survival probability from period $s-1$ to period s, and $\Phi_s = \Phi_{19} \prod_{\sigma=20}^{s} \phi_{\sigma-1,\sigma}$ is the unconditional probability that the household is alive at date s. We normalize $\Phi_{19} = 1$. Θ is a parameter determining the importance of bequests, b, and N_b denotes the age at which bequests are given. Total household consumption is denoted by c, and ψ is the number of consumption equivalents in the household. Labor supply in efficiency units, h, is exogenous but depends on age. Finally, r, w, y, and a denote the interest rate, the wage rate, income, and assets.[2]

2.2 Production

The representative firm in a country takes the world market price of capital, r, as given and chooses capital utilization K to maximize discounted profits,

$$\max_{\{K\}} \sum_{t=1}^{\infty} \left(\prod_{\tau=1}^{t} \frac{1}{1+r_\tau} \right) \left[K_t^\theta \left(Z_t H_t \right)^{1-\theta} - \left(r_t + \delta \right) K_t - \Xi \left(K_{t-1}, K_t \right) \right]$$

subject to a given K_0. Here Z_t is labor productivity, δ is the depreciation rate of capital, and Ξ is cost associated with changing the size of the capital stock. Firms are owned by domestic workers in proportion to their labor supply.[3]

The first order condition to the firm's problem is then

$$\theta \left(Z_t H_t / K_t \right)^{1-\theta} - \left(r_t + \delta \right) - \Xi_2 \left(K_{t-1}, K_t \right) - \frac{\Xi_1 \left(K_t, K_{t+1} \right)}{1 + r_{t+1}} = 0 \qquad (2)$$

where subscripts on Ξ denote derivatives.

[2] To simplify notation, subscripts s on prices r and w denote time relative to a household's entry on the labor market, while subscripts t will be used to denote actual time.

[3] Workers are thus paid their marginal product when adjustment costs for capital are zero. When adjustment costs are non-zero, the wage deviates slightly from the marginal product of labor.

2.3 Equilibrium

Let $\mathrm{R} = \{r_1, r_2, ..., r_\infty\}$ denote the interest rate path, and let $\mathrm{W}_i = \{w_{i,1}, w_{i,2}, ..., w_{i,\infty}\}$ and $\mathrm{K}_i = \{K_{i,1}, K_{i,2}, ..., K_{i,\infty}\}$ denote the paths for wages and capital in country i. Furthermore, let $\mathrm{A}_{i,t}(R, W, a_{i,t,20}) = \{a_{i,t,21}, a_{i,t,22}, ..., a_{N+1}\}$ denote the asset path chosen by a household in country i that enters the labor market at time t with initial assets $a_{i,t,20}$ and similarly let $\mathrm{B}_{i,t}(R, W, a_{i,t,20}) = b_{i,t}$ denote the household's bequests.[4] New entrants on the labor market receive the bequests, so

$$a_{i,t,20} = b_{i,t-N_b} \frac{P_{i,t-1,N_b}}{P_{i,t-1,19}}$$

where $P_{i,t,s}$ denotes the number of people of age s in country i at date t. Finally, let $\bar{A}_{i,t} = \sum_{s=20}^{N} P_{i,t,s} a_{i,t-s+1,s}$ denote total asset holdings in country i at date t.

Definition 1 *An equilibrium consists of a world-market interest rate path* R*, country-specific paths for wages and capital stocks* W_i *and* K_i*, and household decisions* $\mathrm{A}_{i,t}$ *and* $\mathrm{B}_{i,t}$*, such that*

1. *The world market for capital clears,* $\sum_i \left(\bar{A}_{i,t} - K_{i,t}\right) = 0$ *for all* t.
2. *Wages equal profits per efficient labor unit,*

$$w_{i,t} = \left[K_{i,t}^{\theta} (Z_{i,t} H_{i,t})^{1-\theta} - (r_t + \delta) K_{i,t} - \Xi(K_{i,t-1}, K_{i,t})\right] / H_{i,t}$$

   for all i *and* t.

3. *Household plans* $\mathrm{A}_{i,t}$ *and* $\mathrm{B}_{i,t}$ *solve the household's optimization problem (1) for all* i *and* t.
4. *The path for the capital stock,* K_i*, is consistent with firm optimization (2) in all countries* i.

3 Calibration and Solution

Our strategy is to use current account data generated by the model and test its ability to predict and explain real-world current account data. The model economy has to be calibrated with population data and parameter values. We assume that the economy is in an initial steady state in year 1899. In the beginning of year 1900 agents learn about the future demographic development and adjust their decisions. There is no demographic change after year 2050, and eventually the economy settles down in a new steady state.

[4] In period 1, households also enter the economy at ages above 20, and with initial assets $a_{i,1,\cdot}$.

The model economy consists of 18 OECD countries and one country representing the rest of the world.[5] The population data (P) is based on the United Nations (2002), and survival probabilities ϕ are those implied by the development of P.[6] Households aged 20 to 49 share the burden of raising children, and child consumption is 50 percent of adult consumption. More specifically,

$$\psi_{i,t,s} = \begin{cases} 1 + 0.5\frac{\sum_{j=0}^{19} P_{i,t,j}}{\sum_{j=20}^{49} P_{i,t,j}} & \text{if } 20 \leq s \leq 49 \\ 1 & \text{if } s \geq 50 \end{cases}$$

The household dies with certainty at age 100.

Variations in labor productivity across countries are taken from table E7 in Maddison (2001).[7] We assume that these relative levels remain over time by assuming that the growth rate of labor productivity is constant at one percent per year in all countries ($Z_{i,t+1}/Z_{i,t} = 1.01$). Clearly, assuming that relative labor productivity is constant over time is not realistic, but we have chosen to abstract from convergence so that we can isolate the demographic effects on capital flows.

A household's efficient labor supply h varies with age due to changes in productivity and labor market participation. As in Flodén (2003) we multiply Hansen's (1993) productivity estimates with Fullerton's (1999) participation rates, and we assume that the resulting labor-supply profile is constant over time and across countries.

Table 1 summarizes the parameter values used in the utility and production functions. Since the United Nations provide population data and forecasts in five-year intervals and sorts the population in five-year age groups, we transform our model into the same five-year structure. The parameter values for risk aversion (μ), the discount factor (β), the capital share in production (θ), and the depreciation rate of capital (δ) are standard and need no comment. Rather arbitrarily, we assume that all bequests are given just before age 70 ($N_b = 14$). The main motivation for this assumption is technical. The annuity markets for savings simplify the solution of the model. A natural modeling approach with annuity markets would be to let bequests accrue to the survivors so that those who die at the final age (100) leave all the bequests. However, only a small fraction of households survive until age 100,

[5] The 18 countries are the old OECD countries except Greece, Iceland, and Luxembourg. We have also excluded Norway since its current account is dominated by the effects of the oil findings.

[6] The UN reports population data in five-year intervals and for five-year cohorts. The population aged 80+ was lumped together in one group until 1990. We split this group into five-year cohorts by using survival probabilities from Bell et al. (1992). We use their tables for cohorts born in 1900, 1930, 1960, and 1990 and then interpolate to obtain survival probabilities for other years. These survival probabilities refer to US data. We use this data for all OECD countries, but we lag the data 30 years before using it on the rest of the world.

The UN population data ranges from 1950 to 2050. We assume that the population size and structure was constant at the 1950 level before 1950 and that it will be constant at the 2050 level after 2050.

[7] The productivity values vary between 21.94 1990 dollars per hour for Spain and 34.55 for the USA. Maddison does not report values for Portugal or "the rest of the world". We use Spain's value for Portugal and ten percent of the U.S. level for the rest of the world.

and the accumulated bequest per survivor would be enormous, resulting in poor numerical precision in the solution algorithm. Taking into account intergenerational gifts and life expectancy, we argue that age 70 is a realistic choice. The preference parameter Θ affects the equilibrium interest rate and was chosen to get a flat life-cycle consumption profile in the initial steady state.

Eberly (1997) argues that adjustment costs are captured by

$$\Xi\left(K_{t-1}, K_t\right) = \frac{\xi}{\alpha}\left(\frac{K_t - (1-\delta) K_{t-1}}{K_{t-1}}\right)^{\alpha}.$$

She estimates that $\alpha = 1.8197$ in the United States, and her estimates for a number of other OECD countries are similar. In the baseline specification we set $\xi = 0.20$, resulting in equilibrium adjustment costs around two percent of output. The case with no adjustment costs, $\xi = 0$, is also considered.

Table 1: Parameter values

μ	2.00
β	0.98^5
N_b	14
Θ	2.30
θ	0.36
δ	$1.08^5 - 1$
γ	$1.01^5 - 1$
ξ	0.20
α	1.8197

To solve the model, we first find the initial steady state. From this steady state, we get the initial capital stocks for the 19 countries in year 1900, as well as the initial distribution of asset holdings across households of different ages. We then guess an interest rate path for years 1900 to 2149. When there are no adjustment costs for capital, the demographic development together with this interest rate path directly imply paths for the capital stocks in each country, and one common path for wages. In the presence of adjustment costs, we use an equation solver to find each country's path for capital. This path for capital has to satisfy the first order condition for firm profit maximization,

$$\theta\left(\frac{Z_{i,t} H_{i,t}}{K_{i,t}}\right)^{1-\theta} - (r_t + \delta) - \Xi_2\left(K_{i,t-1}, K_{i,t}\right) - \frac{\Xi_1\left(K_{i,t}, K_{i,t+1}\right)}{1 + r_{t+1}} = 0$$

where subindices on Ξ denote derivatives. After having found the capital stock, we calculate the wage rate as

$$w_{i,t} = \frac{K_{i,t}^{\theta}\left(Z_{i,t} H_{i,t}\right)^{1-\theta} - (r_t + \delta) K_{i,t} - \Xi\left(K_{i,t-1}, K_{i,t}\right)}{H_{i,t}}.$$

Knowing these factor prices, we solve for the consumption-savings decision for each household in each country from year 1900 and onward. We then sum all capital stocks implied by firm optimization to obtain a path for the world total capital stock, and similarly we sum all asset holdings implied by household optimization. If asset holdings do not equal the sum of capital stocks in each period, an equation solver updates the interest rate path and starts over.

Figure 1 shows the equilibrium interest rate path for the baseline calibration of the model. As the fraction of prime-age workers falls, the productivity of capital and hence the interest rate declines. The resulting current account balances for the OECD countries are shown in Figures 2 and 4 below. The "rest of the world" is running current account deficits throughout the period. These deficits are around seven percent between 1960 and 2000, and then gradually improves to around one percent in 2050. Although 87 percent of the model population lived in the rest of the world in year 2000, this region did not dominate capital flows. Because of the low labor productivity, production and the capital stock in the rest of the world only amounted to 37 percent of the world total.

4 Does the Model Explain Current Account Data?

We want to examine if capital flows implied by the model explain real-world current accounts in the 18 OECD countries that were used to calibrate the model. These current account data are from OECD (2003) and ranges from 1960 to 2003. For most countries, however, the data series starts in the 1970's. Let $X_{i,t}$ denote the current account balance generated by the model in country i and time period t. Similarily, let $CA_{i,t}$ denote the average current account balance in the OECD data for the same time period. To test the predictive power of the model, we use the fixed effects panel specification

$$CA_{i,t} = \alpha_i + \beta X_{i,t}.$$

Table 2 summarizes the regression results. The first two columns report results using model data from our baseline specification while columns 3-10 report results using data from different specifications of the model. The different specifications we consider are to remove adjustment costs for capital (columns 3 and 4), to exclude the "rest of the world" (columns 5 and 6), to introduce a pay-as-you-go defined-benefits pension systems in all countries (columns 7 and 8), and reducing the degree of risk aversion to unity (columns 9 and 10). In the model with a pension system, we assume that contributions in the initial steady state are four percent of labor income. Pension benefits per retiree are then fixed relative to the average wage but pension contributions increase over time because of the demographic development. The average pension tax is 7 and 15 percent in year 2000 and year 2050, respectively.

A number of interesting results emerge. First, β is significant and has the correct sign in all regressions. Note that if the model were to match the data perfectly, β would equal unity. Second, a substantial fraction of current account fluctuations is explained by the model. In the real world, current accounts are determined by many factors in addition to demographic change, for example business cycle fluctuations, long-term growth trends, and volatile fiscal policy. Still, the model explains more than ten percent of the current account fluctuations. Third, the model explains more of the data, and the parameter estimates are closer to unity when considering the period 1985-2003. This can be understood as follows. A fundamental assumption behind our work is that capital can move freely between countries. Contrary to this assumption, Feldstein and Horioka (1980) found that the correlation between a country's investment and saving rate was close to unity in a sample of OECD countries between 1960 and 1974. During the 1970's and 1980's, however, many countries removed restrictions on international capital flows, and in particular the European economies became more internationally integrated. Blanchard and Giavazzi (2002) consequently find that the correlation between investment and saving diminished after 1975 and in particular after 1990. Consistent with these findings, we find that the parameter estimates for the period 1960-1984 and 1985-2003 are statistically different at the 5 percent level.

Table 2 also shows that the results are not particularly sensitive to the variations in model specification that we consider. The estimates and standard deviations of β are similar, and the different model specifications explain similar fractions of the current account volatility.

The real-world current account data is displayed in Figure 2, together with the values generated by the simulation model and the predicted values from the regressions. From these graphs, it is clear that the model does not explain high-frequency current account fluctuations. The data also contain some episodes of extreme current account deficits, like those in Ireland and Portugal around 1980. As expected, these episodes were not demographically motivated. Maybe surprisingly, however, the huge current account surplus in Switzerland is captured by the model. Switzerland's transition towards an elderly population has progressed further than in other countries. The fraction of prime-age workers (aged 45-60) continually increased and the fraction of young adults fell sharply during the 1990's. There was thus an increasing number of savers and a falling fraction of borrowers in the economy, resulting in a significant current account surplus.

Capital flows between the United States and Japan has received attention both in the popular and in the academic debate, in particular because of the persistent current account and trade surplus in Japan and corresponding deficits in the United States (see the top-left panel in Figure 3). Has demographic developments been an important factor behind these capital flows? Our model suggests that it indeed may have been. The remaining panels of Figure 3 show capital flows implied by different model specifications.

The Japanese current account balance is larger than the American balance for all model specifications. In the baseline specification, both countries run current account surpluses during the 1980's and 1990's. The developing world is the primary recipient of capital in this model specification. By focusing only on OECD countries we bring the model implications more in line with the data. The lower-left panel shows that the United States then runs current account deficits for most of the period, as in the data.[8] The Japanese capital flows are however counterfactually large. The lower-right panel in Figure 3 indicates that introducing a small pension system in the model reduces capital flows. The pension system substitutes for some of the life-cycle savings and reduces aggregate wealth. As a result, the magnitude of capital flows is smaller and more similar to what we see in the data.[9]

5 Projections

In this section, we use the theoretical model and the regression results to assess the demographic effect on future capital flows. Figure 4 shows current account projections based on the baseline model specification.

The model predicts current account improvements in Southern Europe and Ireland and a downward pressure on the current accounts in the United States and Scandinavia during the coming one or two decades. These capital flows are explained by the relative timing of population aging in the different countries. The former group of countries will see an increasing fraction of prime-age workers in the coming decades, with a peak after 2020, while the fraction of prime-age workers has already peaked or is just about to peak in the latter group of countries. These predictions are thus consistent with empirical studies of the relationship between the current account and the age structure in a country. For example Higgins (1998) finds that a large fraction of prime-age workers implies a current account surplus.

We want to point out that the current account projections reported in Figure 4 should not be used as forecasts of future capital flows. First, as we have found in this paper, the demographic development only explains part of the historical data. Moreover, and more importantly, policy reforms will most likely be necessary in many countries if the demographic change turns out to be as dramatic as predicted. Such reforms (for example pension reforms) could substantially affect capital flows. Our projections focus on the direct impact from demographics to capital flows and ignores indirect effects from policy changes. The model is however well suited also for analyzing policy reforms.

[8] When excluding developping countries, our model predicts capital flows for the U.S. and Japan that are similar to those in Feroli (2002) and Henriksen (2002). Neither Feroli nor Henriksen allows for capital flows to developping countries.

[9] Introducing a pension system improves current-account levels not only in the U.S. and Japan, but in most countries.

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Table 2: Regression results

Variation	baseline		no adj. cost		OECD		pensions		$\mu = 1$	
time period	60-03	85-03	60-03	85-03	60-03	85-03	60-03	85-03	60-03	85-03
β	0.37**	0.75**	0.29*	0.51*	0.21	0.59*	0.42**	0.79**	0.39**	0.67**
	(0.13)	(0.28)	(0.12)	(0.23)	(0.15)	(0.27)	(0.13)	(0.28)	(0.14)	(0.24)
$\beta_{85-03} - \beta_{60-84}$		0.75*		0.54*		0.53		0.81*		0.67*
		(0.32)		(0.27)		(0.33)		(0.34)		(0.31)
# obs.	126	72	126	72	126	72	126	72	126	72
R^2	0.56	0.71	0.55	0.69	0.53	0.69	0.57	0.71	0.56	0.71
R^2_X	0.07	0.12	0.05	0.09	0.02	0.08	0.09	0.13	0.07	0.13

Note: R^2_X is the variance explained by X only (i.e. fixed effects not included). Standard deviations in paranthesis. * and ** denote significance at the 5 and 1 percent levels, respectively.

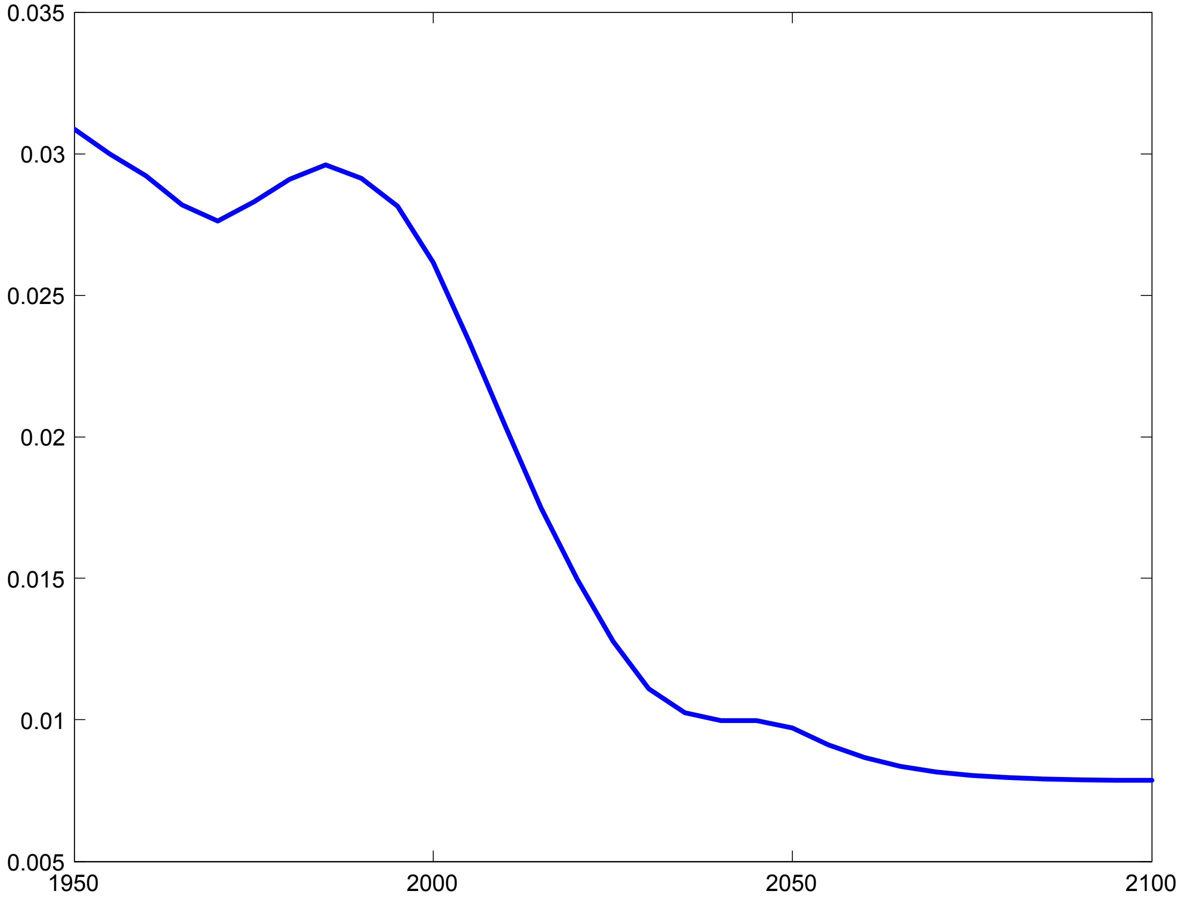

Figure 1: Annualized Interest Rate Path

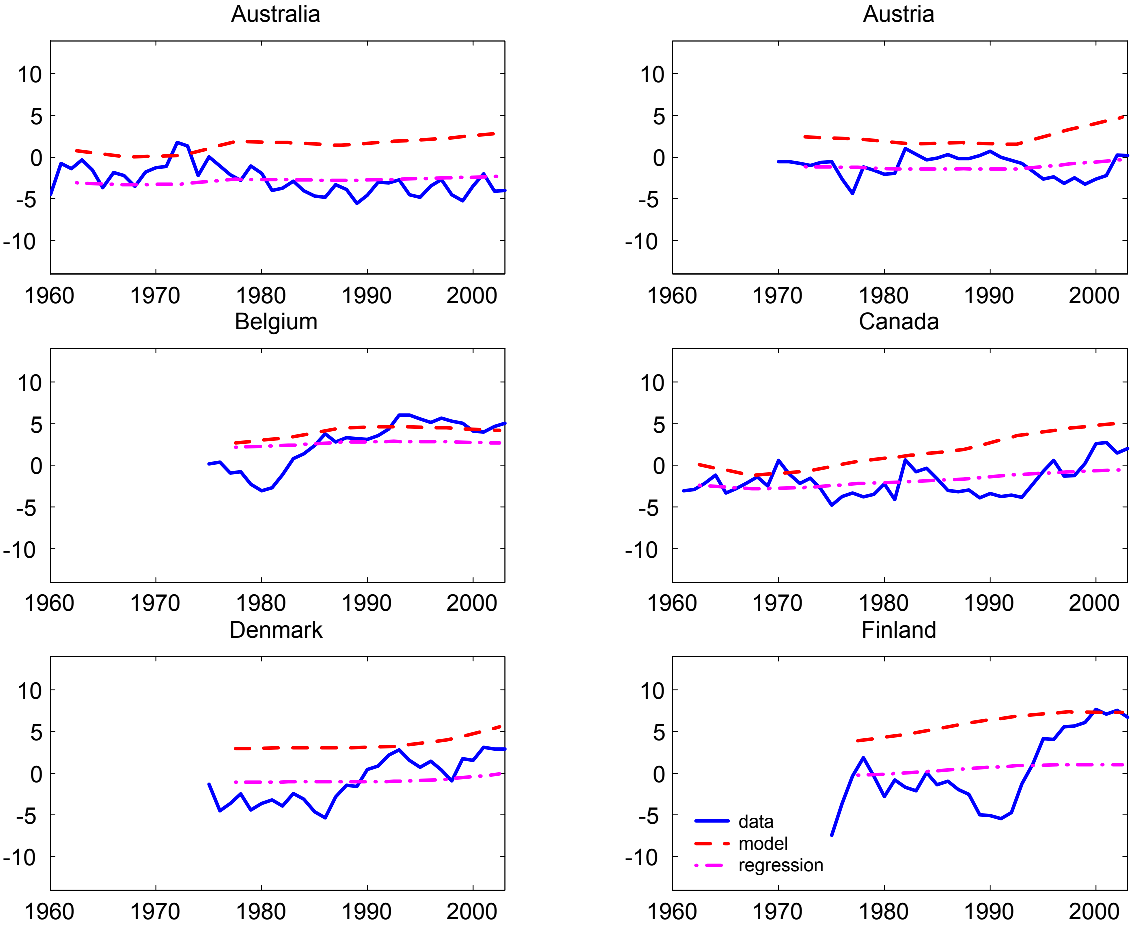

Figure 2a: Current Account Balance – Data and Model

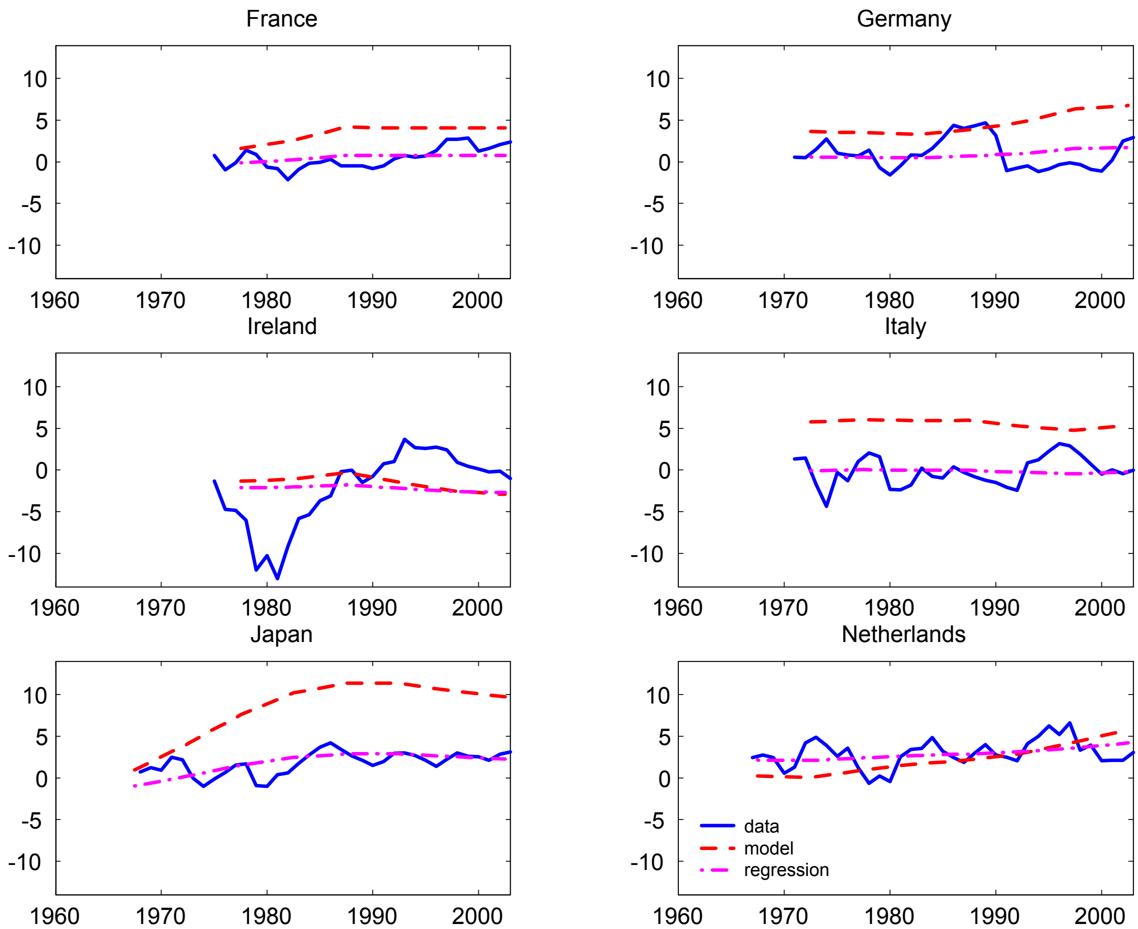

Figure 2b: Current Account Balance – Data and Model

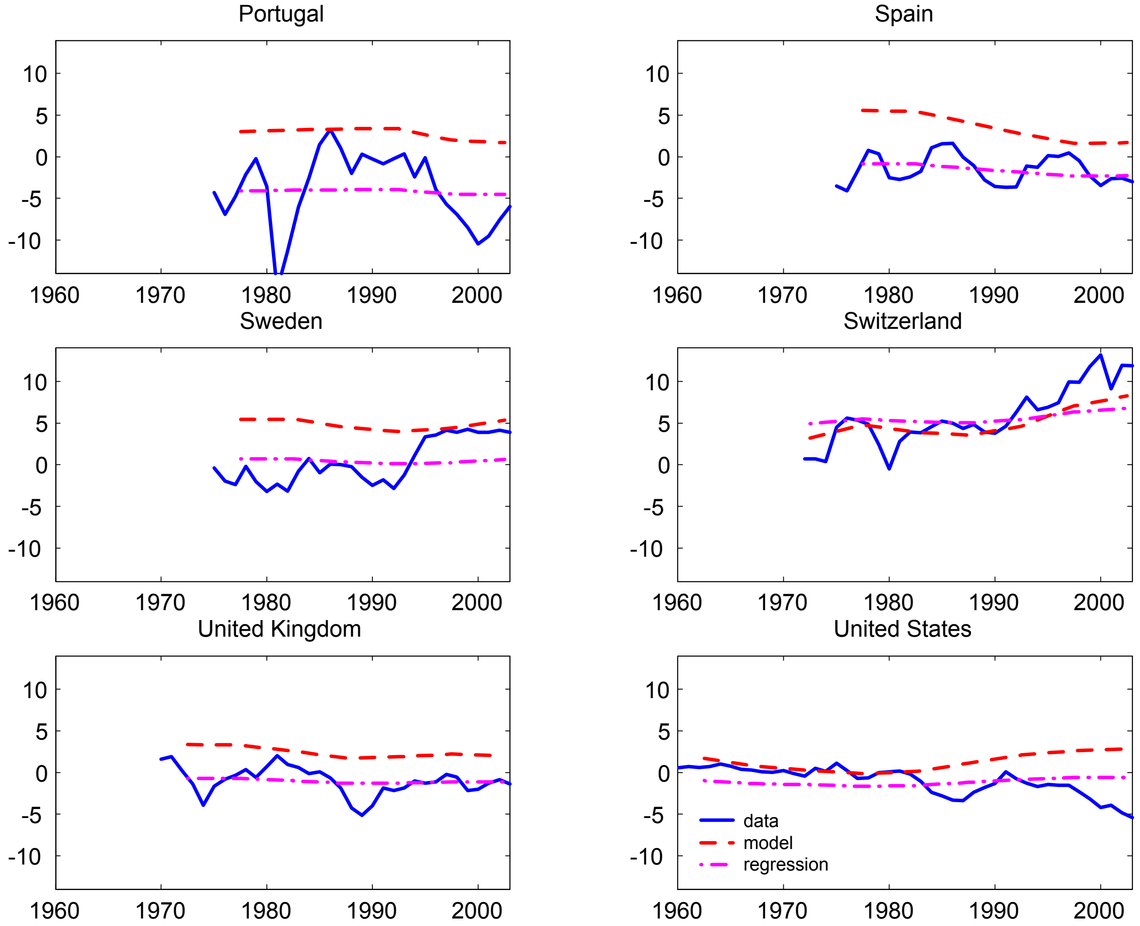

Figure 2c: Current Account Balance – Data and Model

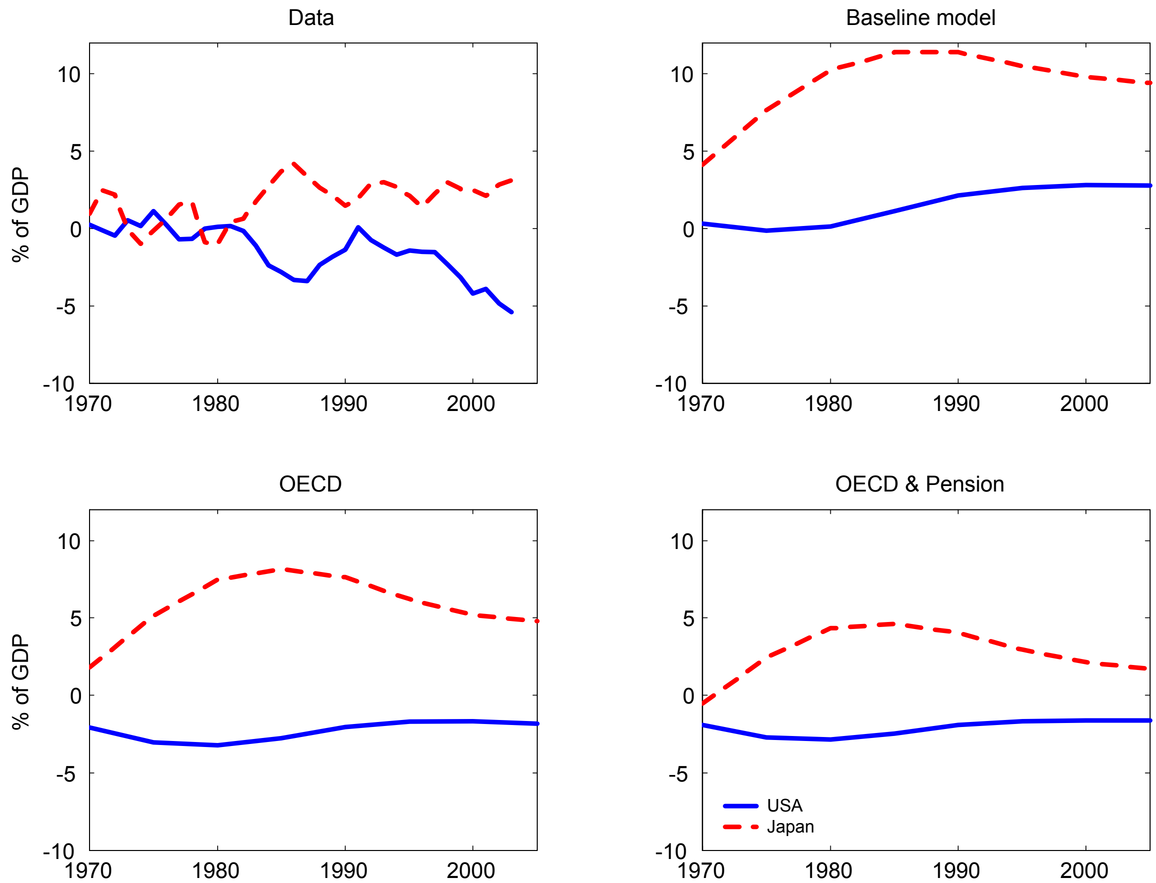

Figure 3: U.S. and Japanese Current Account Balances

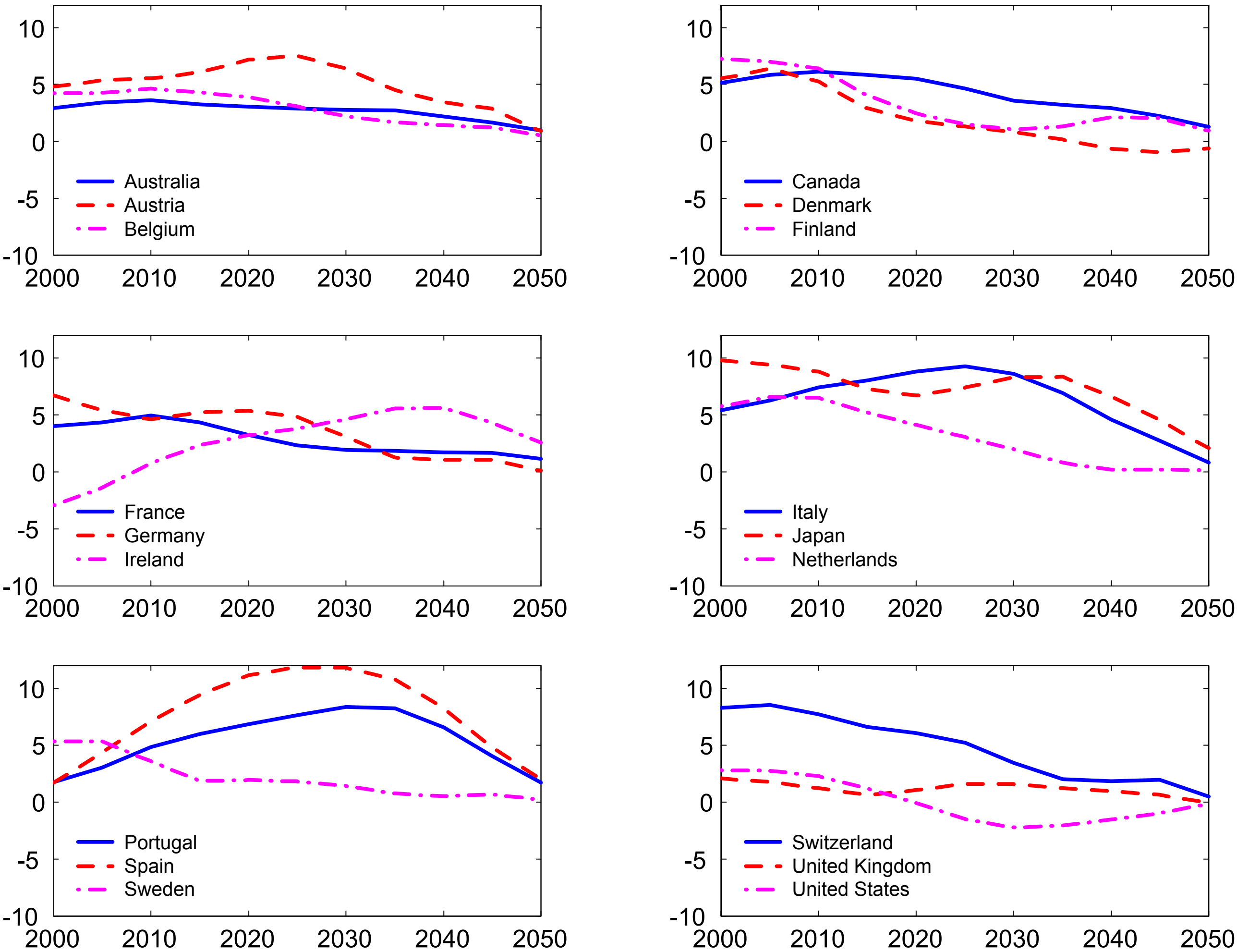

Figure 4: Current Account Projections