INTERNATIONAL ECONOMIC REVIEW
Vol. 47, No. 3, August 2006

POPULATION AGING AND INTERNATIONAL CAPITAL FLOWS*

BY DAVID DOMEIJ AND MARTIN FLODÉN[1]

Stockholm School of Economics, Sweden; CEPR and Stockholm School of Economics, Sweden

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.

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 savings rate depends on the age structure of its population. This direct link between demographics and savings, investment, 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, whereas 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 article, 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 structure, 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

* Manuscript received October 2003; revised August 2004.

[1] We thank Kjetil Storesletten, José-Víctor Ríos-Rull (the editor), two anonymous referees, and seminar participants at the Stockholm School of Economics, CERGE-EI, London School of Economics, Bocconi University, European University Institute, ESSIM 2004, and SED 2002 and 2004 for comments. We also thank the Wallander and Hedelius Foundation and the Bank of Sweden Tercentenary Foundation for generous funding. Please address correspondence to: Martin Flodén, Department of Economics, Stockholm School of Economics, Box 6501, SE-113 83 Stockholm, Sweden. E-mail: *martin.floden@hhs.se.*

account deficits. The correlations between age structure and capital flows will then not be robust. [2] 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 article 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 real-world capital flows between countries. This finding both reinforces the results in previous empirical studies documenting a correlation between age structures 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 onward. This result is consistent with the low mobility of capital documented by 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 savings and capital flows. Much of this work either treats 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. They also point out that the population aging process will be less dramatic in the United States than in most other OECD countries. When looking ahead from 1990, their model therefore predicted that the saving rate in the United States would increase less than in the other countries, and consequently that the United States would run current account deficits during the 1990s.[3]

Brooks (2003) uses an overlapping generations model where individuals live for four periods, and solves for the equilibrium in a world economy with eight regions. He calibrates the model with historical and projected population data to generate paths for capital flows motivated by demographics. In work parallel to and independent of ours, Henriksen (2002) and Feroli (2003) build on Brooks but introduce a richer life-cycle structure. Henriksen focuses on Japan and the United States, whereas Feroli calibrates a four-region world consisting of the United States, Japan, Germany, and other European countries. They both find

[2] 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).

[3] Other papers that solve for general equilibrium capital flows induced by demographic change are Attanasio and Violante (2000) and Flodén (2003). Attanasio and Violante examine how the Latin American demographic transition would be affected by capital mobility, whereas Flodén examines future capital flows between 15 OECD countries.

that their models predict American current account deficits and Japanese surpluses during the last decades, as in the real-world data.

The article 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

$$c_s + a_{s+1} + b\mathrm{I}(s = N_b) = y_s + \frac{(1 + r_s^a)a_s}{\phi_{s-1,s}} \tag{2}$$

$$y_s = (1 - \tau_s)w_s h_s \mathrm{I}(s < 65) + d_s \mathrm{I}(s \geq 65)$$

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

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 age 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. Households hold assets, a, consisting of physical capital and shares in the representative firm in each country as described below. Finally, I $(\cdot)$ is an indicator function, and r^a, w, y, τ, and d denote the return on household assets, the wage rate, income, the social security tax, and the pension benefit.[4]

2.2. *The Pension System.* In each country, the government runs a pay-as-you-go, defined-benefits pension system. There is a flat pension tax on labor income, and the tax revenue is distributed as lump-sum pension benefits among all retirees (aged 65 and above). The budget constraint for the pension system in a country is thus

$$\tau_t = \frac{d_t \sum_{s=65}^{N} P_{t,s}}{w_t H_t} \tag{3}$$

where $P_{t,s}$ denotes the number of people of age s at date t, and H is the aggregate labor supply in efficiency units.

2.3. *Production and Asset Markets.* The representative firm in a country rents labor H at the wage rate w, and capital K at the world market price r to maximize the discounted value of dividends,

$$\max_{\{H,K\}} \sum_{t=1}^{\infty} \left(\prod_{\tau=1}^{t} \frac{1}{1+r_\tau^a} \right) \pi_t$$

where

$$\pi_t = K_t^\theta (Z_t H_t)^{1-\theta} - (r_t + \delta) K_t - \Xi(K_{t-1}, K_t) - w_t H_t \tag{4}$$

and Z_t is productivity per efficiency unit of labor, δ is the depreciation rate of capital, K_0 is given, and Ξ is the cost of changing the size of the capital stock used by the firm. We assume that capital is not installed, so firms only incur adjustment costs if they change the *size* of the capital stock used in production.[5] There is therefore one world market for physical capital, and capital and consumption goods are perfect substitutes.

The first-order conditions to the firm's problem are then

$$w_t = (1-\theta) K_t^\theta Z_t^{1-\theta} H_t^{-\theta} \tag{5}$$

and

$$\theta (Z_t H_t / K_t)^{1-\theta} - (r_t + \delta) - \Xi_2(K_{t-1}, K_t) - \frac{\Xi_1(K_t, K_{t+1})}{1 + r_{t+1}^a} = 0 \tag{6}$$

where subscripts on Ξ denote derivatives.

[4] To simplify notation, subscripts s on prices r and w denote time relative to the household's birth year, whereas subscripts t will be used to denote actual time.

[5] The costs we have in mind are in particular associated with adjusting the size of the labor force. For example, the firm can rent a particular set of machinery and costlessly substitute this machinery for another identical set in the next period. But if the firm rents more machinery, it will have to hire and train new workers.

Since there are adjustment costs, dividends may be nonzero and will accrue to the firm's owners. The households' assets therefore include stakes in the firms in addition to physical capital. More specifically, for a household of age s in country i at time t, the portfolio is

$$a_{i,t,s} = k_{i,t,s} + \sum_j Q_{j,t}\kappa_{j,i,t,s}$$

where k denotes the household's physical capital, κ_j denotes the household's share in the representative firm in country j, and Q_j denotes the price of these shares. Note that the value of the representative firm in country j at time t is

$$V_{j,t} = \sum_i \sum_{s=20}^{N} Q_{j,t}\kappa_{j,i,t,s} \tag{7}$$

2.4. *Equilibrium.* Let $R = \{r_t\}_1^\infty$ and $R^a = \{r_t^a\}_1^\infty$ denote the paths for returns on physical capital and household portfolios, and let $W_i = \{w_{i,t}\}_{t=1}^\infty$, $K_i = \{K_{i,t}\}_{t=1}^\infty$, $Q_i = \{Q_{i,t}\}_{t=1}^\infty$, $\Pi_i = \{\pi_{i,t}\}_{t=1}^\infty$, $V_i = \{V_{i,t}\}_{t=1}^\infty$, $T_i = \{\tau_{i,t}\}_{t=1}^\infty$, $D_i = \{d_{i,t}\}_{t=1}^\infty$, denote the paths for wages, capital, share prices, dividends, firm values, social security taxes, and pension benefits in country i. Furthermore, let $A_{i,t} = \{a_{i,t+\tau,20+\tau}\}_{\tau=1}^{N-19}$ denote the asset path chosen by a household in country i with initial assets $a_{i,t,20}$, and let $B_{i,t} = b_{i,t}$ denote the bequests left by households of age N_b at the end of period $t-1$.[6] New entrants on the labor market receive the bequests, so

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

Finally, let $\bar{A}_{i,t} = \sum_{s=20}^{N} P_{i,t,s}a_{i,t,s}$ denote total asset holdings in country i at date t.

DEFINITION 1. An equilibrium consists of world-market interest rate paths R and R^a; country-specific paths for wages, capital stocks, share prices, dividends, firm values, social security taxes, and pension benefits W_i, K_i, Q_i, Π_i, V_i, T_i, and D_i; and household decisions $A_{i,t}$ and $B_{i,t}$, such that

(1) The world market for capital clears, $\sum_i(\bar{A}_{i,t} - K_{i,t} - V_{i,t}) = 0$ for all t.
(2) Household plans $A_{i,t}$ and $B_{i,t}$ solve the household's optimization problem (1) for all i and t.
(3) The paths for wages, W_i, and the capital stock, K_i, are consistent with firm optimization (5) and (6) in all countries i.

[6] In period 1, households also enter the economy at ages above 20, with initial assets $a_{i,1,s}$, and decisions $\mathrm{A}_{i,1}^{s} = \{a_{i,t,\sigma}\}_{\sigma=s+1}^{N+1}$.

(4) The price on the representative firm in country i is

$$Q_{i,t} = \frac{Q_{i,t+1} + \pi_{i,t+1}}{1 + r_{t+1}}$$

for all i and t.

(5) The budget constraint for the pension system (3) is fulfilled for all i and t.

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. We assume that the economy starts in an initial steady state in period $t = 0$. Households learn about the future demographic development in the beginning of period $t = 1$, and adjust their decisions. Eventually, the economy settles down in a new steady state.

Note that equilibrium condition 4 implies that

$$\frac{Q_{i,t} + \pi_{i,t}}{Q_{i,t-1}} = 1 + r_t$$

as long as there are no information shocks. Consequently, $r_t^a = r_t$ in the initial steady state and for all $t \geq 2$, implying that the composition of equity and physical capital is irrelevant for the return on households' portfolios. In the first period, however, the information shock when households learn about the new demographic development implies that the return on equity may differ from the return on physical capital. The allocation of equity holdings across households in the initial steady state is indeterminate since households do not anticipate the possibility of an information shock. We assume that all households have the same portfolio shares in the initial steady state ($\kappa_{j,i,0,s}/a_{i,0,s}$ is the same for all i and s), solve for $Q_{i,1}$ from equilibrium condition 4, and calculate r_1^a as the total ex post return on the household's portfolio.

The model economy consists of 18 OECD countries and 1 country representing the rest of the world.[7] The population data (P) is based on the United Nations (2002) data, which range from 1950 to 2050, and survival probabilities ϕ are those implied by the development of P. [8] We assume that the population size and structure was constant at the 1950 level before 1950. To generate projections after 2050, we assume that the number of newborns and survival probabilities stabilize in 2050. The world population is then predicted to stabilize just above 10 billion

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

[8] The UN reports population data in 5-year intervals and for 5-year cohorts. The population aged 80+ was lumped together in one group until 1990. We split this group into 5-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 U.S. 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.

around year 2150.[9] Since we use the actual development of the population data to calculate the survival probabilities, we implicitly assume that immigrants arrive without assets and are adopted by domestic households. There are two reasons for modeling immigration and survival probabilities like this. First, we do not have data on the age composition of migrants or survival probabilities for all countries, and therefore cannot calculate or use more explicit survival probabilities. Second, the solution is simplified when immigrants are adopted by domestic households since this ensures homogeneity in asset holdings within cohorts.

Households aged 20–49 share the burden of raising children, and, following OECD (1982), child consumption is 50% of adult consumption.[10] More specifically,

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

The household dies with certainty at age 100.

Variations in labor productivity across countries are taken from table E7 in Maddison (2001).[11] We assume that these relative levels remain constant over time by assuming that the exogenous growth rate of total factor productivity is 1% per year in all countries. Letting γ denote this growth rate, we have $Z_{i,t+1}/Z_{i,t} = (1+\gamma)^{\frac{1}{1-\theta}} = 1.0157$ as in Cooley and Prescott (1995). 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 because of 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 provides population data and forecasts in 5-year intervals and sorts the population in 5-year age groups, we transform our model into the same 5-year structure. In the baseline specification, we set the risk aversion to $\mu = 2$, and the capital share in production to $\theta = 0.36$, which are standard values in the business cycle literature (see, for example, Cooley and Prescott, 1995 and Backus et al., 1995). 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

[9] See Domeij and Flodén (2005) for further information about the demographic development.

[10] See Fernández-Villaverde and Kreuger (2003) for a discussion of consumption equivalence scales.

[11] The productivity values vary between 21.94 1990 dollars per hour for Spain and 34.55 for the United States. Maddison does not report values for Portugal or "the rest of the world." We use Spain's value for Portugal and 10% of the U.S. level for the rest of the world.

TABLE 1

PARAMETER VALUES

μ	2.00
β	0.9562^5
N_b	14
Θ	4.53
θ	0.36
δ	$1 - (1 - 0.0535)^5$
γ	$1.01^5 - 1$
ξ	1.00
α	1.8197

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, 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 discount factor, β, the depreciation rate of capital, δ, and the preference parameter for bequests, Θ, affect the capital–output ratio, the investment share, and the life-cycle consumption profiles. We choose these parameters to match the average capital–output ratio and investment share in 1990 and so that $\beta(1 + r^a)/(1 + \gamma)^\mu = 1$ in the initial steady state.[12] According to World Bank data, the average capital–output ratio was 2.74 in 1990, and according to OECD (2004), the average investment share was 0.19.[13] The third condition generates an interest rate such that life-cycle consumption profiles are flat in the initial steady state.

Eberly (1997) estimates adjustment costs using annual data. Assuming that capital grows at a constant rate within our 5-year periods, her functional form implies that adjustment costs are approximately

$$\Xi(K_{t-1}, K_t) = \frac{5\xi}{\alpha}\left[\left|\left(\frac{K_t}{K_{t-1}}\right)^{1/5} - (1 - \delta_1)\right|\right]^\alpha K_{t-1}$$

where δ_1 is the annualized depreciation rate. Eberly estimates that $\alpha = 1.8197$ in the United States, and her estimates for a number of other OECD countries are similar. Unfortunately, Eberly cannot simultaneously identify ξ and α. We therefore consider different values for ξ. In the baseline specification we set $\xi = 1$, resulting in equilibrium adjustment costs around 2% of output. As a robustness

[12] As a robustness check, we have also fixed the discount factor at its baseline value and chosen country-specific depreciation rates to match each country's 1990 capital–output ratio. The results were unaffected. See Domeij and Flodén (2005) for further details.

[13] We calculate the capital–output ratio and investment shares as the GDP-weighted averages. capital–output ratios are from the Nehru and Dhareshwa World Bank (1995) data set, and investment shares are from OECD (2004). We let India represent the Rest of the World, and take the investment share from the Penn World Tables.

check, we also use a larger cost ($\xi = 2$), and the case with no adjustment costs ($\xi = 0$).

We assume that all countries have an identical defined-benefits pay-as-you-go pension system in the initial steady state. The initial social security tax rate is set to 4% of labor income. The pension benefits per retiree are then fixed relative to the average wage, but the tax rate increases over time because of the demographic development. The implied average social security tax rate is 7% and 14% in year 2000 and year 2050, respectively. The motivation for calibrating identical pension systems in all countries is that we lack necessary country-specific information for more detailed specifications. Public pension systems in most OECD countries are larger than what our calibration implies for the 1990s. But we model a pay-as-you-go system and therefore would need data that excludes the funded parts of pension systems. Nevertheless, in Domeij and Flodén (2005), we calibrate country-specific tax rates to match the size of pension systems in 1990 and show that the results are unaffected.

To solve the model, we first find the initial steady state, which is calibrated to match 1950 values.[14] From this steady state, we get the initial capital stocks for the 19 countries, as well as the initial distribution of asset holdings across households of different ages. We then guess an interest rate path for all years (until 2250). 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 the wage rate. 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 firm's first-order condition with respect to capital, Equation (6). After having found the capital stock, we calculate the wage rate from the firm's first-order condition (5), the value of the representative firm in each country from Equations (4) and (7) together with equilibrium condition 4, and the normalization that $\sum_{i,s} \kappa_{j,i,t,s} = 1$.

Knowing these factor prices, we solve for the consumption–savings decisions for all households in all countries. We then sum all asset holdings implied by household optimization to obtain a path for the total world asset holdings, and similarly we sum all capital stocks and all firm values. If asset holdings do not equal the sum of capital stocks and firm values 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, together with the implied capital–output ratios for all countries. As the fraction of prime-age workers falls, the productivity of capital and hence the interest rate declines and the capital–output ratios increase. The resulting current account balances for the OECD countries are shown in Figures 2a–c and 4 below. The "rest of the world" is running current account deficits throughout the period. These deficits are around 8% between 1960 and 2000, and then gradually

[14] In the first period, households are informed about a new demographic development. To dampen the effects of this information shock, we replicate the demographic data from 1950 for ten 5-year periods, and let the economy start in 1900. In Domeij and Flodén (2005), we show that the results are robust to alternative assumptions about the initial steady state.

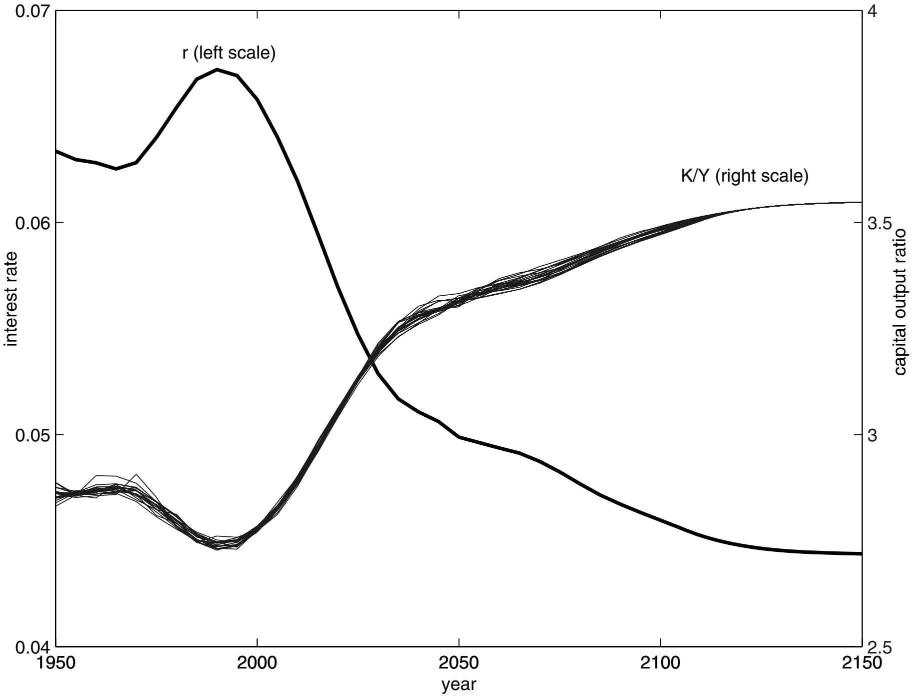

FIGURE 1

ANNUALIZED INTEREST RATE PATH AND ANNUALIZED CAPITAL–OUTPUT RATIOS

improve. In 2050, the current account is almost balanced. Although 87% 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, the capital stock in the rest of the world only amounted to 37% 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. We use OECD data from 1960 to 2002 (see the Appendix for details). Let $X_{i,t}$ denote the current account balance generated by the model in country i and time period t. Similarly, 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

$$CA_{i,t} = \alpha_i + \beta X_{i,t} + \varepsilon_{i,t} \tag{8}$$

and the pooled OLS specification

$$CA_{i,t} = \alpha + \beta X_{i,t} + \varepsilon_{i,t} \tag{9}$$

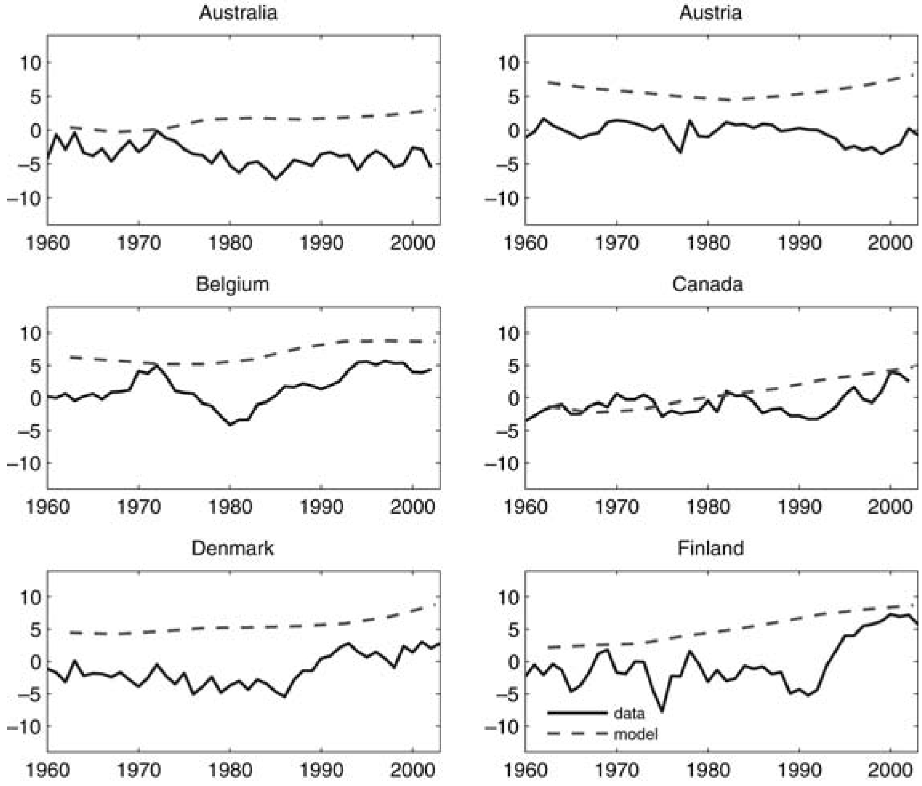

FIGURE 2A

CURRENT ACCOUNT BALANCE (% OF GDP)—DATA AND MODEL

The regression results from our baseline specification are summarized in Table 2. Columns 1 and 4 show the full-sample results for fixed effects and pooled OLS regressions, respectively. Columns 2 and 5 show the results when we only use data from 1985 and onward, and Columns 3 and 6 show the results when we use filtered real-world data to reduce the influence of high-frequency data. The filter, described in detail in the Appendix, is a moving average of the data in periods $t-1$, t, and $t+1$.

A number of interesting results emerge from these regressions. 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 10% of the current account fluctuations.

Third, the results improve when we consider the period 1985–2002. The model then explains more of the data, 17% of fluctuations in the panel regression and 27% in the pooled regression, and the parameter estimates are closer to unity. This

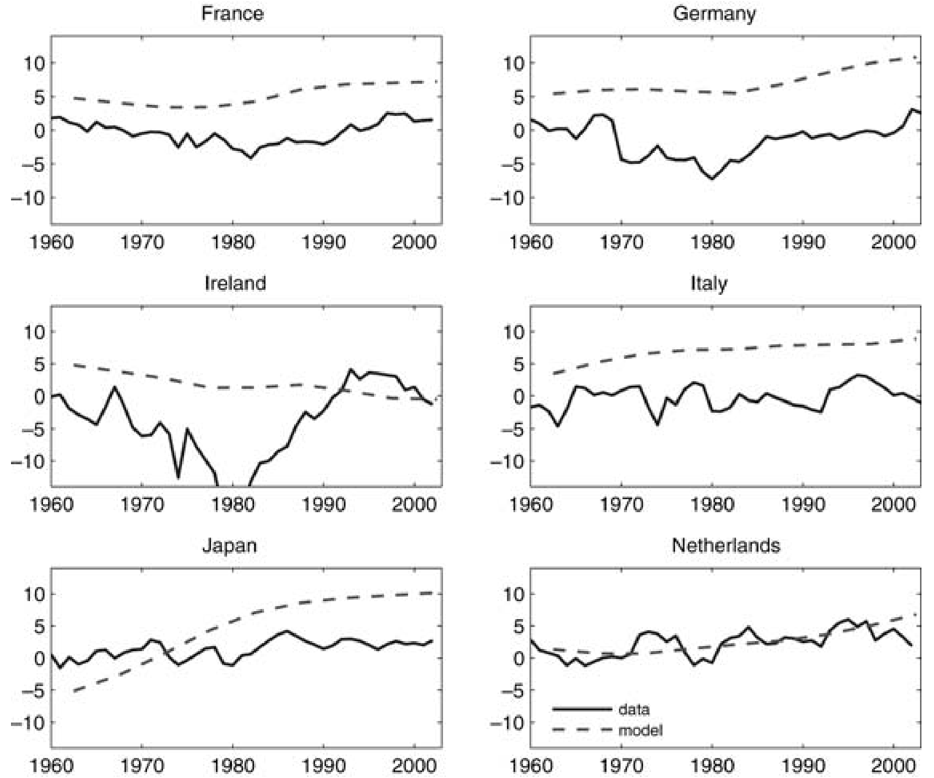

FIGURE 2B

CURRENT ACCOUNT BALANCE (% OF GDP)—DATA AND MODEL

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 savings rate was close to unity in a sample of OECD countries between 1960 and 1974. During the 1970s and 1980s, 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 savings diminished after 1975 and in particular after 1990. Consistent with these findings, we find that the parameter estimates for the period 1960–1984 and 1985–2002 are statistically different at the 1% level in the pooled OLS specification.

Arguably, the demographic impact on current account balances is largest at low frequencies. In most regressions, we focus on the model's ability to explain current account fluctuations over 5-year intervals, thereby eliminating much of business cycle fluctuations. When we reduce the impact of high-frequency fluctuations even further by filtering the real-world data, as in Columns 3 and 6, the explanatory power of the model increases slightly. Furthermore, the high R^2 in the pooled

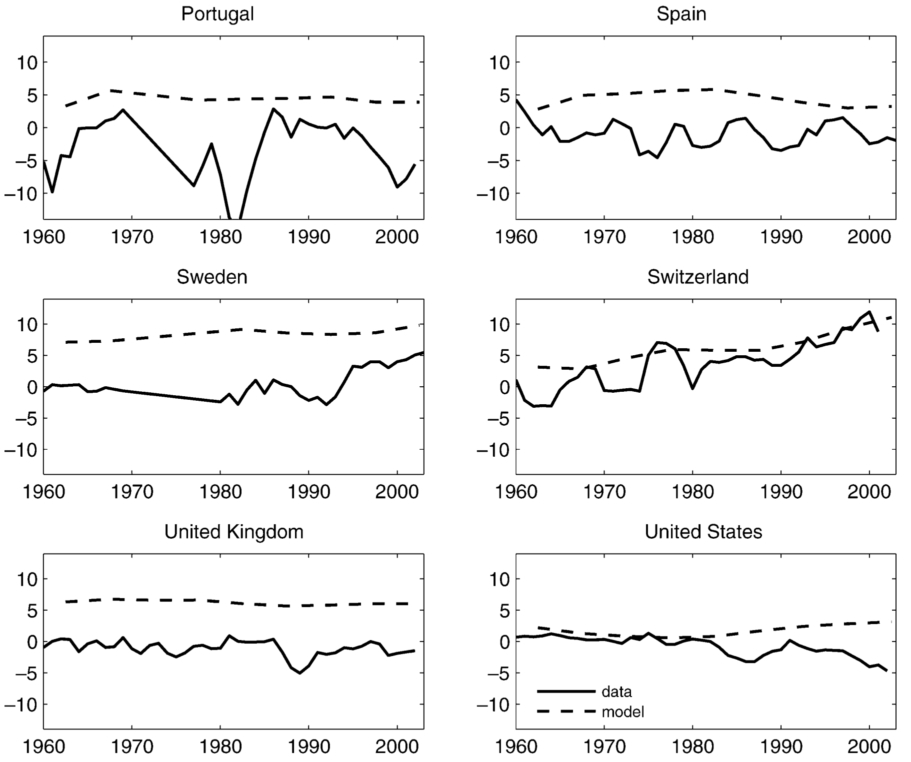

FIGURE 2C

CURRENT ACCOUNT BALANCE (% OF GDP)—DATA AND MODEL

TABLE 2

REGRESSION RESULTS FOR CURRENT ACCOUNT BASELINE SPECIFICATION

	Fixed Effects			Pooled OLS		
	(1)	(2)	(3)	(4)	(5)	(6)
Time period	60–02	85–02	60–02	60–02	85–02	60–02
Filter	No	No	Yes	No	No	Yes
Constant				−2.38	−3.15	−2.29
				(0.44)	(0.78)	(0.39)
β	0.42**	0.82**	0.38**	0.40**	0.60**	0.38**
	(0.09)	(0.25)	(0.07)	(0.08)	(0.12)	(0.07)
$\beta_{85-02} - \beta_{60-84}$		0.50			0.49**	
		(0.30)			(0.16)	
# obs.	159	72	159	159	72	159
R^2	0.49	0.70	0.60	0.14	0.27	0.16
R^2_{within}	0.13	0.17	0.16			

NOTE: R^2_{within} is the variance explained by X only (i.e., fixed effects not included). Standard deviations in parantheses.
** Significant at the 1% levels.

regressions, in particular for the latter period, indicate that the model does not only capture fluctuations in the current account balance over time, but that it also explains level differences between countries.

In Table 3, we report the results of a number of robustness checks based on the fixed effects panel specification.[15] We first examine the importance of adjustment costs by removing adjustment costs ($\xi = 0$, Columns 1 and 2) and by setting adjustment costs to twice the benchmark value ($\xi = 2$, Columns 3 and 4). The results for the full sample are unaffected, but we see that the estimate of β is closer to unity for the 1985–2002 period when adjustment costs are high. Next, we exclude the "rest of the world" and only include the OECD countries in the model calibration (Columns 5 and 6). The regressions now result in less significant estimates and lower explanatory power, but the point estimates for β are still positive and higher in the latter period. The effects of removing the pension system (Columns 7 and 8) and reducing risk aversion to unity (Columns 9 and 10) are negligible.

The real-world current account data are displayed in Figure 2, together with the values generated by the simulation model. 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 toward 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 1990s. 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 the demographic development been an important factor behind these capital flows? Our model suggests that it indeed may have been. The bottom panels of Figure 3 show capital flows implied by two model specifications. The Japanese current account balance after 1980 is larger than the American balance for both specifications. But the United States counterfactually runs current account surpluses during the 1980s and 1990s according to the baseline specification. The developing world is the primary recipient of capital in this model specification. By focusing only on OECD countries (the lower right panel), we bring the model implications for both countries more in line with the data.[16]

[15] See Domeij and Flodén (2005) for further robustness checks. We have also examined the effect of using filtered dependent data in all other regressions (not reported). The pattern is consistently that filtered data increase explanatory power slightly and reduce parameter estimates and standard errors slightly.

[16] When excluding developing countries, our model predicts capital flows for the United States and Japan that are similar to those in Feroli (2003) and Henriksen (2002). Neither Feroli nor Henriksen allows for capital flows to developing countries.

TABLE 3

REGRESSION RESULTS FOR CURRENT ACCOUNT, FIXED-EFFECTS PANEL VARIOUS MODEL SPECIFICATIONS

Variation	No Adj. Cost		High Adj. Cost		OECD		No Pensions		$\mu = 1$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Time period	60–02	85–02	60–02	85–02	60–02	85–02	60–02	85–02	60–02	85–02
β	0.40**	0.59**	0.43**	0.93**	0.26*	0.54	0.40**	0.82**	0.42**	0.77**
	(0.09)	(0.22)	(0.09)	(0.26)	(0.12)	(0.32)	(0.10)	(0.26)	(0.11)	(0.26)
$\beta_{85-02} - \beta_{60-84}$		0.28		0.62*		−0.03		0.47		0.43
		(0.26)		(0.31)		(0.34)		(0.30)		(0.31)
# obs.	159	72	159	72	159	72	159	72	159	72
R^2	0.49	0.68	0.49	0.71	0.44	0.65	0.48	0.69	0.47	0.69
R^2_{within}	0.12	0.12	0.13	0.19	0.03	0.05	0.11	0.16	0.09	0.15

*,** Significant at the 5% and 1% levels, respectively.

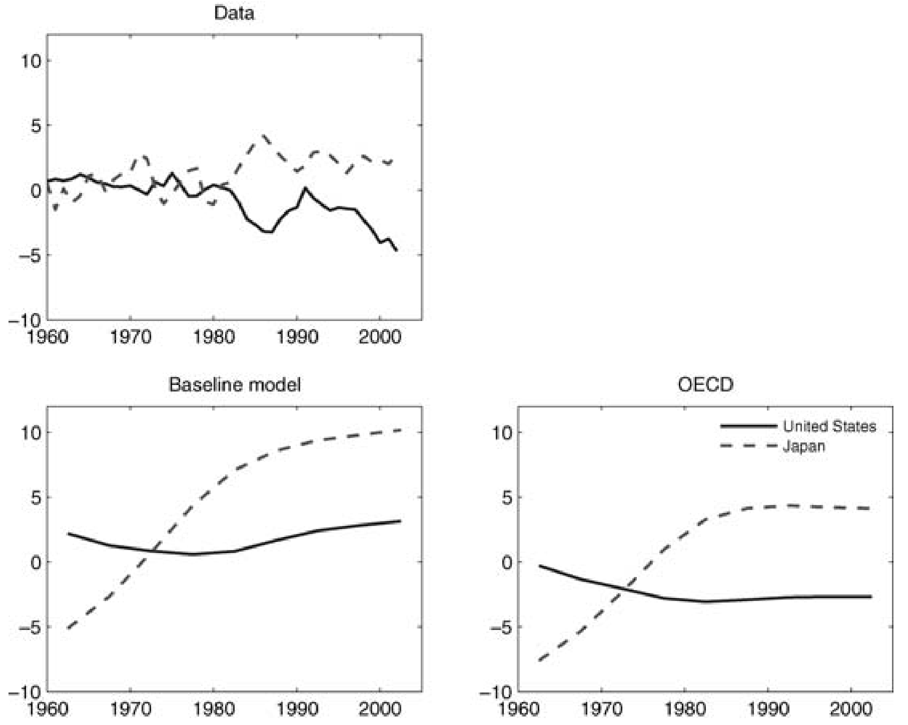

FIGURE 3

U.S. AND JAPANESE CURRENT ACCOUNT BALANCES (% OF GDP)

TABLE 4
REGRESSION RESULTS FOR SAVINGS AND INVESTMENT RATES FIXED EFFECTS PANEL

	Savings Rate		Investment Rate	
Dependent variable	(1)	(2)	(3)	(4)
Time period	60–02	85–02	60–02	85–02
Constant				
β	−0.49**	0.63*	0.45*	0.92**
	(0.13)	(0.31)	(0.21)	(0.33)
$\beta_{85-03} - \beta_{60-84}$		1.18*		−0.20
		(0.50)		(0.45)
# obs.	159	72	162	72
R^2	0.71	0.82	0.55	0.76
R^2_{within}	0.09	0.07	0.03	0.13

*,** Significant at the 5% and 1% levels, respectively.

Behind any change in the current account balance, there must be corresponding changes in savings or investment rates. To examine whether the model also explains fluctuations in savings and investment rates, we run regressions analogous to (8) and (9) but using model data for savings or investment rates as the explanatory X variable and OECD data on savings and investment rates as the dependent variables. The results reported in Table 4 show that point estimates for the recent time period still are close to unity and significantly different from zero. The model explains a smaller fraction of the variance in these variables than in the current account balance.

5. CONCLUDING DISCUSSION

Theory predicts that international capital flows are determined by many factors, for example, business cycle fluctuations, long-term growth trends, and volatile fiscal policy. In this article, we ignore all these factors and use a model where all capital flows are generated by changes in countries' population age structure, and find that the model can explain a substantial fraction of capital flows at low frequencies.

We do not argue that the other factors are unimportant. For example, anticipated changes in productivity or income may explain the current account deficits in Norway in the 1970s, and in Ireland and Portugal around 1980. But allowing for productivity changes in the model would be problematic. If we assume that such changes are perfectly predicted, capital flows would be dramatic and unrealistic (imagine, for example, Japanese households already in 1950 anticipating the country's future productivity development). To avoid such

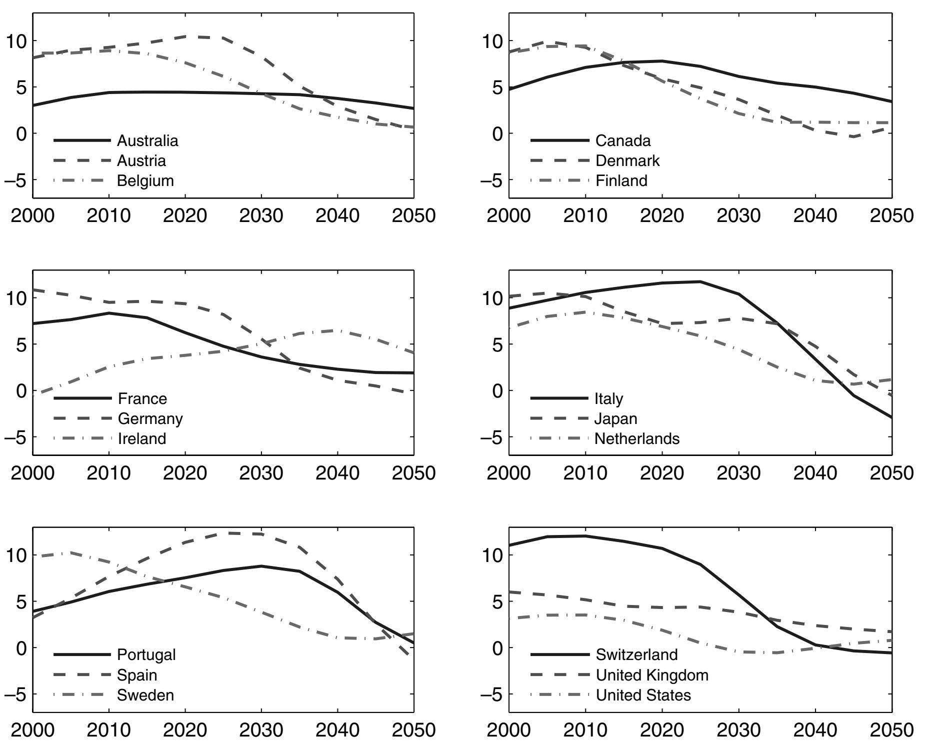

FIGURE 4

CURRENT ACCOUNT PROJECTIONS (% OF GDP)

information problems, we have isolated the effects from demographics to capital flows.

Since the model explains historical data rather well, it may also provide insights about how the demographic development will affect capital flows in the future. Figure 4 therefore 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, whereas the fraction of prime-age workers has already peaked or is just about to peak in the latter group of countries.

We want to point out that the current account projections reported in Figure 4 should not be used as forecasts of future capital flows. Our projections focus on the direct impact from demographics to capital flows and ignores indirect effects from policy changes, and 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.[17]

APPENDIX: DATA

Data for 1960–1969 are from OECD (1988) and data for 1970–2002 are from OECD (2004), and we use current price series for all national accounts data. We calculate the investment share (I) as ("increase in stocks" + "gross fixed capital formation")/GDP for the 1960–1969 period, and as "gross capital formation"/GDP for the 1970–2002 period. The savings rate (S) is calculated as (GNP + "net current transfers from the rest of the world" − "government final consumption expenditure" − "private final consumption expenditure")/GDP for the 1960–1969 period, and as (GNP + "net current transfers from the rest of the world" + "net capital transfers from the rest of the world" − "final consumption expenditure")/GDP for the 1970–2002 period. The current account balance as a fraction of GDP is then calculated as $CA = S - I$.

In Columns 3 and 6 in Table 2, we use filtered real-world data as the dependent variable. As before, $CA_{i,t}$ is the average current account balance relative to GDP for that 5-year period. We then calculate $\overline{CA}_{i,t}$ as $0.25 \times CA_{i,t-1} + 0.50 \times CA_{i,t} + 0.25 \times CA_{i,t+1}$. If the value for $CA_{i,t}$ is missing, we set a missing value for $\overline{CA}_{i,t}$, but if the value for $CA_{i,t-1}$ or $CA_{i,t+1}$ is missing, we use the available observations and adjust the weights. For example, if $t = 1960$ values for $t = 1955$ are missing, and we calculate $\overline{CA}_{i,1960} = (0.50 \times CA_{i,1960} + 0.25 \times CA_{i,1965})/0.75$. Columns 3 and 6 report results with $\overline{CA}_{i,t}$ as the dependent variable.

[17] Börsch-Supan et al. (2004) examine how pension reforms would affect future capital flows.

REFERENCES

ATTANASIO, O., AND G. VIOLANTE, "The Demographic Transition in Closed and Open Economy: A Tale of Two Regions," Working Paper No. 412, Research Department, Inter-American Development Bank, Washington, 2000.

AUERBACH, A. J., AND L. J. KOTLIKOFF, *Dynamic Fiscal Policy* (Cambridge, UK: Cambridge University Press, 1987).

——, ——, R. P. HAGEMANN, AND G. NICOLETTI, "The Economic Dynamics of an Ageing Population: The Case of Four OECD Countries," Working Paper No. 62, Department of Economics and Statistics, OECD, Paris, 1989.

BACKUS, D. K., P. J. KEHOE, AND F. E. KYDLAND, "International Business Cycles: Theory and Evidence," in T. F. Cooley, ed., *Frontiers of Business Cycle Research* (Princeton: Princeton University Press, 1995).

BELL, F. C., A. H. WADE, AND S. C. GOSS, "Life Tables for the United States Social Security Area 1900-2080," Actuarial Study No. 107, U.S. Department of Health and Human Services, 1992.

BLANCHARD, O., AND F. GIAVAZZI, "Current Account Deficits in the Euro Area: The End of the Feldstein Horioka Puzzle?" *Brookings Papers on Economic Activity* 2 (2002), 147–209.

BÖRSCH-SUPAN, A., A. LUDWIG, AND J. WINTER, "Aging, Pension Reform, and Capital Flows: A Multi-Country Simulation Model," Mimeo, Mannheim Research Institute for the Economics of Aging, 2004.

BROOKS, R., "Population Aging and Global Capital Flows in a Parallel Universe," *IMF Staff Papers* 50 (2003), 200–21.

COOLEY, T. F., AND E. C. PRESCOTT, "Economic Growth and Business Cycles," in T. F. Cooley, ed., *Frontiers of Business Cycle Research* (Princeton: Princeton University Press, 1995).

CUTLER, D. M., J. M. POTERBA, L. M. SHEINER, AND L. H. SUMMERS, "An Aging Society: Opportunity or Challenge?" *Brookings Papers on Economic Activity* 1 (1990), 1–73.

DOMEIJ, D., AND M. FLODÉN, "More on Population Aging and International Capital Flows," Mimeo, Stockholm School of Economics, 2005.

EBERLY, J. C., "International Evidence on Investment and Fundamentals," *European Economic Review* 41 (1997), 1055–78.

FAIR, R. C., AND K. M. DOMINGUEZ, "Effects of the Changing U.S. Age Distribution on Macroeconomic Equations," *American Economic Review* 81 (1991), 1276–94.

FELDSTEIN, M., AND C. HORIOKA, "Domestic Saving and International Capital Flows," *Economic Journal* 90 (1980), 314–29.

FERNÁNDEZ-VILLAVERDE, J., AND D. KRUEGER, "Consumption over the Life Cycle: Some Facts from the Consumer Expenditure Survey Data," Mimeo, University of Pennsylvania, 2003.

FEROLI, M., "Capital Flows among the G-7 Nations: A Demographic Perspective," Finance and Economics Discussion Series 2003-54, Board of Governors of the Federal Reserve System, 2003.

FLODÉN, M., "Public Saving and Policy Coordination in Aging Economies," *Scandinavian Journal of Economics* 105 (2003), 379–400.

FULLERTON, H. N. JR., "Labor Force Participation: 75 Years of Change, 1950–98 and 1998-2025," *Monthly Labor Review* 122 (1999), 3–12.

HANSEN, G. D., "The Cyclical and Secular Behaviour of the Labor Input: Comparing Efficiency Units and Hours Worked," *Journal of Applied Econometrics* 8 (1993), 71–80.

HENRIKSEN, E. R., "A Demographic Explanation of U.S. and Japanese Current Account Behavior," Mimeo, Carnegie Mellon University, 2002.

HIGGINS, M., "Demography, National Savings, and International Capital Flows," *International Economic Review* 39 (1998), 343–69.

——, AND J. G. WILLIAMSON, "Age Structure Dynamics in Asia and Dependence on Foreign Capital," *Population and Development Review* 23 (1997), 261–93.
LANE, P. R., AND G. M. MILESI-FERRETTI, "Long-Term Capital Movements," *NBER Macroeconomics Annual* 1 (2001), 73–116.
MADDISON, A., *The World Economy: A Millennial Perspective* (Paris: OECD Development Centre Studies, 2001).
OECD, *The OECD List of Social Indicators* (Paris: OECD, 1982).
——, *National Accounts 1960–1986: Main Aggregates, Volume I* (Paris: OECD, 1988).
——, *Annual National Accounts: Main Aggregates, Volume I, Release 02* (Paris: OECD, 2004).
UNITED NATIONS, *The 2002 Revision Population Database*, http://esa.un.org/unpp/, 2002.
WORLD BANK, *Nehru and Dhareshwa Dataset* (Washington: The World Bank Group, 1995).