A Party Without A Hangover?

On the Effects of U.S. Government Deficits

Michael Kumhof, International Monetary Fund

Douglas Laxton, International Monetary Fund

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Abstract

This paper develops a 2-country non-Ricardian overlapping generations model suitable for the joint evaluation of monetary and fiscal policies. Ricardian equivalence does not hold because of consumers with finite economic lifetimes and lifecycle income that are myopic with respect to future tax liabilities. We use the model to investigate the implications of a permanent increase in government deficits and debt in the U.S. and find that such a policy results in significant crowding-out effects both in the U.S. and the rest of the world by reducing world savings and raising the world real interest rate. It also leads to a very sizeable U.S. current account deterioration, especially in the medium and long term. We critique conventional models that rely on the infinite horizon model and show that such models are ill-equipped to deal with fiscal issues that involve permanent changes in government debt. In addition our model offers more sensible predictions regarding the effects of changes in government infrastructure investment expenditures, which have very different effects from the conventionally assumed wasteful government expenditures. Finally we study the effects of lower U.S. and higher rest of the world private sector savings rates. The latter is a candidate explanation for the currently observed low world real interest rates despite very large U.S. current account deficits.

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1 Introduction

The short-term expansionary effects of fiscal deficits and the medium- and long-term crowding-out effects of the resulting increased government debt continue to be topics of considerable interest in policymaking circles. In an age of increasing macroeconomic interdependence across countries this interest is no longer exclusively motivated by the study of individual economies but also by spillovers between multiple economies. Probably the most pressing example, and the subject of this paper, is the concern with U.S. fiscal deficits in the context of global current account imbalances. The question we ask is whether the post-2001 deterioration in U.S. fiscal balances should be seen as a major contributing factor to the simultaneous further deterioration in current account balances. Or conversely, would a U.S. fiscal consolidation make a sizeable contribution to the resolution of current account imbalances? The analytical framework we use to answer these questions also allows us to explore the likely short- and longer-run effect of fiscal policy on real interest rates and on real activity.

In this context, recent model-based estimates derived from the Federal Reserve Board's SIGMA model and the IMF's Global Economy Model (GEM) have attracted considerable attention in policymaking circles. The estimates from both of these institutions are based on a new generation of open economy monetary business cycle models with both nominal and real rigidities that are being deployed rapidly in central banks to replace the previous generation of models, which were not based on explicit microfoundations. While we argue that this class of models is well suited to address many monetary policy issues, their Ricardian nature makes them much less suitable for addressing fiscal issues such as the crowding-out effects of a permanent increase in public debt. Indeed, the pure predictions of both of these models would suggest that U.S. fiscal deficits would have very small medium- and long-term effects on the current account balance and on world savings.¹ It is important to emphasize that the results of the IMF analysis using GEM suggest larger and more sustained effects than the Federal Reserve Board's SIGMA model because the IMF's scenarios assume that the desired net foreign liability position will shift in response to higher levels of government debt—see Faruquee and others (2005).

¹ For documentation and applications using the Fed's SIGMA see Erceg, Guerrieri, and Gust, (2005a, b) and for the IMF's GEM see Faruquee and others (2005). Both of these models have been used actively in policymaking discussions—see, for example, Bernanke (2005) and publications of the IMF's World Economic Outlook by Laxton and Milesi-Ferretti (2005) and Kumhof and Laxton (2006).

Standard models in this class specify an infinitely-lived representative agent in a rational expectations setting and with nondistortionary taxation, which implies that the Ricardian equivalence hypothesis holds.² But as argued in several important papers³, such models face difficulties in adequately replicating the dynamic effects of fiscal policy. In view of the importance of fiscal policy problems, the idea of bringing models with microfoundations as rigorous as those of open economy monetary business cycle models to the analysis of fiscal policies is very appealing.⁴ But to do so the microfoundations of non-Ricardian household and firm behavior need to be built while maintaining the nominal and real rigidities of existing models.

The candidate non-Ricardian features known from the literature are overlapping generations models following Blanchard (1985) and Weil (1989) and liquidity constrained agents following Gali, López-Salido and Vallés (2003). While liquidity constraints for a subset of agents are capable of producing powerful short-run effects of fiscal policy, there are no medium- or long-run crowding out effects of government debt when the remaining agents are infinitely lived, and there is no endogenous determination of net foreign liability positions as a function of government debt. But both crowding out and the link between government debt and foreign debt are clearly critical to understanding the connection between fiscal and current account deficits that is the object of our study. An overlapping generations structure on the other hand does lead to powerful fiscal policy effects in the long- as well as the short-run, and it does endogenously determine the net foreign liabilities position of countries as a function of government debt. It is therefore a critical ingredient of this paper.

Bringing an overlapping generations setting into an open economy monetary business cycle model has been undertaken by Ghironi (2003a,b) and by Ganelli (2003a). The former does not consider the effects of government debt, but shows that an overlapping generations structure following Blanchard (1985) and Weil (1989) ensures the existence of a well-defined steady state for net foreign liability positions (see also Buiter (1981)). Our model bears the closest resemblance to Ganelli (2003a), which is the first attempt to analyze alternative fiscal policies in an open economy monetary business

² This literature is very large. For some examples see Obstfeld and Rogoff (1995, 1996), Betts and Devereux (2001), Caselli(2001), Corsetti and Pesenti (2001), Ganelli (2003b) and Laxton and Pesenti (2003).

³ See Fatas and Mihov (2001), Blanchard and Perotti (2002), Gali, López-Salido and Vallés (2003).

⁴ See Ganelli and Lane (2002) for a discussion about the need to give a greater role to fiscal policy in these models.

cycle model with finite lives.⁵ Our model adds to this several additional non-Ricardian features, a very general specification of preferences and technologies, and a number of nominal and real rigidities that are critical for the quantitative implications of our policy simulations. We show that the resulting model nests the extreme Ricardian predictions of models such as SIGMA and GEM when the planning horizon is assumed to be infinite. We then use the model to help us understand some of the potential implications of the recent build up in government debt.

Our model has four non-Ricardian features. First, it features overlapping generations agents with finite economic lifetimes. The consequence is that today's agents discount future tax liabilities at a high rate because they do not attach a high probability to being responsible for them. Second, the model exhibits a stylized form of life-cycle income patterns whereby agents exhibit declining labor productivity throughout their lifetimes. They therefore discount future labor income tax liabilities at an even higher rate because they expect to be supplying less effective labor in the future. Third, the model features liquidity constrained agents who do not have access to financial markets to smooth consumption, so that they have to vary their consumption one-for-one with their after-tax labor income. And fourth, labor and consumption taxes are distortionary because labor effort and consumption respond to relative price movements that result directly from tax wedges.

The combination of these features imply that any change in taxes and debt has very significant real effects. But in addition we are interested in a meaningful analysis of the spending component of fiscal policy. In this context, another important simplifying assumption of models such as SIGMA and GEM is that they assume that all government expenditures are wasted and do not add to productive capacity. This is clearly far too simple for a complete analysis of the potential costs that would be associated with future cuts in government expenditures instead of higher taxes. We therefore also extend the standard model to allow for government investment in infrastructure to show the risk that would be associated with cuts that were to fall on these expenditures.

As for preferences and technologies, our utility function goes beyond the log case studied in Ganelli (2003a) and thereby allows us to highlight the critical role of the intertemporal elasticity of substitution in the propagation of fiscal shocks. Furthermore, the labor supply decision is endogenous. Another critical ingredient is endogenous capital formation, which provides

⁵ Ganelli (2003a) is in turn closely related to the work of Frenkel and Razin (1992).

an additional channel through which government debt can crowd out economic activity. The specification of technology contains both traded and nontraded goods. Furthermore, the model economy features a full set of nominal and real rigidities typical of existing monetary business cycle models. Nominal rigidities go beyond the simple case of one-period price rigidities to allow for meaningful business cycle dynamics. They include multiple levels of sticky goods prices as well as sticky nominal wages. Local currency pricing is allowed for. Real rigidities include habit persistence in consumption, investment adjustment costs, and import adjustment costs.

The combination of non-Ricardian features and meaningful rigidities allows us to introduce two policy reaction functions that interact with one another. First, there is a monetary policy reaction function familiar from state-of-the-art monetary theory, and whose role is to stabilize inflation and output. And second, a fiscal policy rule stabilizes government debt. The short-run dynamics of the model is determined by the interaction of both of these rules, while the medium- and long-run dynamics depends only on the fiscal rule.

The remainder of this paper is organized as follows. Section 2 summarizes the theoretical structure of the model leaving the details of the model's equations and derivation of optimality conditions to a detailed Technical Appendix. Section 3 discusses a base-case calibration of the model and Section 4 then compares the model's near-term and long-term predictions of the implications of higher levels of government debt with the predictions of standard infinite horizon models augmented with liquidity-constrained consumers. We show that under plausible assumptions for agents' planning horizons there is an economically significant link between government deficits and current account deficits with important crowding out effects from deficit-financed tax cuts in both the United States and the rest of the world. Section 4 also studies the implications of permanent cuts in government investment and government consumption showing that the former permanently reduces output while the latter raises it. Section 5 then uses the model to look at some specific issues that have drawn attention in the recent debate about the causes and consequences of the U.S. current account deficits. In particular, after showing the dynamic implications of alternative fiscal policies that involve permanent changes in government debt we consider two scenarios involving fundamental changes in private sector behavior that can account for the combination of low real interest rates and the large and persistent projected decline in the U.S. net foreign liability position. Section 6 concludes.

2 The Model

The world consists of 2 countries, the United States (U.S.) and the rest of the world (RW). The flow of goods and factors between the different domestic sectors, and between the two economies, is illustrated in Figure 1. When discussing the behavior of agents in one country alone we will not identify the country by additional notation. When the interaction between two countries is discussed we identify the U.S. by an asterisk.

Each country is populated by two types of households, both of which consume final retailed output and supply labor to unions. First, there are overlapping generations households with finite planning horizons as in Blanchard (1985), and exhibiting external habit persistence. In each period, $n^*(1 - \psi^*)(1 - \theta)$ and $n(1 - \psi)(1 - \theta)$ of such individuals are born in the U.S. and RW, respectively. Second, there are liquidity constrained households who do not have access to financial markets, and who consequently are forced to consume their after tax income in every period. The number of such agents born in each period in the U.S. and in RW is $n^*\psi^*(1 - \theta)$ and $n\psi(1 - \theta)$. Each agent faces a constant probability of death $(1 - \theta)$ in each period, which implies an average planning horizon of $1/(1 - \theta)$.⁶ This implies that the total number of agents in the U.S. and in RW is n^* and n . In addition to the probability of death households also experience labor productivity that declines at a constant rate over their lifetimes. The absence of explicit demographics in our model permits this simplified treatment of life-cycle income profiles, which adds another powerful channel through which fiscal policies have non-Ricardian effects. Households of both types are subject to a uniform labor income tax and a uniform consumption tax. We will denote variables pertaining to these two groups of households by *OLG* and *LIQ*.

Firms are managed in accordance with the preferences of their owners, myopic *OLG* households, and they therefore also have finite planning horizons. Each country's primary production is carried out by manufacturers producing tradable and nontradable goods. Manufacturers buy investment goods from distributors and labor from unions. Unions are subject to nominal wage rigidities and buy labor services from households. Manufacturers are subject to nominal rigidities in price setting

⁶ In general we allow for the possibility that agents may be more myopic than what would be suggested by a planning horizon based on a biological probability of death.

as well as real rigidities in capital accumulation. Manufacturers' domestic sales go to domestic distributors. Their foreign sales go to import agents that are domestically owned but located in each export destination country. Import agents in turn sell their output to foreign distributors subject to nominal rigidities in foreign currency (pricing-to-market). Distributors first assemble manufactured nontradable and home and foreign tradable goods, where changes in the volume of imported inputs are subject to an adjustment cost. This private sector output is then combined with a publicly provided capital stock (infrastructure) as an essential further input. This capital stock is maintained through government investment expenditure that is financed by tax revenue. The combined domestic private and public sector output is then combined with foreign final output to produce domestic final output. Foreign final output is purchased through a second set of import agents that can price to the domestic market, and again changes in the volume of these imported goods are subject to an adjustment cost. Domestic final output is sold to domestic consumption goods retailers, domestic manufacturing firms (in their role as investors), the domestic government, and to final goods import agents located in foreign economies. Distributors are subject to another layer of nominal rigidities in price setting. Retailers, who are also monopolistically competitive, face real instead of nominal rigidities. While their output prices are flexible they find it costly to rapidly adjust their sales volume. This feature contributes to generating inertial consumption dynamics.

Asset markets are incomplete. There is complete home bias in government debt, which takes the form of nominally non-contingent one-period bonds denominated in domestic currency. The only assets traded internationally are nominally non-contingent one-period bonds denominated in the currency of the U.S. There is also complete home bias in ownership of domestic firms. In addition equity is not traded in domestic financial markets, instead households receive lump-sum dividend payments. This assumption is required to support our assumption that firm and not just household preferences feature myopia.

The world economy grows at the constant rate $g = T_t/T_{t-1}$, where T_t is the level of labor augmenting world technology. The model's real variables, say x_t , therefore have to be rescaled by T_t , where we will use the notation $\tilde{x}_t = x_t/T_t$. The steady state of $\tilde{x}_t$ is denoted by $\bar{x}$. To avoid complicating the presentation we only show this normalization for optimality conditions. In our derivations per capita variables are only considered at the level of disaggregated households. All

aggregate variables represent absolute rather than per capita quantities. The paper focuses on the perfect foresight case, but extensions to log-linear approximations are trivial, as explained in the Technical Appendix. The latter also contains a much more detailed exposition of the algebra and optimality conditions than is possible in this paper.

2.1 Households

2.1.1 Overlapping Generations Households

We first describe the optimization problem of *OLG* households. A representative member of this group and of age a derives utility at time t from consumption $c_{a,t}^{OLG}$ relative to the consumption habit $h_{a,t}^{OLG}$, leisure $(1 - \ell_{a,t}^{OLG})$ (where 1 is the time endowment), and real balances $(M_{a,t}/P_t^R)$ (where P_t^R is the retail price index). The lifetime expected utility of a representative household of age a at time t has the form

$$E_t \sum_{s=0}^{\infty} (\beta\theta)^s \left[\frac{1}{1-\gamma} \left(\left(\frac{c_{a+s,t+s}^{OLG}}{h_{a+s,t+s}^{OLG}} \right)^{\eta^{OLG}} (1 - \ell_{a+s,t+s}^{OLG})^{1-\eta^{OLG}} \right)^{1-\gamma} + \frac{u^m}{1-\gamma} \left(\frac{M_{a+s,t+s}}{P_{t+s}^R} \right)^{1-\gamma} \right], \quad (1)$$

where $\beta < 1$ is the discount factor, $\theta < 1$ determines the degree of myopia, $\gamma > 0$ is the coefficient of relative risk aversion, and $0 < \eta^{OLG} < 1$. As for money demand, in the following analysis we will only consider the case of the cashless limit advocated by Woodford (2003), where $u^m \rightarrow 0$. The Technical Appendix discusses this in more detail. The consumption habit is given by lagged per capita consumption of *OLG* households

$$h_{a,t}^{OLG} = \left(\frac{c_{t-1}^{OLG}}{n(1-\psi)} \right)^v, \quad (2)$$

where v parameterizes the degree of habit persistence. This is the external, catching up with the Joneses variety of habit persistence. Consumption $c_{a,t}^{OLG}$ is given by a CES aggregate over retailed consumption goods varieties $c_{a,t}^{OLG}(i)$, with elasticity of substitution σ_R :

$$c_{a,t}^{OLG} = \left(\int_0^1 (c_{a,t}^{OLG}(i))^{\frac{\sigma_R-1}{\sigma_R}} di \right)^{\frac{\sigma_R}{\sigma_R-1}}. \quad (3)$$

This gives rise to a demand for individual varieties

$$c_{a,t}^{OLG}(i) = \left(\frac{P_t^R(i)}{P_t^R} \right)^{-\sigma_R} c_{a,t}^{OLG}, \quad (4)$$

where $P_t^R(i)$ is the retail price of variety i , and the aggregate retail price level P_t^R is given by

$$P_t^R = \left(\int_0^1 (P_t^R(i))^{1-\sigma_R} di \right)^{\frac{1}{1-\sigma_R}}. \quad (5)$$

A household can hold two types of bonds, domestic government bonds $B_{a,t}$ denominated in domestic currency, and foreign bonds denominated in the currency of the U.S. The nominal exchange rate vis-a-vis the U.S. is denoted by $\mathcal{E}_t$, and $\mathcal{E}_t F_{a,t}$ are nominal net foreign asset holdings in terms of domestic currency. Of course $\mathcal{E}_t^* = 1$. In each case the time subscript t denotes financial claims held from period t to period $t + 1$. Gross nominal interest rates on U.S. and RW currency denominated assets held from t to $t + 1$ are i_t^* and i_t . Participation by households in financial markets requires that they enter into an insurance contract with companies that pay a premium of $\frac{(1-\theta)}{\theta}$ on a household's financial wealth for each period in which that household is alive, and that encash the household's entire financial wealth in the event of his death.⁷

Apart from returns on financial assets, households also receive labor and dividend income. Households sell their labor to unions that are competitive in their input market and monopolistically competitive in their output market, vis-à-vis manufacturing firms. The productivity of an individual household's labor declines throughout his lifetime, with productivity $\Phi_{a,t} = \Phi_a$ of age group a given by

$$\Phi_a = \kappa \chi^a, \quad (6)$$

where $\chi < 1$. The overall population's average productivity is assumed without loss of generality to be equal to one. Household pre-tax nominal labor income is therefore $W_t \Phi_{a,t} \ell_{a,t}^{OLG}$. Dividends are received in a lump-sum fashion from all firms in the nontradables (N) and tradables (T) manufacturing sectors, the distribution (D), retail (R) and import agent (M) sectors, and from all unions (U) in the labor market, with after-tax nominal dividends received from firm/union i denoted by $D_{a,t}^j(i)$, $j = N, T, D, R, U, M$. OLG households are liable to pay lump-sum transfers $\tau_{T,a,t}^{OLG}$ to the government, which in turn redistributes them to the relatively less well off LIQ agents. Household labor income is taxed at the rate $\tau_{L,t}$ and consumption is taxed at the rate $\tau_{c,t}$. It is assumed that retailers, due to adjustment costs, periodically offer incentives (or disincentives) that

⁷ The turnover in the population is assumed to be large enough that the income receipts of the insurance companies exactly equal their payouts.

are incorporated into the effective retail purchase price P_t^R . The consumption tax $\tau_{c,t}$ is however assumed to be payable on the pre-incentive price P_t , which equals the price at which retailers purchase consumption goods from distributors. We choose the aggregate final goods price level P_t (determined by distributors) as our numeraire.

We denote the real wage by $w_t = W_t/P_t$, the nominal price, relative price and gross inflation rate of any good x by P_t^x , $p_t^x = P_t^x/P_t$ and $\pi_t^x = P_t^x/P_{t-1}^x$, gross final goods inflation by $\pi_t = P_t/P_{t-1}$, and gross nominal exchange rate depreciation by $\varepsilon_t = \mathcal{E}_t/\mathcal{E}_{t-1}$.⁸ The production based real exchange rate vis-a-vis the U.S. is $e_t = (\mathcal{E}_t P_t^*)/P_t$, with $e_t^* = 1$. We adopt the convention that each nominal asset is deflated by the final output price index of the currency of its denomination, so that real domestic bonds are $b_t = B_t/P_t$ and real internationally traded bonds are $f_t = F_t/P_t^*$. The real interest rate in terms of final output is $r_t = i_t/\pi_{t+1}$.

The household's budget constraint in nominal terms is

$$P_t^R c_{a,t}^{OLG} + P_t c_{a,t}^{OLG} \tau_{c,t} + B_{a,t} + \mathcal{E}_t F_{a,t} = \frac{1}{\theta} [i_{t-1} B_{a-1,t-1} + i_{t-1}^* \mathcal{E}_t F_{a-1,t-1}] \quad (7)$$

$$+ W_t \Phi_{a,t} \ell_{a,t}^{OLG} (1 - \tau_{L,t}) + \sum_{j=N,T,D,R,U,M} \int_0^1 D_{a,t}^j(i) di - \tau_{T,a,t}^{OLG}.$$

The *OLG* household maximizes (1) subject to (2), (3), (6) and (7). The derivation of the first-order conditions for each generation, and aggregation across generations, is discussed in detail in the Technical Appendix. Aggregation takes account of the size of each age cohort at the time of birth, and of the remaining size of each generation. Using the example of overlapping generations households' consumption, we have

$$c_t^{OLG} = n(1 - \psi)(1 - \theta) \sum_{a=0}^{\infty} \theta^a c_{a,t}^{OLG}. \quad (8)$$

The first-order conditions for the goods varieties and for the consumption/leisure choice are, after rescaling by technology, given by

$$\check{c}_t^{OLG}(i) = \left(\frac{P_t^R(i)}{P_t^R} \right)^{-\sigma_R} \check{c}_t^{OLG}, \quad (9)$$

$$\frac{\check{c}_t^{OLG}}{n(1 - \psi) - \ell_t^{OLG}} = \frac{\eta^{OLG}}{1 - \eta^{OLG}} \check{w}_t \frac{(1 - \tau_{L,t})}{(p_t^R + \tau_{c,t})}. \quad (10)$$

⁸ We adopt the convention throughout the paper that all nominal price level variables are written in upper case letters, and that all relative price variables are written in lower case letters.

The arbitrage condition for foreign currency bonds (the uncovered interest parity relation) is

$$i_t = i_t^* \varepsilon_{t+1} . \quad (11)$$

We now discuss a key condition of the model. It expresses current aggregate consumption of *OLG* households as a function of their real aggregate financial wealth $f w_t$ and human wealth $h w_t$, with the marginal propensity to consume of out of wealth given by $1/\Theta_t$. Human wealth is in turn composed of $h w_t^L$, the expected present discounted value of households' time endowments evaluated at the after-tax real wage, $h w_t^K$, the expected present discounted value of capital or dividend income plus the expected present discounted value of lump-sum transfers to or from the government τ_{T_t} . After rescaling by technology we have

$$\check{c}_t^{OLG} \Theta_t = \check{f} w_t + \check{h} w_t , \quad (12)$$

where

$$\check{f} w_t = \frac{1}{\pi_t g} [i_{t-1} \check{b}_{t-1} + i_{t-1}^* \varepsilon_t \check{f}_{t-1} e_{t-1}] , \quad (13)$$

$$\check{h} w_t = \check{h} w_t^L + \check{h} w_t^K , \quad (14)$$

$$\check{h} w_t^L = (n(1 - \psi)(\check{w}_t(1 - \tau_{L,t}))) + \frac{\theta \chi g}{r_t} \check{h} w_{t+1}^L , \quad (15)$$

$$\check{h} w_t^K = (\check{d}_t^N + \check{d}_t^T + \check{d}_t^D + \check{d}_t^R + \check{d}_t^U + \check{d}_t^M - \check{\tau}_{T,t}) + \frac{\theta g}{r_t} \check{h} w_{t+1}^K , \quad (16)$$

$$\Theta_t = \frac{p_t^R + \tau_{c,t}}{\eta^{OLG}} + \frac{\theta j_t}{r_t} \Theta_{t+1} , \quad (17)$$

$$\begin{aligned} j_t = & \left(\beta \frac{i_t}{\pi_{t+1}} \right)^{\frac{1}{\gamma}} \left(\frac{p_t^R + \tau_{c,t}}{p_{t+1}^R + \tau_{c,t+1}} \right)^{\frac{1}{\gamma}} \left(\frac{\check{w}_{t+1} g (1 - \tau_{L,t+1}) (p_t^R + \tau_{c,t})}{\check{w}_t (1 - \tau_{L,t}) (p_{t+1}^R + \tau_{c,t+1})} \right)^{(1 - \eta^{OLG})(1 - \frac{1}{\gamma})} \\ & \left(\frac{\check{c}_t^{OLG} g}{\check{c}_{t-1}^{OLG}} \right)^{v \eta^{OLG} (1 - \frac{1}{\gamma})} \chi^{(1 - \eta^{OLG})(1 - \frac{1}{\gamma})} . \end{aligned} \quad (18)$$

The intuition of (12) - (18) is as follows. Financial wealth (13) is equal to the domestic government's and foreign households' *current* financial liabilities. For the government debt portion, the government services these liabilities through different forms of taxation, and these *future* taxes are reflected in the

different components of human wealth (14) as well as in the marginal propensity to consume (17). But unlike the government, which is infinitely lived, an individual household factors in that he might not be around by the time higher future tax payments fall due. Hence *a household discounts future tax liabilities by a rate of at least r_t/θ , which is higher than the market rate r_t* , as reflected in the discount factors in (15), (16) and (17). The discount rate for the labor income component of human wealth is even higher at $r_t/\theta\chi$, due to the decline of labor incomes over individuals' lifetimes. The implication is that government debt is net wealth to the extent that households do not expect to become liable for the taxes necessary to service that debt. The more myopic households are, the greater the portion of outstanding government debt that they consider to be net wealth.

A fiscal expansion through lower taxes represents a tilting of the tax payment profile from the near future to the more distant future, so as to effect an increase in the debt stock. The government has to respect its intertemporal budget constraint in effecting this tilting, and this means that the expected present discounted value of its future primary surpluses has to remain equal to the current debt $i_{t-1}b_{t-1}/\pi_t$ *when future surpluses are discounted at the market interest rate r_t* . But when individual households discount future taxes at a higher rate than the government, the same tilting of the tax profile represents an increase in human wealth because it decreases the value of future taxes for which the household expects to be responsible. For a given marginal propensity to consume, this increase in human wealth leads to an increase in consumption.

The marginal propensity to consume $1/\Theta_t$ is, in the simplest case of logarithmic utility, exogenous labor supply and no consumption taxes, equal to $(1 - \beta\theta)$. For the case of endogenous labor supply, household wealth can be used to either enjoy leisure or to generate purchasing power to buy goods. The main determinant of the split between consumption and leisure is the consumption share parameter η^{OLG} , which explains its presence in the marginal propensity to consume (17). While other forms of taxation affect the different components of wealth, the time profile of consumption taxes affects the marginal propensity to consume, increasing it with a balanced-budget shift of such taxes from the present to the future. The intertemporal elasticity of substitution $1/\gamma$ is another key parameter for the marginal propensity to consume. As can be seen in (18) it determines among other things the responsiveness of consumption to changes in the real interest rate r and the decline rate of labor income χ . For the conventional assumption of $\gamma > 1$, the income effect of an increase in r or

a decrease in χ is stronger than the substitution effect and tends to increase the marginal propensity to consume, thereby partly offsetting the contractionary effects of a higher r or lower χ on human wealth $\tilde{h}w_t$. Expression (18) also reflects the effects of habit persistence on current consumption.

In our policy simulations we will compare our model to an infinite horizon representative agent alternative that is identical in all but two respects. First, the parameters θ and χ are assumed to be equal to one. Second, to nevertheless generate similar non-Ricardian behavior in the short run, the model will be calibrated with a higher share of *LIQ* households than the baseline model. As is well known, that type of model is unable to determine the steady state level of net foreign liabilities in linearized or perfect foresight environments, and it therefore also requires a third ancillary assumption whereby positive deviations from a target net foreign liabilities to GDP ratio raise the external interest rate faced by the country. As shown in the Technical Appendix, that model gives rise to an identical system of equations except for a (numerically small) change to the uncovered interest rate parity condition, and more importantly to a replacement of the consumption system (12)-(18) with the equation

$$\check{c}_{t+1}^{OLG} = \frac{j_t}{g} \check{c}_t^{OLG} , \quad (19)$$

where in (18) we set $\chi = 1$.

2.1.2 Liquidity Constrained Households

The objective function of *LIQ* households is assumed to be identical to that of *OLG* households except for the absence of money. But their budget constraint is different in that these agents can consume at most their current income, which consists of their after tax wage income plus government transfers $\tau_{T_{a,t}}^{LIQ}$. *LIQ* agents are not to be confused with the “rule of thumb” agents found in the literature, because unlike the latter they do solve an intratemporal optimization problem for their consumption-leisure choice. The aggregated first-order conditions for this problem, after rescaling by technology, are

$$\check{c}_t^{LIQ}(i) = \left(\frac{P_t^R(i)}{P_t^R} \right)^{-\sigma_R} \check{c}_t^{LIQ} , \quad (20)$$

$$\check{c}_t^{LIQ}(p_t^R + \tau_{c,t}) = \check{w}_t \ell_t^{LIQ}(1 - \tau_{L,t}) + \check{\tau}_{T,t} , \quad (21)$$

$$\frac{\check{c}_t^{LIQ}}{n\psi - \ell_t^{LIQ}} = \frac{\eta^{LIQ}}{1 - \eta^{LIQ}} \check{w}_t \frac{(1 - \tau_{L,t})}{(p_t^R + \tau_{c,t})}. \quad (22)$$

2.1.3 Aggregate Household Sector

To obtain aggregate consumption demand and labor supply we simply add the respective quantities for *OLG* and *LIQ* households:

$$C_t = c_t^{OLG} + c_t^{LIQ}, \quad (23)$$

$$L_t = \ell_t^{OLG} + \ell_t^{LIQ}. \quad (24)$$

2.2 Firms and Unions

In each sector there is a continuum of agents, indexed by $i \in [0, 1]$, that are perfectly competitive in their input markets and monopolistically competitive in their output markets. Their price setting is subject to nominal rigidities for manufacturers, unions, import agents and distributors, and subject to real rigidities for retailers. Manufacturers and distributors face a fixed cost of production that is calibrated to make the steady state shares of labor and capital in GDP consistent with the data. This becomes necessary because the model counterpart of the aggregate income share of capital equals not only the return to capital but also the profits of monopolistically competitive firms. Each sector pays out each period's net cash flow as dividends to *OLG* households. It maximizes the present discounted value of these dividends. The discount rate it applies in this maximization includes the parameter θ so as to equate the discount factor of firms θ/r_t with the pricing kernel for nonfinancial income streams of their owners, myopic households, which equals $\beta\theta (\lambda_{a+1,t+1}/\lambda_{a,t})$. This equality follows directly from *OLG* households' Euler equation $\lambda_{a,t} = \beta (\lambda_{a+1,t+1} r_t)$.

2.2.1 Manufacturers

There are two manufacturing sectors indexed by $J \in [N, T]$, and prices in these two sectors are indexed by $\tilde{J} \in [N, TH]$. Manufacturers buy labor from unions and capital from distributors. They sell goods to domestic distributors, to import agents abroad, and (for adjustment costs) back to manufacturers. All of these agents demand a CES aggregate of manufactured varieties, with elasticity

of substitution σ_J . The aggregate demand for variety i produced by sector J can then be derived by aggregating over all sources of demand. We obtain

$$Z_t^J(i) = \left(\frac{P_t^{\tilde{J}}(i)}{P_t^{\tilde{J}}} \right)^{-\sigma_J} Z_t^J, \quad (25)$$

where $P_t^{\tilde{J}}$ is defined similarly to (5), and where $Z_t^J(i)$ and Z_t^J remain to be specified by way of market clearing conditions. The technology of each manufacturing firm is given by a CES production function in capital $K_t^J(i)$ and union labor $U_t^J(i)$, with elasticity of substitution ξ_J and labor augmenting productivity T_t :

$$Z_t^J(i) = F(K_t^J(i), U_t^J(i)) = \left((1 - \alpha_J^U)^{\frac{1}{\xi_J}} (K_t^J(i))^{\frac{\xi_J-1}{\xi_J}} + (\alpha_J^U)^{\frac{1}{\xi_J}} (T_t U_t^J(i))^{\frac{\xi_J-1}{\xi_J}} \right)^{\frac{\xi_J}{\xi_J-1}}. \quad (26)$$

Manufacturing firms are subject to inflation adjustment costs $G_{P,t}^J(i)$. Following Ireland (2001) and Laxton and Pesenti (2003), they are quadratic in changes in the rate of inflation rather than in price levels, which helps to generate realistic inflation dynamics:

$$G_{P,t}^J(i) = \frac{\phi_{P^J}}{2} Z_t^J \left(\frac{\frac{P_t^{\tilde{J}}(i)}{P_{t-1}^{\tilde{J}}(i)}}{\frac{P_{t-1}^{\tilde{J}}}{P_{t-2}^{\tilde{J}}}} - 1 \right)^2. \quad (27)$$

Capital accumulation is subject to quadratic adjustment costs $G_{I,t}(i)$ in gross investment $I_t^J(i)$:

$$G_{I,t}^J(i) = \frac{\phi_I}{2} K_t^J(i) \left(\frac{I_t^J(i)}{K_t^J(i)} - \frac{I_{t-1}^J}{K_{t-1}^J} \right)^2. \quad (28)$$

The law of motion of capital is described by

$$K_{t+1}^J(i) = (1 - \delta) K_t^J(i) + I_t^J(i), \quad (29)$$

where δ represents the depreciation rate of capital. Dividends $D_t^J(i)$ equal nominal revenue $P_t^{\tilde{J}}(i)Z_t^J(i)$ minus nominal cash outflows. The latter include the wage bill $V_t U_t^J(i)$, where V_t is the aggregate wage rate charged by unions, investment $P_t I_t^J(i)$, investment adjustment costs $P_t G_{I,t}(i)$, a fixed cost $P_t^{\tilde{J}} T_t \omega^J$ and price adjustment costs $P_t^{\tilde{J}} G_{P,t}^J(i)$. The fixed resource cost arises as long as the firm chooses to produce positive output. Net output in sector J is therefore equal to $\max(0, Z_t^J(i) - T_t \omega^J)$. The optimization problem of each manufacturing firm is given by

$$\begin{aligned} & \text{Max} \\ & \{P_{t+s}^{\tilde{J}}(i), U_{t+s}^J(i), I_{t+s}^J(i), K_{t+s+1}^J(i)\}_{s=0}^{\infty} \sum_{s=0}^{\infty} \tilde{R}_{t,s} D_{t+s}^J(i), \end{aligned} \quad (30)$$

where

$$\tilde{R}_{t,s} = \Pi_{l=1}^s \frac{\theta}{i_{t+l-1}} \text{ for } s > 0 \text{ (} = 1 \text{ for } s = 0 \text{)}, \quad (31)$$

$$D_t^J(i) = P_t^{\tilde{J}}(i) Z_t^J(i) - V_t U_t^J(i) - P_t I_t^J(i) - P_t G_{I,t}^J(i) - P_t^{\tilde{J}} G_{P,t}^J(i) - P_t^{\tilde{J}} T_t \omega^J, \quad (32)$$

and subject to (25), (26), (27) and (28). The first-order conditions for this problem are derived in detail in the Technical Appendix. Apart from standard conditions for optimal choices of labor, investment and capital they include a Phillips curve equation for sectorial inflation $\pi_t^{\tilde{J}}$. We report it here partly for reference purposes, as it is identical in form to all other Phillips curves in the model. Letting λ_t^J be the real marginal cost of sector J output, we have

$$\begin{aligned} \left[\frac{\sigma_J}{\sigma_J - 1} \frac{\lambda_t^J}{p_t^{\tilde{J}}} - 1 \right] &= \frac{\phi_{P^J}}{\sigma_J - 1} \left(\frac{\pi_t^{\tilde{J}}}{\pi_{t-1}^{\tilde{J}}} \right) \left(\frac{\pi_t^{\tilde{J}}}{\pi_{t-1}^{\tilde{J}}} - 1 \right) \\ &- \frac{\theta g}{r_t} \frac{\phi_{P^J}}{\sigma_J - 1} \frac{p_{t+1}^{\tilde{J}}}{p_t^{\tilde{J}}} \frac{\tilde{Z}_{t+1}^J}{\tilde{Z}_t^J} \left(\frac{\pi_{t+1}^{\tilde{J}}}{\pi_t^{\tilde{J}}} \right) \left(\frac{\pi_{t+1}^{\tilde{J}}}{\pi_t^{\tilde{J}}} - 1 \right). \end{aligned} \quad (33)$$

2.2.2 Unions

Unions buy labor from households and sell labor to manufacturers. Manufacturers demand a CES aggregate of labor varieties, with elasticity of substitution σ_U . The aggregate demand for labor variety i is therefore

$$U_t(i) = \left(\frac{V_t(i)}{V_t} \right)^{-\sigma_U} U_t, \quad (34)$$

where V_t is defined similarly to (5), and where U_t is aggregate labor demand by all manufacturing firms. Nominal wage rigidities in this sector take the same functional form $G_{P,t}^U(i)$ as in (27). The optimization problem of a union consists of maximizing the present discounted value of nominal wages paid by firms $V_t(i)U_t(i)$ minus nominal wages paid out to workers $W_t U_t(i)$, minus nominal wage inflation adjustment costs $P_t G_{P,t}^U(i)$. The first-order condition is a Phillips curve for wage inflation π_t^U similar to (33).

2.2.3 Import Agents

The U.S. owns two continua of import agents located in RW (and vice versa), and indexed by $J \in [T, D]$. Import agents in T (D) buy tradable goods (final goods) from manufacturers

(distributors) in the U.S. and sell them to distributors in RW. The latter demand a CES aggregate of imported varieties $Y_t^{JM}(i)$, with elasticity of substitution σ_{JM} . The aggregate demand for variety i is

$$Y_t^{JM}(i) = \left(\frac{P_t^{JM}(i)}{P_t^{JM}} \right)^{-\sigma_{JM}} Y_t^{JM} . \quad (35)$$

where P_t^{JM} is defined similarly to (5), and where Y_t^{JM} is aggregate import demand by all RW distributors in sector J . Nominal price rigidities for import agents take the same functional form $G_{P,t}^{JM}(i)$ as in (27). We denote the price of imported inputs at the border by $P_t^{M,cif}$, the cif (cost, insurance, freight) import price. By purchasing power parity this satisfies

$$p_t^{JM,cif} = p_t^{JH*} e_t \quad , \quad p_t^{JM,cif*} = \frac{p_t^{JH}}{e_t} . \quad (36)$$

The optimization problem consists of maximizing the present discounted value of nominal revenue $P_t^{JM}(i)Y_t^{JM}(i)$ minus nominal costs of inputs $P_t^{JM,cif}Y_t^{JM}(i)$, minus nominal inflation adjustment costs $P_t G_{P,t}^{JM}(i)$. The first-order condition is a Phillips curve for import price inflation π_t^{JM} similar to (33).

2.2.4 Distributors

This sector produces final output. Distributors buy goods from manufacturers and import agents. They also use the stock of public infrastructure. Distributors sell final output to consumption goods retailers, manufacturing firms (in their role as investors), the government, final goods import agents located in foreign countries, and to various other sectors for fixed costs and adjustment costs. These agents demand a CES aggregate of distributed varieties, with elasticity of substitution σ_D . The aggregate demand for variety i is

$$\mathcal{D}_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\sigma_D} \mathcal{D}_t , \quad (37)$$

where the numeraire price index P_t is defined similarly to (5), and where $\mathcal{D}_t(i)$ and $\mathcal{D}_t$ remain to be specified by way of market clearing conditions. We divide our description of the technology of distributors into a number of stages. In the first stage a tradables composite $Y_t^T(i)$ is produced by combining foreign tradables $Y_t^{TF}(i)$ with domestic tradables $Y_t^{TH}(i)$, subject to an adjustment cost that makes rapid changes in the share of foreign tradables costly.⁹ In the second stage a tradables-

⁹ This addresses a key concern in open economy DSGE models, namely the potential for an excessive short-term responsiveness of international trade to real exchange rate movements.

nontradables composite $Y_t^A(i)$ is produced. In the third stage this composite is in turn combined with a publicly provided stock of capital K_t^G to produce Y_t^{DH} . And in the fourth stage, similar to the first stage, the private-public composite is combined with foreign final output, again subject to an import adjustment cost, to produce domestic final output Y_t . We have the following set of nested production functions:

$$Y_t^T(i) = \left((\alpha_{TH})^{\frac{1}{\xi_T}} (Y_t^{TH}(i))^{\frac{\xi_T-1}{\xi_T}} + (1 - \alpha_{TH})^{\frac{1}{\xi_T}} (Y_t^{TF}(i)(1 - G_{F,t}^T(i)))^{\frac{\xi_T-1}{\xi_T}} \right)^{\frac{\xi_T}{\xi_T-1}}, \quad (38)$$

$$Y_t^A(i) = \left((1 - \alpha_N)^{\frac{1}{\xi_A}} (Y_t^T(i))^{\frac{\xi_A-1}{\xi_A}} + (\alpha_N)^{\frac{1}{\xi_A}} (Y_t^N(i))^{\frac{\xi_A-1}{\xi_A}} \right)^{\frac{\xi_A}{\xi_A-1}}, \quad (39)$$

$$Y_t^{DH}(i) = Y_t^A(i) (K_t^G)^{\alpha_G} \mathcal{S}, \quad (40)$$

$$Y_t(i) = \left((\alpha_{DH})^{\frac{1}{\xi_D}} (Y_t^{DH}(i))^{\frac{\xi_D-1}{\xi_D}} + (1 - \alpha_{DH})^{\frac{1}{\xi_D}} (Y_t^{DF}(i)(1 - G_{F,t}^D(i)))^{\frac{\xi_D-1}{\xi_D}} \right)^{\frac{\xi_D}{\xi_D-1}}. \quad (41)$$

The import adjustment cost term for intermediates is given by

$$G_{F,t}^T(i) = \frac{\phi_{FT}}{2} \frac{(\mathcal{R}_t^T - 1)^2}{1 + (\mathcal{R}_t^T - 1)^2}, \quad \mathcal{R}_t^T = \frac{Y_t^{TF}(i)}{\frac{Y_{t-1}^{TF}}{Y_{t-1}^T}}, \quad (42)$$

and similarly for imports of final goods. The stock of public infrastructure K_t^G is identical for all firms and provided free of charge to the end user (but not of course to the taxpayer). It enters in a similar fashion to the level of technology, but with decreasing returns to public capital. The advantage of this formulation is that it retains constant returns to scale at the level of each firm. The term $\mathcal{S}$ is a technology scale factor that is used to normalize the relative size of each economy to correspond to its relative population weight $n/(n + n^*)$. Nominal price rigidities in this sector take the same functional form $G_{P,t}^D(i)$ as in (27). The profit maximization problem of distributors consists of maximizing the present discounted value of nominal revenue $P_t(i)Y_t(i)$ minus nominal costs of production $P_t^{TH}Y_t^{TH}(i) + P_t^{TF}Y_t^{TF}(i) + P_t^N Y_t^N(i) + P_t^{DF}Y_t^{DF}(i)$, a fixed cost $P_t T_t \omega^D$, and inflation adjustment costs $P_t G_{P,t}^D(i)$. First-order conditions for this problem consist of a Phillips curve for final goods inflation π_t similar to (33) and a number of factor demands that are listed in full in the Technical Appendix.

2.2.5 Retailers

Retailers buy final output from distributors and sell to households. Demand for the output varieties $C_t(i)$ supplied by retailers follows directly from (9) and (20) as

$$C_t(i) = \left(\frac{P_t^R(i)}{P_t^R} \right)^{-\sigma_R} C_t. \quad (43)$$

Retailers face quantity adjustment costs that take the form¹⁰

$$G_{Y,t}^R(i) = \frac{\phi_C}{2} C_t \left(\frac{(C_t(i)/g) - C_{t-1}(i)}{C_{t-1}(i)} \right)^2. \quad (44)$$

The optimization problem of retailers consists of maximizing the present discounted value of nominal revenue $P_t^R(i)C_t(i)$ minus nominal costs of inputs $P_t C_t(i)$, minus nominal quantity adjustment costs $P_t G_{Y,t}^R(i)$. The first order condition for the retailer's problem has the form

$$\begin{aligned} \left[\frac{\sigma_R - 1}{\sigma_R} p_t^R - 1 \right] &= \phi_C \left(\frac{\check{C}_t - \check{C}_{t-1}}{\check{C}_{t-1}} \right) \frac{\check{C}_t}{\check{C}_{t-1}} \\ &\quad - \frac{\theta g}{r_t} \phi_C \left(\frac{\check{C}_{t+1} - \check{C}_t}{\check{C}_t} \right) \left(\frac{\check{C}_{t+1}}{\check{C}_t} \right)^2. \end{aligned} \quad (45)$$

2.3 Government

2.3.1 Fiscal Policy

Fiscal policy consists of a specification of taxes $\tau_{L,t}$ and $\tau_{c,t}$, transfers $\tau_{T,t}$, and government spending for consumption and investment purposes G_t^{cons} and G_t^{inv} . The government's policy rule for transfers from *OLG* agents to *LIQ* agents specifies that dividends of the retail and union sector are redistributed in proportion to *LIQ* agents' share in consumption and labor supply, while the redistributed share of dividends in the four remaining sectors is $\iota \leq \psi$. We therefore have the following rule:

$$\tau_{T,t} = \iota (d_t^N + d_t^T + d_t^D + d_t^M) + \frac{c_t^{LIQ}}{C_t} d_t^R + \frac{\ell_t^{LIQ}}{L_t} d_t^U. \quad (46)$$

Government consumption spending is exogenous and unproductive. Government investment spending on the other hand augments the stock of publicly provided infrastructure capital K_t^G , the

¹⁰ The presence of the growth term in (44) ensures that adjustment costs are zero along the balanced growth path.

evolution of which is given by

$$K_{t+1}^G = (1 - \delta_G) K_t^G + G_t^{inv} . \quad (47)$$

The government issues nominally non-contingent one-period debt B_t at the gross nominal interest rate i_t . The real government budget constraint therefore takes the form

$$b_t = \frac{i_{t-1}}{\pi_t} b_{t-1} - s_t , \quad (48)$$

$$s_t = \tau_{L,t} w_t L_t + \tau_{c,t} C_t - G_t^{cons} - G_t^{inv} . \quad (49)$$

Fiscal policy ensures a non-explosive government debt to GDP ratio by adjusting tax rates to generate sufficient revenue, or by reducing expenditure. Such a policy is implemented by a fiscal rule in which the primary surplus s_t responds to deviations of the government debt to GDP ratio from a desired value. The required adjustments are determined by the following equation:

$$\frac{b_t}{gdp_t} = (1 - \mu_b) \bar{b} + \mu_b \frac{b_{t-1}}{gdp_{t-1}} - \mu_{bgr} \frac{b_t - b_{t-1} g}{gdp_t} . \quad (50)$$

where μ_b determines the speed at which the actual government debt to GDP ratio ($\frac{b_t}{gdp_t}$) is adjusted to its exogenous desired level $\bar{b}$.¹¹ The term μ_{bgr} is a flow condition and is included to prevent excessive cycling in the primary surplus and the real economy.

2.3.2 Monetary Policy

Monetary policy uses an interest rate rule to smooth nominal interest rates and to stabilize inflation and output growth. The rule is similar to the class of rules suggested by Orphanides (2003), with one important exception. This is that in our non-Ricardian model there is no unchanging steady state real interest rate. The term proxying the steady state nominal interest rate $r_t^{smooth} \pi_t$ therefore includes a moving average of past and future real interest rates:

$$i_t = (i_{t-1})^{\mu_i} \left(r_t^{smooth} \pi_t \right)^{1-\mu_i} \left(\frac{\pi_{t+1}}{\bar{\pi}} \right)^{(1-\mu_i)\mu_\pi} \left(\frac{gdp_t}{gdp_{t-1}} \right)^{(1-\mu_i)\mu_{ygr}} , \quad (51)$$

$$r_t^{smooth} = E_t (r_{t-1} r_t r_{t+1})^{\frac{1}{3}} . \quad (52)$$

We define a government policy to be a sequence of policy instruments $\{G_s^{inv}, G_s^{cons}, \tau_{L,s}, \tau_{c,s}, i_s\}_{s=t}^\infty$ such that (46), (48), (49), (50), (51) and (52) hold at all times.

¹¹ The definition of gdp_t is given below after the definition of equilibrium.

2.4 Equilibrium and Balance of Payments

A perfect foresight equilibrium is an allocation, a price system, and a government policy such that *OLG* and *LIQ* households maximize lifetime utility, manufacturers, unions, import agents, distributors and retailers maximize the present discounted value of their cash flows, and the following market clearing conditions for labor, nontradables, tradables and final output hold.¹²

$$U_t = U_t^N + U_t^H = L_t = \ell_t^{OLG} + \ell_t^{LIQ} , \quad (53)$$

$$Z_t^N = Y_t^N + T_t \omega^N + G_{P,t}^N , \quad (54)$$

$$Z_t^T = Y_t^{TH} + Y_t^{TF*} + T_t \omega^T + G_{P,t}^{TH} , \quad (55)$$

$$Y_t = C_t + I_t^N + I_t^H + G_t^{inv} + G_t^{cons} + Y_t^{DF*} + T_t \omega^D + G_{I,t}^N + G_{I,t}^T + G_{P,t}^D + G_{P,t}^U + G_{P,t}^M + G_{Y,t}^R . \quad (56)$$

Furthermore, the net foreign asset evolution is given by¹³

$$e_t f_t = \frac{i_{t-1}^* \varepsilon_t}{\pi_t} e_{t-1} f_{t-1} + p_t^{TH} Y_t^{TF*} + d_t^{TM} - p_t^{TF} Y_t^{TF} + Y_t^{DF*} + d_t^{DM} - p_t^{DF} Y_t^{DF} . \quad (57)$$

The market clearing condition for international bonds is

$$f_t + f_t^* = 0 . \quad (58)$$

Finally, the level of GDP is given by the following expression:

$$gdp_t = C_t + I_t^N + I_t^H + G_t^{inv} + G_t^{cons} + p_t^{TH} Y_t^{TF*} + d_t^{TM} + Y_t^{DF*} + d_t^{DM} - p_t^{TF} Y_t^{TF} - p_t^{DF} Y_t^{DF} . \quad (59)$$

3 Calibration

We calibrate the model to a two-country world representing the U.S. and RW. Because the critical fiscal effects stressed in this model are of a medium- to long-term nature, we work with an annual version of the model.

¹² Only the market clearing conditions for RW are listed. U.S. conditions are symmetric.

¹³ Note that export earnings include the markup profits d_t^{TM} and d_t^{DM} earned by domestically owned import agents.

We begin with the parameters that are assumed to be different between the U.S. and RW. First, the denomination of international bonds is in U.S. currency. The U.S. is calibrated to represent 25 percent of world GDP, and to have initial steady state government debt and net foreign liabilities (NFL) to GDP ratios of 60 percent and 55 percent. RW therefore has a net foreign assets to GDP ratio of 18.3 percent, and is assumed to have a government debt to GDP ratio of 30 percent. Another difference between U.S. and RW is the assumed share ψ of liquidity constrained agents in the population, which is 33 percent for the U.S. and 50 percent in RW. The assumption for the U.S. is significantly lower than the 50 percent assumed by Erceg, Guerrieri and Gust (2005b), but may still be on the high side given the empirical evidence presented in Weber (2002). We calibrate the trade share parameters α_{TH} , α_{DH} , α_{TH}^* and α_{DH}^* to produce U.S. ratios to GDP of intermediate and final goods imports and of intermediate goods exports of 6 percent, which is in line with historical averages, and to normalize the initial steady state final output based real exchange rate e to 1. Given the size difference between U.S. and RW this does of course produce correspondingly lower import and export shares for RW. Finally we assume an asymmetry in price setting behavior, in that exporters are subject to nominal rigidities in the U.S. market while U.S. exporters do not price to the RW market. All other structural parameters and macroeconomic ratios are assumed to be equal in both economies.

We fix the steady state world real growth rate at 1.5% per annum or $\bar{g} = 1.015$, and the steady state inflation rate in each country at 2% per annum or $\bar{\pi} = 1.02$. Trend nominal exchange rate depreciation is therefore zero. Given that there are no long-run trends in relative productivities and therefore in real exchange rates, the long-run real interest rate is equalized across countries, and we assume a value of 2% per annum or $\bar{r} = 1.02$. We find the values of β and β^* that are consistent with these and the following assumptions.

The parameters θ and χ are critical for the non-Ricardian behavior of the model. We assume an average remaining time at work of 20 years, which corresponds to $\chi = 0.95$. The degree of myopia is given by the planning horizon $1/(1 - \theta)$. We assume that the planning horizon equals 10 years, which implies $\theta = 0.9$.¹⁴ The main criterion used in choosing these parameters is the empirical

¹⁴ Based on U.S. annual data starting in 1955 Bayoumi and Sgherri (2006) decisively reject the infinite horizon model and estimate a planning horizon that is significantly shorter than 10 years. However, in their study it was difficult to identify both the share of liquidity-constrained consumers and the length of the planning horizon.

evidence for the effect of government debt on real interest rates. Our model is calibrated so that a one percentage point increase in the government debt to GDP ratio in the U.S. leads to an approximately four basis points increase in the U.S. (and world) real interest rate. This value is towards the lower end of the estimates of Engen and Hubbard (2004) and Laubach (2003). Household preferences are further characterized by an intertemporal elasticity of substitution of 0.25, or $\gamma = 4$, and by habit persistence $v = 0.4$. The Frisch elasticity of labor supply depends on the steady state value of labor supply among both *OLG* and *LIQ* households, which is in turn determined by the leisure share parameters η^{OLG} and η^{LIQ} . We adjust these parameters to obtain a Frisch elasticity of 0.5. Pencavel (1986) reports that most microeconomic estimates of the Frisch elasticity are between 0 and 0.45, and our calibration is at the upper end of that range, in line with much of the business cycle literature.¹⁵

We now turn to the calibration of technologies. The elasticities of substitution between capital and labor in both tradables and nontradables, ξ_{ZN} and ξ_{ZT} , are assumed to be equal to one, the conventional Cobb-Douglas case. The elasticities of substitution between domestic and foreign intermediates and final goods, ξ_T and ξ_D , which correspond to the long-run price elasticities of demand for imports, are assumed to be equal to 1.5 as in Erceg, Guerrieri and Gust (2005b). We also explore the sensitivity of our results to lower values for these elasticities, as their macroeconomic estimates are typically closer to one, see Hooper and Marquez (1995) and Hooper, Johnson and Marquez (2000). Finally, the elasticity of substitution between tradables and nontradables, ξ_A , is assumed to equal 0.5, based on the evidence cited in Mendoza (2005).

The real adjustment cost parameters are chosen to yield aggregate dynamics consistent with the empirical evidence.¹⁶ We set investment adjustment costs to $\phi_I = 10$. Trade and consumption adjustment costs ϕ_{FT} , ϕ_{FD} and ϕ_C are equal to 5. The trade adjustment costs ensure that our impulse responses roughly match the behavior of exports and imports in Erceg, Guerrieri and Gust (2005b), who choose a different functional form for adjustment costs.

¹⁵ As discussed by Chang and Kim (2005), a very low Frisch elasticity makes it difficult to explain cyclical fluctuations in hours worked, and they present a heterogeneous agent model in which aggregate labor supply is considerably more elastic than individual labor supply.

¹⁶ A fully satisfactory calibration of these parameters will ultimately require the model to be estimated. Given its size this is a formidable challenge, but given its expected wide application to policy analysis inside the IMF this is nevertheless an important part of our research agenda.

As for price setting in different sectors, the degree of market power is reflected in the markup of price over marginal cost. We assume that this markup is equal to 20 percent in the two manufacturing sectors and in the labor market. This is a typical assumption in the monetary business cycle literature. For the distribution and retail sectors we assume smaller markups of 5 percent, and for import agents of 2.5 percent. The key parameter for nominal rigidities is the inflation adjustment cost. Here we choose values that yield plausible dynamics over the first two to three years following a shock. Specifically, for all sectors except import agents in RW (where adjustment costs are zero) we set this parameter equal to 10.

A number of share and other parameters is calibrated by reference to long-run values for the shares of different expenditure and income categories in GDP. The manufacturing labor share parameters α_N^U and α_T^U are set to ensure labor income shares of 64 percent in each sector. The import share parameters have already been mentioned. The nontradables share parameter α_N is adjusted to ensure a nontradables share in GDP (i.e. not simply in the value of the tradables-nontradables composite $P_t^A Y_t^A$) of 50 percent. The steady state shares of investment spending and government spending in GDP are calibrated based on historical averages to equal 16 percent and 18 percent, respectively. Given the assumptions about real interest rates and net foreign liabilities, this implies consumption to GDP ratios of 65.7 percent in the U.S. and 66.1 percent in RW.

Calibrating the depreciation rate of private capital would ordinarily present a problem given that we have already calibrated the two capital income shares and the investment to GDP ratio. The only three free parameters available for to fix these four values would typically be α_N^U , α_T^U and δ . But we note that in our model the income of capital consists not only of the return to capital in manufacturing, but also of economic profits due to market power in multiple sectors. We have introduced fixed costs in manufacturing and distribution that partly or wholly eliminate these profits. The percentage of steady state economic profits that is eliminated by fixed costs can therefore be specified as a fourth free parameter. This allows us to calibrate the annual depreciation rate of private capital at the conventional 10 percent while maintaining the investment to GDP ratio and capital income shares stated above.

The most challenging aspect of the model calibration is the specification of public capital stock accumulation and of its productivity, because our specification is to our knowledge new in

macroeconomic studies.¹⁷ First, the U.S. national accounts data allow us to decompose public spending into spending on infrastructure investment and spending on all other items. As a share of GDP, the former represents 3 percent and the latter 15 percent. We use this to determine the ratio between the steady state values of productive and unproductive government spending, but it should be clear that other decompositions would be very justifiable. Most troubling is that education and health spending are thereby classified as unproductive. Kamps (2004) presents evidence for the depreciation rate of public capital of 4 percent per annum. We therefore calibrate $\delta_G = 0.04$. Together with a 3 percent productive spending to GDP ratio and a 1.5 percent per annum real growth rate this implies a public capital stock to GDP ratio of 54.5 percent, which is consistent with Kamps' (2004) evidence of around 50 percent. The productivity of public capital is determined by the parameter α_G . Ligthart and Suárez (2005) present a meta analysis that evaluates a large number of studies on the elasticity of aggregate output with respect to public capital. Their best estimate puts this elasticity at 0.14. This is considerably below the highly controversial estimates of Aschauer (1989, 1998), but it is nevertheless very significant. We adjust the value of α_G to obtain a long-run elasticity of GDP with respect to K^G of 0.14.

We finally turn to the specification of policy rules. For the fiscal rule we assume $\mu_b = 0.7$ and $\mu_{bgr} = 0.25$, which ensures a reasonable speed and dynamics of adjustment following a shock to the desired government debt to GDP ratio. For the interest rate rule we assume relatively little interest rate smoothing, $\mu_i = 0.25$, given that this is an annual model. The coefficient on inflation is assumed to be $\mu_\pi = 1.6$, and the coefficient on output growth is $\mu_{ygr} = 0.25$.

4 Implications of U.S. Government Deficits

Over the last few years there has been considerable progress building a new generation of models with stronger microfoundations and then using these models to study a number of issues, including the effects of U.S. fiscal deficits. Much of this work has been based on the infinite horizon representative agent paradigm augmented for liquidity-constrained consumers (REP). While we would argue that these models have provided very useful frameworks for looking at many issues,

¹⁷ An exception is the recent working paper by Straub and Tchakarov (2006).

we are concerned with the application of such models to studying the effects of fiscal deficits that involve permanent increases in government debt. To illustrate the differences between the predictions of REP models with overlapping-generation models with finite horizons (OLG), this section starts by discussing the differences in the long-run predictions of both models and then provides some illustrative simulations that directly compare both the short-run and the long-run predictions of the two models.

4.1 *Useful Steady-State Relationships*

To better understand the current account implications of changes in public savings rates, it is useful to start by recalling the steady-state relationship between the stock of net foreign liabilities and the current account deficit. In steady state all nominal variables must grow at their steady-state nominal growth rate, which under our calibration is 3.5 percent (2 percent inflation plus 1.5 percent productivity growth). The condition for balanced growth in steady state implies that the current account deficit expressed as a ratio of nominal GDP ($CDEF^{rat}$) should be approximately equal to the steady-state nominal growth rate times the NFL position also expressed as a share of nominal GDP (NFL^{rat}). The logic is as follows. Assume that all nominal stock and flow variables grow at the gross growth rate of nominal income g_{yn} . The current account deficit is equal to the change in the level of NFL:

$$CDEF_t = NFL_t - NFL_{t-1} . \quad (60)$$

If we then impose the steady-state condition that $NFL_{t-1} = NFL_t / g_{yn}$ and divide both sides of (60) by nominal GDP, we obtain a very simple expression that links steady-state current account deficits and NFL:

$$CDEF^{rat} = \frac{g_{yn} - 1}{g_{yn}} NFL^{rat} . \quad (61)$$

In our calibration, which assumes that the population will eventually stabilize¹⁸, the factor $(g_{yn} - 1)/g_{yn}$ equals 0.034. This relationship is very useful for understanding the long-term implications of permanent changes in government debt that result in permanent changes in NFL. For example,

¹⁸ With declining fertility rates most long-term population projections usually assume that over the next several decades population growth will gradually decline to zero. In this paper we ignore the transitional effects of population growth, but we are in the process of generalizing the model to account for population growth in either the steady state or along a transition path to a steady state with zero population growth.

a 10 percentage point increase in the NFL ratio is associated in the very long run with a 0.34 percentage point increase in the current account deficit ratio. However, along the transition path to the higher NFL position the current account deficit generally changes by larger amounts over some period of time until the NFL ratio reaches its new steady-state value. A first key difference between OLG models and REP models is that in the latter the steady-state value of NFL^{rat} is imposed exogenously and independent of the level of government debt, while in OLG models it depends on several fundamental factors that affect savings and investment, including the level of government debt.¹⁹ Obviously, since the government deficit is equal to the change in government debt, a similar expression exists relating the government deficit ratio $GDEF^{rat}$ to the stock of government debt $GDEBT^{rat}$:

$$GDEF^{rat} = \frac{g_{yn} - 1}{g_{yn}} GDEBT^{rat} \quad (62)$$

A second key difference between OLG models and REP models is that the latter assume that consumers always save sufficiently to pay the future tax burden associated with higher levels of government debt, while in OLG models consumers are assumed to be disconnected from future generations and do not save sufficiently to pay the additional tax burden. In practical terms this means that in REP models the NFL position is independent of the level of government debt, while in OLG models there is a long-term positive causal relationship between government debt and net foreign liabilities. Given the two relationships above linking flows and stocks, it is clear that OLG models also imply that there is a long-term causal relationship between government savings and the current account deficit. On the other hand, given the strong long-run assumption of REP models, fiscal deficits can have effects on the current account deficit, but by design they are much smaller in all but the short run, and they must die out over time. In fact, following standard practise in calibrating REP models to the U.S. economy we set the parameter that governs the speed of adjustment in NFL^{rat} as small as possible so that we can generate as much persistence as possible without creating dynamic instabilities in the model's properties. This allows the current account deficit to be pushed away from its exogenously imposed equilibrium value in response to shocks, while in the OLG model changes in

¹⁹ Other key drivers of savings and investment dynamics will include the rate of time preference and the length of planning horizons, but it will also be affected by assumptions that affect the sensitivity of savings and investment to real interest rates, including the intertemporal elasticity of substitution, the share of liquidity constrained consumers, and parameters in the production function.

savings behavior that imply long-term changes in NFL^{rat} require larger and more persistent changes in the current account deficit to achieve a new equilibrium, with permanent changes in both NFL and current account deficit positions. Another important difference is that in the REP model the long-run equilibrium real interest rate is tied down by the rate of time preference and productivity growth, while in the OLG model it is also related to the same fundamental parameters that affect savings and investment dynamics.

4.2 *The Quantitative Predictions of the Two Models*

To study the predictions of the two models we consider a stylized tax cut in the U.S. that permanently raises the government debt ratio by about 15 percentage points. In both models the fiscal expansion is implemented by permanently reducing the government savings ratio by 0.5 percentage points, but to accelerate the increase in government debt we assume that the fiscal expansion is much larger in the short run (-2.5 for the first 2 years and then gradually falling to -0.5 by the 5th year of the simulation). In both models we assume that the reduction in government savings is a result of lower tax rates on labor income, which will have important expansionary effects on consumption and aggregate demand in the short run. Figures 2 and 3 illustrate.

Both models predict that a reduction in government savings will result in a gradual increase in the government debt ratio of 14.7 percentage points ($\Delta GDEF_RAT / 0.034$)—see the top right panel of Figure 2, where the solid lines report the responses of the OLG model and the dashed lines report the predictions of the REP model. The top left panel shows the labor tax rate, which declines by about 5 percentage points in the first 2 years and then starts to rise gradually to pay the additional interest payments on the rising stock of government debt. In the long run the labor tax rate is about 1.5 percentage point higher in the OLG model and about 0.5 percentage points higher in the REP model. This difference reflects a permanent increase in the real interest rate and much stronger crowding-out effects in the OLG model that require larger tax hikes over time to pay the higher interest burden on the higher levels of government debt.

The left column of panels in Figure 2 shows the sources and uses of savings (public savings, private savings, investment and the current account deficit) while the right column of panels shows how these flows cumulate into government debt, financial wealth (government debt and NFL),

physical capital and NFL. In the short run the private sector savings rate rises by somewhat less than the decline in the government savings rate in both models, as consumers spend part of the proceeds of the tax cut. The similarity in the short-run responses of consumption reflects an assumption that the share of liquidity-constrained individuals has been increased from 33% in the OLG model to 50% in the REP model. It is not uncommon for calibrations of REP models to use a higher share of liquidity-constrained individuals to generate plausible short-run consumption responses—for example, see Erceg, Guerrieri and Gust (2005b), who use an assumption of 50%. Obviously, in the OLG model it is not necessary to use such a large share of liquidity-constrained agents to generate similar short-run effects on consumption as the finite-planning-horizon assumption implies that unconstrained consumers in the OLG model will spend a larger portion of their tax proceeds than the unconstrained consumers in the REP model. Because the initial effects of the shock fall on consumption it is not surprising that the short run effects on real GDP as well as its major components (investment, exports and imports) are very similar across the two models—see the left hand column of panels in Figure 3. However, the similarities in the predictions of the models end here.

Looking beyond the short run there are vast differences in the predictions. The OLG model predicts permanent increases in both the current account deficit and the NFL position, while the REP model predicts much smaller but persistent increases reflecting the assumption discussed earlier that guarantees extremely slow convergence back to the assumed long-run value of the NFL ratio. The non-Ricardian nature of the OLG model means that there will be a strong tendency for excessive consumption in response to debt-financed fiscal expansions because consumers do not save sufficiently to pay the future higher tax burden that will be imposed on future generations. The implication is that the world real interest rate must rise permanently to equilibrate world savings and investment and this results in long-term crowding-out effects on investment, consumption and GDP. Given the permanent changes in the level of world savings and real interest rates there will also be large spillover effects on RW.

In the short run the real exchange rate appreciates in the OLG model to generate the trade deficits that are consistent with the reduction in national savings in the U.S., but then it must depreciate over time to generate an improvement in the trade balance to finance the larger interest obligations associated with a higher stock of net foreign liabilities. By contrast, the real exchange rate moves

by significantly less in the REP model, and again this simply reflects the assumption in REP models that fiscal deficits will have only very small effects on the current account over the medium and long term.

A number of the quantitative results from the OLG model will be sensitive to parameter values and other assumptions. First, the particular magnitudes of the exchange rate response will depend critically on the elasticity of substitution between imported goods and domestically produced tradables, which has been assumed to be 1.5 in the base-case calibration. Obviously, lower estimates of this elasticity would require much larger short-run and long-run changes in the real exchange rate to generate the profile for trade volumes that is consistent with savings and investment dynamics. Second, the short-run response of real GDP may seem small and inconsistent with the effects estimated in historical episodes when monetary policy accommodated shocks to aggregate demand. When interpreting the results it's important to understand that the monetary policy rule has been designed to keep inflation close to the target so the short-run expansionary effects of any positive aggregate demand shock will be constrained by a rise in the real interest rate. Obviously, a policy that accommodated the expansion in demand by delaying hikes in nominal interest rates would generate a much larger short-run multiplier. For example, holding the short-term interest rate fixed for the first 2 years of the simulation approximately doubles the short-run effects on GDP. Lastly, the magnitude of the crowding-out effects will depend on a number of key assumptions. When the planning horizon is lengthened considerably the results of the model will tend to mimic the Ricardian predictions of the REP model. In addition, for a given planning horizon, the magnitude of crowding-out effects on investment will depend critically on how sensitive consumption is to real interest rates, as low degrees of interest rate sensitivity will require larger changes in real interest rates to equilibrate world savings and investment. By contrast, the medium and long-term predictions of REP models for net foreign liabilities and real interest rates will be far less sensitive to parameter assumptions since the basic long-term predictions are hardwired by an assumption that net foreign liabilities positions and world real interest rates are independent of government debt. In our view the inability of REP models to account for any long-term effects of government debt represents an obvious weakness of using them for fiscal experiments that involve permanent increases in government debt.

The preceding analysis suggests that fiscal deficits may have contributed to the further deterioration of U.S. current account deficits since 2000, and that given the long time lags involved in the build-up of larger government debt and NFL positions the main current account effects of these fiscal policies may in fact still be to come. These same time lags also imply that any empirical investigation of the fiscal deficit-current account nexus may be very challenging. Looking forward, the above analysis can of course be used to suggest that an improvement in U.S. fiscal deficits should be a part of a policy package that aims to raise national savings in the U.S. to help resolve global current account imbalances. Such fiscal deficit improvements could take the form of higher taxes, but also of lower government spending. The consequences of the latter are dealt with in the remainder of this section. However, many commentators argue that the relative sizes of U.S. fiscal and current account deficits strongly suggest that this can only be part of the solution. The remainder requires either policy measures in the rest of the world, or adjustments in private sector behavior that may be difficult to accomplish through policy measures. The next section therefore explores the role of private sector savings behavior in bringing about global current account imbalances. It considers both the “global savings glut” explanation advanced by Bernanke (2005), and the role of low U.S. savings identified by a number of authors—see Faruquee and others (2005).

4.3 Cuts in Government Investment and Consumption

A significant weakness of conventional macro models is that they assume that all government expenditures are wasteful and do not affect the productive capacity of the economy. Indeed, one risk going forward is that pressure to cut expenditures in all categories may result in a decline in government investment and reduce the capacity of the private sector to produce output. Consequently, we have extended the basic OLG model to allow for government investment. To contrast the implications of changes in government investment with previous model results based on changing government consumption, we provide two simulations that consider reductions in these expenditure categories—see Figure 4. The solid lines report the results for a permanent 10 percent reduction in government investment and the dashed lines report the results for a 10 percent reduction in government consumption. For both of these shocks we hold the government balance fixed by computing a profile for labor tax rates that are necessary to achieve this. We do this so that we

can see the pure effects of expenditure cuts and so that we do not confuse these effects with the effects that are related to changes in the levels of public sector savings and government debt.

When the cut in expenditures falls on government investment the model predicts a long-run decline in real GDP in the U.S. of about 1.4 percent, which is consistent with the empirical evidence discussed earlier. In the short run, the reduction in government investment reduces aggregate demand and this results in a decline in real interest rates, which stimulates consumption and investment in the private sector. However, over time as the lower level of government investment reduces the government capital stock, the supply-side effects start to dominate these short-run demand effects resulting in significant declines in private sector investment and consumption. In this case a reduction in supply to RW eventually results in an appreciation in the U.S. real exchange rate, which crowds in imports and reduces the amount of exports. The short-term and medium-term spillover effects on GDP in RW are positive, mainly because RW experiences a real depreciation without experiencing a reduction in their productive capacity. The real depreciation implies that consumption increases by significantly less than GDP.

The effects of a cut in government consumption have the opposite effects on GDP over the medium and long run. In this case, less government spending in the U.S. simply frees up resources for private sector consumption. Investment declines in the short run as the boom in consumption results in higher interest rates. Part of the increase in GDP represents an increase in supply to RW (higher exports) and causes a depreciation in the real exchange rate, which allows significantly higher levels of consumption in RW.

5 Implications of Private Sector Savings Behavior

OLG models produce well-defined steady states where countries can be net debtors or creditors, depending on both public-sector and private-sector savings rates. Indeed, given the importance of shifts over time in both private and public savings rates, OLG models should be expected to provide a much richer framework for assessing NFL dynamics than models that impose a fixed value for the steady-state NFL position and that only allow for temporary deviations around this fixed value.²⁰

²⁰ In applications using the REP framework researchers have often assumed a zero value for

To illustrate the potential for OLG models to explain the combination of a rising U.S. NFL position and low world real interest rates we show two simulation experiments that increase the U.S. NFL position. In one experiment we consider a permanent reduction in the rate of time preference in the U.S. that reduces private sector savings in the U.S. In another experiment we consider a permanent increase in the rate of time preference in RW that raises the savings rate in RW. This case of a “global savings glut” is the most interesting, because it is consistent not only with an elevated U.S. NFL position but also with the observation of low world real interest rates over the last few years. It suggests that a major driving force behind the large U.S. current account deficits has not just been low private and public sector savings rates in the U.S., but that it may also be a result of factors outside the U.S. that have increased the gap between savings rates and investment in RW. In our simple illustrative example we model this solely as an increase in the rate of time preference in RW and abstract from changes in perceived investment opportunities both inside and outside of the U.S., but we recognize that a complete analysis would consider both. This is not to say that shifts in asset preferences or shifts in the perceived attractiveness of investment opportunities are not important factors for determining recent movements in current account balances, but they are unlikely in our view to be the whole story given the degree of persistence in the U.S. NFL position.

Figure 5 contrasts the implications of a scenario with lower private sector savings in the U.S. with a scenario with higher private sector savings in RW.²¹ These scenarios are created by permanently reducing the rate of time preference in the U.S. by 1 percentage point (solid line) and permanently raising the rate of time preference in RW by 1 percentage point (dashed lines).

the steady-state NFL position—see, for example, Erceg, Guerrier, Gust (2005a,b) for a description and application of the Fed’s SIGMA model. A similar REP approach has been employed in the development of the IMF’s Global Economy Model (GEM), but in GEM a positive steady-state value for the desired U.S. NFL position was assumed and in some experiments—such as fiscal shocks—the authors shift it to try to mimic the properties of OLG models—see Faruquee and others (2005). Obviously, a preferred framework would allow for the possibility that the NFL position can shift endogenously, rather than imposing ad hoc permanent adjustments to the desired NFL position.

²¹ Not all of the higher demand for U.S. assets from the rest of the world is a result of an increase in private sector savings relative to foreign uses of savings, as a significant amount of it has been a result of a large buildup of U.S. treasury bonds by central banks. However, to the extent that that this represents a net reduction in government debt or a build up in government assets, the non-Ricardian feature of the OLG model would produce a similar implication as a rise in private sector savings as it would also raise total savings in the rest of the world and have similar spillover effects on the United States and world real interest rates.

We begin with a higher savings rate in RW. This shock initially results in lower levels of consumption in RW that crowds in investment and expands production. Over time consumption in RW rises, but it lags the increases in production, and this persistent rise in savings results in a 100 basis reduction in real interest rates in both the U.S. and RW. This results in a consumption boom in the U.S. and eventually higher growth in GDP as the lower real interest rate stimulates investment. It is important to note again that in the short run GDP declines in the U.S. as monetary policy is assumed to resist inflationary pressure, but just as was the case with the fiscal multipliers discussed earlier, a policy that delayed hikes in nominal interest rates would result in lower real interest rates in the short run and an expansion in GDP. The middle right panel of Figure 5 shows the path for the NFL position in the U.S., which declines initially, but then shows a steady rise that stabilizes at a new higher steady-state values that is almost 10 percentage points higher. In this case there is a sharp real exchange rate appreciation in the U.S. currency that must be large enough to generate the profile for trade deficits that is consistent with savings and investment dynamics.

The solid lines in Figure 5 show the results of a reduction in the rate of time preference in the U.S. This simulation results in a reduction in world savings, permanently higher real interest rates and a decline in output and consumption in both the U.S. and RW. In this case, both real interest rates and the U.S. NFL position increase by less than in the previous case because the U.S. represents a smaller share of world output and savings.

Although we have not yet performed a full-accounting for the shocks that have been driving both real interest rates and the U.S. NFL position, these basic scenarios show that the OLG model may well be able to account for the recent combination of low real world interest rates and a rising U.S. NFL position that would be difficult to account for in REP models that tie the NFL position down with arbitrary assumptions about its steady-state value.

6 Conclusion

This paper has developed a new open-economy macro model suitable for the analysis of both fiscal and monetary policies. The model combines the rigorous foundations of recent models developed for short-run monetary policy analysis with an overlapping generations and lifecycle income model that can be used to study the medium- and longer term effects of fiscal policy. We use the model to show the potential effects of permanent tax cuts that increase government deficits and debt, and their implications for real interest rates, the current account and net foreign liability positions. We conclude that higher government deficits have a strong negative effect on the current account, especially in the medium to long term. Conversely, fiscal consolidation can therefore make a substantial contribution to improving current account imbalances.

The paper highlights other strengths of the model relative to conventional models that have been designed primarily for short-run monetary policy analysis. First, we show that it is important to distinguish between cuts in wasteful government expenditures that simply crowd in private-sector expenditures (the standard assumption) and cuts in government investment, which lower productive capacity. Looking forward this feature will be very useful for studying alternative strategies for fiscal consolidation (higher tax rates versus expenditure cutting) that require careful consideration of the tradeoff between short-term demand management and longer-term supply repercussions.

The paper also analyzes the role of changes in private sector savings behavior on current accounts and real interest rates. Specifically, we study the effects of lower private sector savings rates in the United States and higher private sector savings rates in the rest of the world. The latter is a candidate explanation for the currently observed low world real interest rates despite very large U.S. current account deficits.

There are a number of worthwhile extensions in progress. First, it will be useful to extend the model to a multi-country setting to provide a more elaborate and detailed accounting for the causes and consequences of the recent behavior of private and public sector savings rates in both the U.S. and rest of the world. Second, we will develop a linearized version of the model that can be taken to the data and estimated with Bayesian methods so that we can account for a much larger set of shocks that are relevant for a more complete analysis of the role of both monetary and fiscal policies.

7 References

1. Aschauer, D.A. (1989), "Does Public Capital Crowd Out Private Capital?", *Journal of Monetary Economics*, **24**, 171-188.
2. Aschauer, D.A. (1998), "How Big Should the Public Capital Stock Be?", Jerome Levy Institute, Policy Brief No. 43.
3. Bayoumi, T. and S. Sgherri (2006), "Mr. Ricardo's Great Adventure: Estimating Fiscal Multipliers in a Truly Intertemporal Model", IMF Working Paper Series, WP/06/168.
4. Bernanke, B. (2005), "The Global Saving Glut and the U.S. Current Account Deficit", March 15 speech available at [http:// www.federalreserve.gov/ boarddocs/ speeches/ 2005/](http://www.federalreserve.gov/boarddocs/speeches/2005/).
5. Betts, C. and Devereux, M. (2001), "The International Monetary Transmission of Monetary and Fiscal Policies in a Two-Country Model", in: M. Obstfeld and G. Calvo, eds., *Essays in Honor of Robert A. Mundell*. Cambridge: MIT Press.
6. Blanchard, O.J. (1985), "Debt, Deficits, and Finite Horizons", *Journal of Political Economy*, **93**, 223-247.
7. Blanchard, O.J. and Perotti, R. (2002), "An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output", *Quarterly Journal of Economics*, **117** (4), 1329-1368.
8. Buiter, W.H. (1981), "Time Preference and International Lending and Borrowing in an Overlapping-Generations Model", *Journal of Political Economy*, **89**, 769-797.
9. Calvo, G.A. (1983), "Staggered Prices in a Utility-Maximizing Framework", *Journal of Monetary Economics*, **12**, 383-398.
10. Chang, Y. and Kim, S.-B. (2005), "On the Aggregate Labor Supply", *Federal Reserve Bank of Richmond Economic Quarterly*, **91**(1), 21-37.
11. Caselli, P. (2001), "Fiscal Consolidation Under Fixed Exchange Rates", *European Economic Review*, **45** (3), 425-450.
12. Corsetti, G. and Pesenti, P. (2001), "Welfare and Macroeconomic Interdependence", *Quarterly Journal of Economics*, **116**, 421-445.
13. Engen, E.M. and Hubbard, R.G. (2004), "Federal Government Debt and Interest Rates", *NBER Macroeconomics Annual*, **19**, 83-138.
14. Erceg, C., Guerrieri, L. and Gust, C. (2005a), "SIGMA: A New Open Economy Model for Policy Analysis," mimeo, Federal Reserve Board.
15. Erceg, C., Guerrieri, L. and Gust, C. (2005b), "Expansionary Fiscal Shocks And The Trade Deficit", International Finance Discussion Paper 825, Board of Governors of the Federal Reserve System.
16. Faruquee, H., Laxton, D., Muir, D. and Pesenti, P. (2005), "Smooth Landing or Crash? Model-Based Scenarios of Global Current Account Rebalancing", NBER Working Paper No. 11583.
17. Fatas, A., and Mihov, I. (2001), "The Effects of Fiscal Policy on Consumption and Employment: Theory and Evidence", Mimeo, INSEAD.

- 18 Frenkel, J.A., and Razin, A. (1992), *Fiscal Policies and the World Economy*, Second Edition. Cambridge: MIT Press.
- 19 Gali, J., López-Salido, J.D. and Vallés, J. (2003), "Understanding the Effects of Government Spending on Consumption", Mimeo, CREI.
- 20 Ganelli, G. (2003a), "The New Open Economy Macroeconomics of Government Debt", *Journal of International Economics* (forthcoming).
- 21 Ganelli, G. (2003b), "Useful Government Spending, Direct Crowding-Out and Fiscal Policy Interdependence", *Journal of International Money and Finance*, **22 (1)**, 87-103.
- 22 Ganelli, G., and Lane, P.R. (2002), "Dynamic General Equilibrium Analysis: The Open Economy Dimension", in: S. Altug, J. Chadha, C. Nolan, eds., *Dynamic Macroeconomic Analysis*. Cambridge: Cambridge University Press.
- 23 Ghironi, F. (2003a), "Macroeconomic Interdependence Under Incomplete Markets", Mimeo, Boston College.
- 24 Ghironi, F. (2003b), "Understanding Macroeconomic Interdependence: Do We Really Need to Shut Off the Current Account?", Mimeo, Boston College.
- 25 Hooper, P. and Marquez, J. (1995), "Exchange Rates, Prices, and External Adjustment in the United States and Japan", in: Kenen, P., ed., *Understanding Interdependence*, Princeton University Press, Princeton, NJ, 107-168.
- 26 Hooper, P., Johnson, K. and Marquez, J. (2000), "Trade Elasticities for the G-7 Countries", *Princeton Studies in International Economics*, 87.
- 27 Ireland, P. (2001), "Sticky-Price Models of the Business Cycle: Specification and Stability", *Journal of Monetary Economics*, **47**, 3-18.
- 28 Kamps, C. (2004), "New Estimates of Government Net Capital Stocks for 22 OECD Countries 1960-2001", IMF Working Paper Series, WP/04/67.
- 29 Kumhof, M. and Laxton, D. (2006), "How Will Global Imbalances Adjust?", Box 1.3 of Chapter 1 of the September 2006 IMF World Economic Outlook.
- 30 Laxton, D. and Milesi-Ferretti, G.-M. (2005), "How Will Global Imbalances Adjust?", Appendix 1.2 of Chapter 1 of the September 2005 IMF World Economic Outlook.
- 31 Laubach, T. (2003), "New Evidence on the Interest Rate Effects of Budget Deficits and Debt", Finance and Economics Discussion Series 2003-12, Board of Governors of the Federal Reserve System.
- 32 Ligthart, J.E. and Suárez, R.M.M. (2005), "The Productivity of Public Capital: A Meta Analysis", Working Paper, Tilburg University.
- 33 Laxton, D. and Pesenti, P. (2003), "Monetary Rules for Small, Open, Emerging Economies", *Journal of Monetary Economics*, **50(5)**, 1109-1152.
- 34 Obstfeld, M., and Rogoff, K. (1995), "Exchange Rate Dynamics Redux", *Journal of Political Economy*, **103**, 624-660.

- 35.Mendoza, E. (2005), “Real Exchange Rate Volatility and the Price of Nontradables in Sudden-Stop-Prone Economies”, NBER Working Papers, No. 11691. Economic Outlook, International Monetary Fund, available at www.imf.org.
- 36.Obstfeld, M., and Rogoff, K. (1996), *Foundations of International Macroeconomics*. Cambridge: MIT Press.
- 37.Orphanides, A. (2003), “Historical Monetary Policy Analysis and the Taylor Rule”, *Journal of Monetary Economics*, **50**, 983-1022.
- 38.Pencavel, J. (1986), “Labor Supply of Men”, in: O. Ashenfelter and R. Layards, eds., *Handbook of Labor Economics*, Vol. 1. Amsterdam: North Holland.
- 39.Straub, R. and Tchakarov, I. (2006), “Assessing the Impact of Change in Composition of Public Spending: A DSGE Approach”, Working Paper.
- 40.Weber, C.E. (2002), “Intertemporal Non-Separability and "Rule of Thumb" Consumption”, *Journal of Monetary Economics*, **49**(2), 293-308.
- 41.Weil, P. (1989), “Overlapping Families of Infinitely-Lives Agents”, *Journal of Public Economics*, **38**, 183-198.
- 42.Woodford, M. (2003), *Interest and Prices: Foundations of a Theory of Monetary Policy*. Princeton: Princeton University Press.

Figure 1: Flow Chart of the OLG Model

Figure 2: Permanent Increase in Government Debt in OLG and REP - Part I

Figure 3: Permanent Increase in Government Debt in OLG and REP - Part II

Figure 4: Cuts in Government Investment and Consumption

Figure 5: Lower U.S. Rate of Time Preference and Higher RW Rate of Time Preference