Current Accounts and Global Rebalancing in a Multi-Country Simulation Model[1]

Hamid Faruqee
International Monetary Fund

Douglas Laxton
International Monetary Fund

Dirk Muir
Norges Bank

Paolo Pesenti
Federal Reserve Bank of New York, NBER and CEPR

This draft: May 2005

[1]Preliminary and incomplete. To be presented at the NBER Conference on G7 Current Account Imbalances: Sustainability and Adjustment, Newport RI, June 2005. We thank Susana Mursula for invaluable assistance and Nathalie Carcenac for data support. We also thank Nicoletta Batini, Tamim Bayoumi, Giancarlo Corsetti, Thomas Helbling, Michael Kumhof, Gian Maria Milesi-Ferretti, Papa N'Diaye, Alessandro Rebucci, and Cedric Tille for comments and suggestions. The views expressed in this paper are those of the authors and should not be attributed to the International Monetary Fund, its Executive Board, or its management, the Norges Bank, the Federal Reserve Bank of New York, the Federal Reserve System, or any other institution with which the authors are affiliated.

1 Introduction

Widening external imbalances have been a defining feature of the global landscape in recent years and, for many, constitute a key macroeconomic risk for the world economy. But the debate is far from settled. Two issues are central. First, is the present global pattern of current account imbalances sustainable and for how long? Second, if these positions require unwinding, can an orderly rebalancing be achieved without substantial disruption to global growth, international trade and capital flows, and under what circumstances? At the center of concern is the massive U.S. current account deficit and whether its resolution foreshadows a hard landing for the dollar. For example, while the dollar has steadily depreciated (in real effective terms) since 2002, the U.S. deficit and external surpluses elsewhere (e.g., Japan and emerging Asia) have only widened further. The cautionary tale of past external adjustments underscores the possible wider ramifications of large, unsustainable current account deficits for exchange rates, domestic demand, and growth.[1] Moreover, the prospect of large, disorderly swings in the value of the dollar — given its dominant role in the international monetary system — presents an additional financial risk with potentially far-reaching consequences, and where the regions that may be most deeply affected lie well beyond U.S. shores.

Leaving the possible fallout aside, how did we arrive at this point? A decade ago, the current account deficit of the United States stood around 100 billion dollars or $1\frac{1}{2}$ percent of annual output. Over the next ten years, that deficit would balloon six-fold to over 600 billion dollars or $1\frac{1}{2}$ percent of world output, designating arguably the world's wealthiest nation as its largest external borrower (by far). In terms of U.S. saving and investment, the initial leg of widening deficits was led by brisk capital spending in the mid-1990s, which retreated after the equity bust around the turn of the century. At that same time, declining national saving — led by growing public deficits — assumed a lead role in the further expansion of the U.S. current account deficit in recent years.

In historical perspective, the large U.S. external deficit is unprecedented. Over the past half-century, the United States had sustained a small deficit over most of the post-war period, but the last decade has borne witness to a remarkable extension of the left tail of the distribution; see chart. During the 1980s, an emergence of large U.S. current account deficits—against the backdrop of budgetary deficits and dollar appreciation — were reminiscent of recent developments. However, unlike that previous episode when the counterpart to U.S. deficits was largely confined to other G-7 industrial countries, the current global constellation of external imbalances has expanded the roster of players considerably.[2]

This more recent episode clearly suggest that matters are best viewed from a wider, multilateral perspective, including in terms of the uneven global pattern of growth and demand. A sanguine view of these developments (and their ultimate resolution) typically revolves around three related but distinct considerations: the Lawson doctrine, the 'new Bretton Woods', and globalization. Under a generalized interpretation of the Lawson doctrine, external imbalances are inconsequential, as they merely reflect the market's (optimal)

[1] The literature on current account reversals is extensive; see for example Milesi-Ferretti and Razin. On the nexus between external adjustment, growth and other variables, see Edwards (2004) and Freund (2001).

[2] China's reserves increased by $117 billion in 2003, after subtracting $45 billion in reserves transferred in the recent bank recapitalization. These funds apparently remain in USD assets. South Korea, Taiwan, and Singapore increased reserves by $34 billion, $44 billion, and $14 billion, respectively.

decisions regarding saving and investment.[3] But two qualifications should be noted. First, this presumes that the public sector's balances remains in good standing. And second, private sector decisions are not distorted by any major market imperfections or failures. Prima facie, the emergence of large budgetary deficits in the United States (at least since 2000) and the role of emerging market economies in prevailing global imbalances raise important caveats to the doctrine's application in the current circumstance.[4] Nevertheless, the view that the current account deficit *per se* is not a problem, but remains the natural outgrowth of a strong domestic economy relative to persistent weakness in major partner countries, mainly Japan and Europe, has not receded.

Focusing on the important role of emerging markets in understanding global imbalances, the 'new Bretton Woods' hypothesis — advanced by Dooley, Folkerts-Landau and Garber (2003) — posits that the constellation of external imbalances partly reflects the deliberate actions (e.g., *de facto* pegs) of 'periphery' countries seeking export-led growth as a development strategy. In practical terms, this involves pegging the currency to the U.S. dollar to help domestic exporters safeguard U.S. market share and accumulating dollar reserves as a result of payment imbalances. So long as the periphery, which has new entrants waiting in the wings (e.g., India), willingly acquires dollar claims, this arrangement of external imbalances can endure indefinitely.[5] For its part at the 'center', the United States (i) resurrects its passive exchange rate role as the n-th currency, and (ii) provides liquidity and intermediation to the rest of the world, while benefiting by borrowing short (e.g., foreign sales of U.S. treasuries) at favorable terms while lending long profitably (i.e., FDI).[6]

The third major aspect of the sanguine side of the debate is globalization. A quarter-century after Feldstein and Horioka (1980), saving and investment no longer appear as quite so constrained to move in tandem, and the universe of current account imbalances has clearly expanded.[7] In other words, the mere fact that external imbalances, in many cases, have grown to unprecedented levels can be viewed as a testament to better functioning and increasing integration in global capital markets. Indeed, the vast amounts of foreign saving mobilized to finance the ample shortfall of U.S. saving relative to investment, for example, have broken new ground. With a new-found ability to borrow (and lend), countries belonging to an increasingly integrated global economy can further engage in intertemporal trade to buffer against local shocks, smooth consumption, and raise welfare. A by-product of globalization and larger net external positions is that "valuation" effects — operating on larger net foreign asset or liabilities — can augment the traditional expenditure-switching effects of exchange rate adjustment and thereby facilitate a rebalancing scenario.[8]

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[3] See Corden (1994).

[4] In the late 1980s, Nigel Lawson, then British Chancellor of the exchequer, argued that the large U.K. current account deficit was a matter of no consequence, given that the public sector balance was in surplus. He also argued that this principle applied only to developed countries, where it was more reasonable to assume that private agents behaved optimally.

[5] Eichengreen (2004) criticizes this assessment, arguing that the 'periphery' is not a cohesive, uniform group, and could quickly unravel when national interests come into conflict with collective ones. The possibility of two viable international currencies — i.e., also the euro — further complicates the picture.

[6] Dooley, Folkerts-Landau, Garber (2004) elaborate on this maturity transformation under the present global alignment. Eichengreen (2005) criticizes this too; arguing that being an international financial center and providing intermediation service does not necessitate a large (or any) deficit on the part of the United States.

[7] See WEO (2005), Lee and Faruqee (2005).

[8] See Milesi-Ferreti and Lane (2001, 2003, 2004), Tille ( ), WEO (2005). An extreme form of this

As implied by the stylized facts and various interpretations of the present episode, the evolution (and resolution) of global imbalances need to be understood within a coherent multilateral framework. This paper re-examines the issues surrounding global rebalancing through the lens of a dynamic, multi-region model of the global economy of sufficient complexity to furnish a rigorous macroeconomic framework to assess the economic implications, related risks, and policy recommendations associated with the prevailing global constellation of current account imbalances and the prospect of global rebalancing.

(To be completed)

2 Theoretical framework

2.1 General structure

The structure of the model is illustrated in Figure 1. The world economy consists of four regional blocs ('countries'): US (United States),[9] JE (Japan and Euro area), AS (Emerging Asia), and RC (Remaining Countries).[10] In each country there are households, firms, and a government. World population is normalized to unit. Country sizes are denotes s^{CO}, with $\sum s^{CO} = 1$. We denote $TREND_t$ the common stochastic trend for the world economy and $g_{t,\tau}$ its (gross) rate of growth, with $TREND_\tau = g_{t,\tau} TREND_t$. All quantity variables in the model are expressed in detrended terms, i.e. as ratios of $TREND$.

Each household is infinitely lived. Each household consumes a non-tradable final good (C). Each household is the monopolistic supplier of a differentiated labor input (ℓ) to all domestic firms.[11] Wage contracts are subject to adjustment costs (nominal wage rigidities).

In each country there are two types of households: forward-looking ones (with subscript FL) and liquidity-constrained ones (with subscript LC). Liquidity-constrained agents do not have access to capital markets and finance their consumption exclusively through labor incomes. Instead, forward-looking households own domestic firms and the domestic capital stock (K), which they rent to domestic firms. The market for capital is competitive. Capital accumulation is subject to adjustment costs. Labor and capital are immobile internationally.

Forward-looking households in each country also own two short-term nominal bonds, one denominated in domestic currency and issued by the country's government, and another denominated in US currency and issued in zero net supply worldwide. There are intermediation costs for national households entering the international bond market. No other asset is traded internationally.

Firms produce two final goods, a consumption good (A) and an investment good (E). The consumption good can be consumed by domestic households or by the government (G_C). Similarly, demand for the investment good is split between private agents (I) and the government (G_I).

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argument where valuation effects supplant the requisite adjustment in the trade balance is exposited in Gourinchas and Rey (2004).

[9] To avoid confusion, in the text we refer to US as the region of the model, and to the U.S. as the real-world United States.

[10] The choice of regional aggregation is dicussed in Section 3.1 below.

[11] Interpreting $TREND_t$ as labor-augmenting technical change, ℓ_t in the model is time devoted to work, assumed to be bounded by endowment, while effective labor is $TREND_t \ell_t$. It follows that the nominal wage (the monetary remuneration for one unit of labor services ℓ) can be trending both because of nominal inflation and because of real (labor-augmenting) growth.

Firms also produce intermediate goods, used up in the production of final goods. Intermediate goods are either non-traded (N) or traded internationally (T). Finally, firms provide intermediation services without use of human or physical resources.

In each country, perfectly competitive firms produce the final goods using all types of intermediate goods as inputs (nontradables, domestic tradables Q, and imports M). Intermediate goods come in different varieties, each produced by a single firm under conditions of monopolistic competition worldwide. Intermediate goods are produced with domestic labor inputs and domestic capital. The prices of intermediate goods are subject to adjustment costs (nominal price rigidities).

The government purchases the two national final goods, as well as nontradable services G_N. As Treasury, the government finances the excess of its expenditure over net taxes by borrowing from the domestic private sector. As Central Bank, the government controls the national short-term nominal interest rate. Monetary policy is specified in terms of a credible commitment to an interest rate rule.

Needless to say, the model is fairly complex even though it abstracts from a number of issues (such as trade in oil, commodities and other 'upstream' intermediate inputs, distribution costs, etc.[12]) of obvious relevance for the analysis of the international transmission mechanism. In what follows we provide a brief but comprehensive overview of the model. In some sections we focus on country-specific equations that are independent of foreign variables, thus qualitatively similar across countries. We therefore drop country indexes for notational simplicity, with the understanding that all four countries are analogously characterized. In the sections involving international transactions, instead, we explicitly incorporate country indexes in our notation.

As a general convention throughout the paper, when we state that variable X follows an autoregressive process, we mean that:

$$X_t = (1 - \lambda_X) X + \lambda_X X_{t-1} + e_{X,t} \tag{1}$$

where $0 < \lambda_X < 1$, X is the steady-state value of X_t, and $e_{X,t}$ is a noise term.

2.2 Final goods

In each country there is a continuum of symmetric firms producing the two final goods, A (the consumption good) and E (the investment good) under perfect competition.

Consider first the consumption sector. Each firm is indexed by $x \in [0, s]$, where $0 < s < 1$ is the country size. Firm x's output at time (quarter) t is denoted $A_t(x)$. The consumption good is produced with the following nested constant elasticity of substitution (CES) technology:

$$\begin{aligned} A_t(x)^{1-\frac{1}{\varepsilon_A}} &= \left(1 - \gamma_{A,t}\right)^{\frac{1}{\varepsilon_A}} N_{A,t}(x)^{1-\frac{1}{\varepsilon_A}} \\ &+ \gamma_{A,t}^{\frac{1}{\varepsilon_A}} [\nu_A^{\frac{1}{\mu_A}} Q_{A,t}(x)^{1-\frac{1}{\mu_A}} + (1 - \nu_A)^{\frac{1}{\mu_A}} M_{A,t}(x)^{1-\frac{1}{\mu_A}}]^{\frac{\mu_A}{\mu_A - 1}\left(1-\frac{1}{\varepsilon_A}\right)} \end{aligned} \tag{2}$$

Three intermediate inputs are used in the production of the consumption good A: a basket N_A of nontradable goods, a basket Q_A of domestic tradable goods, and a basket M_A of imported goods. The elasticity of substitution between tradables and nontradables is $\varepsilon_A > 0$, and the elasticity of substitution between domestic and imported tradables is $\mu_A > 0$. The

[12] The reader interested in these two features is referred to the variant of the model considered in Laxton and Pesenti (2003).

weights of the three inputs are, respectively, $1-\gamma_A$, $\gamma_A \nu_A$ and $\gamma_A (1-\nu_A)$ with $0 < \gamma_A, \nu_A < 1$.

Firm x takes as given the prices of the three inputs and minimizes its costs subject to the technological constraint (2). As a convention throughout the paper, A is the *numeraire* of the economy and all national prices are expressed in terms of domestic consumption units, that is relative to the Consumer Price Index (CPI).[13] Cost minimization implies that firm x's demands for intermediate inputs are:

$$N_{A,t}(x) = \left(1-\gamma_{A,t}\right) p_{N,t}^{-\varepsilon_A} A_t(x) \tag{3}$$

$$Q_{A,t}(x) = \gamma_{A,t} \nu_A p_{Q,t}^{-\mu_A} p_{XA,t}^{\mu_A - \varepsilon_A} A_t(x) \tag{4}$$

$$M_{A,t}(x) = \gamma_{A,t} (1-\nu_A) p_{MA,t}^{-\mu_A} p_{XA,t}^{\mu_A - \varepsilon_A} A_t(x) \tag{5}$$

where p_N, p_Q and p_{MA} are the relative prices of the inputs in terms of consumption baskets and p_{XA} is the price of the composite basket of domestic and foreign tradables, or:

$$p_{XA,t} \equiv \left[\nu_A p_{Q,t}^{1-\mu_A} + (1-\nu_A) p_{MA,t}^{-\mu_A}\right]^{\frac{1}{1-\mu_A}} \tag{6}$$

The technologies of production of consumption and investment goods can be quantitatively different but their formal characterizations are similar, with self-explanatory changes in notation. For instance, a firm $e \in [0, s]$ that produces the investment good demands nontradable goods according to:

$$N_{E,t}(e) = \left(1-\gamma_{E,t}\right) \left(p_{N,t}/p_{E,t}\right)^{-\varepsilon_E} E_t \tag{7}$$

Note that p_{MA} and p_{ME} are sector-specific as they reflect the different composition of imports in the two sectors, while p_N and p_Q are identical across sectors.

2.3 Demand for domestic intermediate goods

Consider now the composition of the baskets of intermediate goods. Intermediate inputs come in different varieties (brands) and are produced under conditions of monopolistic competition. In each country there are two kinds of intermediate goods, tradables and nontradables. Each kind is defined over a continuum of mass s. Without loss of generality, we assume that each nontradable good is produced by a single domestic firm indexed by $n \in [0, s]$, and each tradable good is produced by a firm $h \in [0, s]$.

Focusing first on the basket N_A, this is a CES index of all domestic varieties of nontradables. Denoting as $N_A(n, x)$ the demand by firm x of an intermediate good produced by firm n, the basket $N_A(x)$ is:

$$N_{A,t}(x) = \left[\left(\frac{1}{s}\right)^{\frac{1}{\theta_{N,t}}} \int_0^s N_{A,t}(n,x)^{1-\frac{1}{\theta_{N,t}}} dn\right]^{\frac{\theta_{N,t}}{\theta_{N,t}-1}} \tag{8}$$

where $\theta_{N,t} > 1$ denotes the elasticity of substitution among intermediate non-tradables.

Firm x takes as given the prices of the nontradable goods $p(n)$. Cost minimization implies:

$$N_{A,t}(n,x) = \frac{1}{s}\left(\frac{p_t(n)}{p_{N,t}}\right)^{-\theta_{N,t}} N_{A,t}(x) \tag{9}$$

[13] The transformation of all prices in relative terms and all quantities in detrended terms is motivated by the desire to avoid dealing with unit roots, either nominal or real, in quantitative simulations of the model with stochastic inflation and growth rates.

where p_N is the price of one unit of the non-tradable basket, or:

$$p_{N,t} = \left[\left(\frac{1}{s} \right) \int_0^s p_t\left(n\right)^{1-\theta_{N,t}} dn \right]^{\frac{1}{1-\theta_{N,t}}} \tag{10}$$

The basket N_E is similarly characterized. Aggregating across firms,[14] and accounting for public demand of nontradables — here assumed to have the same composition of private demand — we obtain the total demand for good n as:

$$\int_0^s N_{A,t}(n,x)dx + \int_0^s N_{E,t}(n,e)de + G_{N,t}(n) = \left(\frac{p_t(n)}{p_{N,t}} \right)^{-\theta_{N,t}} \left(N_{A,t} + N_{E,t} + G_{N,t}\right) \tag{11}$$

Following the same steps we can derive the domestic demand schedules for the intermediate goods h:

$$\int_0^s Q_{A,t}(h,x)dx + \int_0^s Q_{E,t}(h,e)de = \left(\frac{p_t(h)}{p_{Q,t}} \right)^{-\theta_{T,t}} \left(Q_{A,t} + Q_{E,t}\right). \tag{12}$$

2.4 Demand for imports

The derivation of the foreign demand schedule for good h is analytically more complex but, as we show in (19) at the end of this section, it shares the same functional form as (11) and (12) above and can be written a function of the relative price of good h (with elasticity $\theta_{T,t}$) and total foreign demand for imports.

Let's focus first on import demand in the consumption good sector. Since we deal with goods produced in different countries, we need to introduce explicit country indexes in our notation. Thus, we will refer to a generic country as CO, to the importing country as H, and to the representative firm in the consumption sector as $x^H \in [0, s^H]$. Its imports $M_A^H(x^H)$ are a CES function of baskets of goods imported from the other countries, or:

$$M_{A,t}^H(x^H)^{1-\frac{1}{\rho_A^H}} = \sum_{CO \neq H} \left(b_A^{H,CO}\right)^{\frac{1}{\rho_A^H}} \left(M_{A,t}^{H,CO}(x^H) \left(\;1 - \Gamma_{MA,t}^{H,CO}(x^H) \right) \right)^{1-\frac{1}{\rho_A^H}} \tag{13}$$

where:

$$0 \leq \; b^{H,CO} \leq 0, \quad \sum_{CO \neq H} b^{H,CO} = 1 \tag{14}$$

In (13) above ρ_A^H is the elasticity of import substitution across countries: the higher is ρ_A^H, the easier is for firm x^H to substitute imports from one country with imports from another. The parameters $b_A^{H,CO}$ determine the composition of the import basket across countries. $M_A^{H,CO}(x^H)$ denotes imports of country H's firm x^H from country CO.

The response of imports to changes in fundamentals and their price elasticities are typically observed to be smaller in the short term than in the long run. To model realistic dynamics of imports volumes (such as delayed and sluggish adjustment to changes in relative prices) we assume that imports are subject to adjustment costs $\Gamma_{MA}^{H,CO}$. These costs are specified in terms of import shares relative to firm x^H's output and can be different across

[14] The convention throughout the model is that variables which are not explicitly indexed (to firms or households) are expressed in per-capita (average) terms. For instance, $A_t \equiv (1/s) \int_0^s A_t(x)dx$.

exporters. They are zero in steady state. Specifically, we adopt the parameterization:

$$\Gamma_{MA,t}^{H,CO}[\frac{M_{A,t}^{H,CO}(x^H)}{A_t^H(x)}/\frac{M_{A,t-1}^{H,CO}}{A_{t-1}^H}] = \frac{\phi_{MA}^{H,CO}}{2}\frac{\left[\left(M_{A,t}^{H,CO}(x^H)/A_t^H(x)\right)/\left(M_{A,t-1}^{H,CO}/A_{t-1}^H\right)-1\right]^2}{\left(1+\left[\left(M_{A,t}^{H,CO}(x^H)/A_t^H(x)\right)/\left(M_{A,t-1}^{H,CO}/A_{t-1}^H\right)-1\right]^2\right)} \tag{15}$$

so that $\Gamma_{MA}^{H,CO}[1]=0$, $\Gamma_{MA}^{H,CO}[\infty]=\phi_{MA}^{H,CO}/2$, and $\Gamma_{MA}^{H,CO}[0]=\Gamma_{MA}^{H,CO}[2]=\phi_{MA}^{H,CO}/4$.[15]

Denoting $p_M^{H,CO}$ the price in country H of a basket of intermediate inputs imported from CO, cost minimization implies:

$$\frac{M_{A,t}^{H,CO}(x^H)\left(1-\Gamma_{MA,t}^{H,CO}(x^H)\right)}{\left(1-\Gamma_{MA,t}^{H,CO}(x^H)-M^{H,CO}(x^H)\Gamma_{MA,t}^{\prime H,CO}(x^H)\right)^{\rho_A^H}} = b_A^{H,CO}\left(\frac{p_{M,t}^{H,CO}}{p_{MA,t}^H(x^H)}\right)^{-\rho_A^H} M_{A,t}^H(x^H) \tag{16}$$

where $\Gamma_{MA}^{\prime H,CO}(x^H)$ is the first derivative of $\Gamma_{MA}^{H,CO}(x^H)$ with respect to $M_A^{H,CO}(x^H)$. The import price in the consumption sector, p_{MA}^H, is defined as:

$$p_{MA,t}^H(x^H) = \left[\sum_{CO\neq H} b^{H,CO}\left(\frac{p_{M,t}^{H,CO}}{1-\Gamma_{MA,t}^{H,CO}(x^H)-M^{H,CO}(x^H)\Gamma_{MA,t}^{\prime H,CO}(x^H)}\right)^{1-\rho_A^H}\right]^{\frac{1}{1-\rho_A^H}} \tag{17}$$

In principle, the cost-minimizing import price $p_{MA}^H(x^H)$ is firm-specific, as it depends on firm x^H's import share. To the extent that all firms x^H are symmetric within the consumption sector, however, there will be a unique import price p_{MA}^H.[16]

Let's now consider the basket $M_A^{H,CO}(x^H)$ in some detail. In analogy with (8) above, it is a CES index of all varieties of tradable intermediate goods produced by firms h^{CO} operating in country CO and exported to country H. Denoting as $M_A^{H,CO}\left(h^{CO},x^H\right)$ the demand by firm x^H of an intermediate good produced by firm h^{CO}, the basket $M_A^{H,CO}\left(x^H\right)$ is:

$$M_{A,t}^{H,CO}(x^H) = \left[\left(\frac{1}{s^{CO}}\right)^{\frac{1}{\theta_{T,t}^{CO}}}\int_0^{s^{CO}} M_{A,t}^{H,CO}\left(h^{CO},x^H\right)^{1-\frac{1}{\theta_{T,t}^{CO}}}dh^{CO}\right]^{\frac{\theta_{T,t}^{CO}}{\theta_{T,t}^{CO}-1}} \tag{18}$$

where $\theta_T^{CO}>1$ is the elasticity of substitution among intermediate tradables, the same elasticity entering (12) in country CO.

The cost-minimizing firm x^H takes as given the prices of the imported goods $p^H(h^{CO})$ and determines its demand of good h^{CO} according to:

$$M_{A,t}^{H,CO}(h^{CO},x^H) = \frac{1}{s^{CO}}\left(\frac{p_t^H(h^{CO})}{p_{M,t}^{H,CO}}\right)^{-\theta_{T,t}^{CO}} M_{A,t}^{H,CO}(x^H) \tag{19}$$

where $M_{A,t}^{H,CO}(x^H)$ has been defined in (16) and $p_M^{H,CO}$ is:

$$p_{M,t}^{H,CO} = \left[\left(\frac{1}{s^{CO}}\right)\int_0^{s^{CO}} p_t^H\left(h^{CO}\right)^{1-\theta_{T,t}^{CO}}dh^{CO}\right]^{\frac{1}{1-\theta_{T,t}^{CO}}} \tag{20}$$

[15] Relative to the quadratic specification adopted e.g. in Laxton and Pesenti (2003), this parameterization of import adjustment costs allows the non-linear model to deal with potentially large shocks.

[16] It follows that $p_{MA}^H M_A^H = \sum_{CO\neq H} p_M^{H,CO}M^{H,CO}(1-\Gamma_{MA}^{H,CO})/(1-\Gamma_{MA}^{H,CO}-M_{MA}^{H,CO}\Gamma_{MA}^{\prime H,CO})$

The import demand schedules in the investment good sector can be derived in perfect analogy with the analysis above. As a last step, we can derive country CO's demand schedule for country H's intermediate good h^H, that is, the analog of (12). Aggregating across firms (and paying attention to the order of the country indexes) we obtain:

$$\int_0^{s^{CO}} M_{A,t}^{CO,H}(h^H, x^{CO})dx^{CO} + \int_0^{s^{CO}} M_{E,t}^{CO,H}(h^H, e^{CO})de^{CO}$$
$$= \frac{s^{CO}}{s^H}\left(\frac{p_t^{CO}(h^H)}{p_{M,t}^{CO,H}}\right)^{-\theta_{T,t}^H}\left(M_{A,t}^{CO,H} + M_{E,t}^{CO,H}\right) \tag{21}$$

2.5 Supply of intermediate goods

The nontradable n is produced with the following CES technology:

$$N_t(n) = Z_{N,t}\left[(1-\alpha_N)^{\frac{1}{\xi_N}}\ell_t(n)^{1-\frac{1}{\xi_N}} + \alpha_N^{\frac{1}{\xi_N}}K_t(n)^{1-\frac{1}{\xi_N}}\right]^{\frac{\xi_N}{\xi_N-1}} \tag{22}$$

Firm n uses labor $\ell(n)$ and capital $K(n)$ to produce $N(n)$ units of its variety. $\xi_N > 0$ is the elasticity of input substitution, and Z_N is a productivity shock common to all producers of nontradables.[17]

Defining as w_t and r_t the prices of labor and capital, the marginal cost in nontradables production is:[18]

$$mc_t(n) = \frac{\left\{(1-\alpha_N)\,w_t^{1-\xi_N} + \alpha_N r_t^{1-\xi_N}\right\}^{\frac{1}{1-\xi_N}}}{Z_{N,t}} \tag{23}$$

and the capital-labor ratio is:

$$\frac{K_t(n)}{\ell_t(n)} = \frac{\alpha_N}{1-\alpha_N}\left(\frac{r_t}{w_t}\right)^{-\xi_N} \tag{24}$$

Labor inputs are differentiated and come in different varieties (skills). They are defined over a continuum of mass equal to the country size and indexed by $j \in [0, s]$. Each firm n uses a CES combination of labor inputs:

$$\ell_t(n) = \left[\left(\frac{1}{s}\right)^{\frac{1}{\psi_t}}\int_0^s \ell(n,j)^{1-\frac{1}{\psi_t}}dj\right]^{\frac{\psi_t}{\psi_t-1}} \tag{25}$$

where $\ell(n,j)$ is the demand of labor input of type j by the producer of good n and $\psi > 1$ is the elasticity of substitution among labor inputs. Cost minimization implies that $\ell(n,j)$ is a function of the relative wage:

$$\ell_t(n,j) = \left(\frac{1}{s}\right)\left(\frac{w_t(j)}{w_t}\right)^{-\psi_t}\ell_t(n) \tag{26}$$

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[17] Recall that a productivity shock is defined as a deviation from the common world trend. Variants of the model allow for the possibility of shocks to labor productivity or capital productivity instead of total factor productivity.

[18] Following the notational convention regarding prices, mc_t, w_t and r_t denote marginal costs, wages and rental rates in consumption units.

where $w(j)$ is the wage paid to Home labor input j and the wage index w is defined as:

$$w_t = \left[\left(\frac{1}{s} \right) \int_0^s w_t(j)^{1-\psi_t} dj \right]^{\frac{1}{1-\psi_t}} \tag{27}$$

Similar considerations hold for the production of tradables. We denote by $T(h)$ the supply of each intermediate tradable h. Using self-explanatory notation, we have:

$$T_t\left(h\right) = Z_{T,t} \left[\left(1-\alpha_T\right)^{\frac{1}{\xi_T}} \ell_t(h)^{1-\frac{1}{\xi_T}} + \alpha_T^{\frac{1}{\xi_T}} K_t(h)^{1-\frac{1}{\xi_T}} \right]^{\frac{\xi_T}{\xi_T-1}} \tag{28}$$

where Z_T is an autoregressive process (in logarithm). Aggregating across firms, we obtain the total demand for labor input j as:

$$\begin{aligned} &\int_0^s \ell_t(n,j)dn + \int_0^s \ell_t(h,j)dh \\ &= \left(\frac{w_t(j)}{w_t} \right)^{-\psi_t} \left(\frac{1}{s} \right) \left(\int_0^s \ell_t\left(n\right)dn + \int_0^s \ell_t\left(h\right)dh \right) \equiv \left(\frac{w_t(j)}{w_t} \right)^{-\psi_t} \ell_t \end{aligned} \tag{29}$$

where ℓ is per-capita total labor in the economy.

2.6 Price setting in the nontradables sector

Consider now profit maximization in the intermediate nontradables sector. Each firm n takes into account the demand (11) for its product and sets its nominal price by maximizing the present discounted value of real profits. There are costs of nominal price adjustment measured in terms of total profits foregone. The adjustment cost is denoted $\Gamma_{PN,t}$ $[p_t(n), p_{t-1}(n)]$.[19]

The price-setting problem is then characterized as:

$$\max_{\{p_\tau(n)\}_{\tau=t}^{\infty}} \mathsf{E}_t \sum_{\tau=t}^{\infty} D_{t,\tau}\pi_{t,\tau}g_{t,\tau} \left[p_\tau(n) - mc_\tau(n)\right] \left(\frac{p_\tau(n)}{p_{N,\tau}} \right)^{-\theta_{N,t}} \left(N_{A,\tau} + N_{E,\tau} + G_{N,\tau}\right)\left(1-\Gamma_{PN,\tau}(n)\right) \tag{30}$$

where $D_{t,\tau}$ (with $D_{t,t} = 1$) is the appropriate discount rate, to be defined below in eq. (48). As real variables are detrended and prices are deflated by the CPI, eq. (30) includes $\pi_{t,\tau}$, the CPI inflation rate between time t and time τ, and $g_{t,\tau}$, the rate of growth of the global trend between t and τ.

As firms n are symmetric and charge the same equilibrium price $p(n) = p_N$, the first order condition can be written as:

$$\begin{aligned} 0 = &\left(1-\Gamma_{PN,t}(n)\right)\left[p_t(n)\left(1-\theta_{N,t}\right) + \theta_{N,t}mc_t(n)\right] - \left[p_t(n) - mc_t(n)\right] \frac{\partial \Gamma_{PN,t}}{\partial p_t(n)} p_t(n) \\ &- \mathsf{E}_t D_{t,t+1}\pi_{t,t+1}g_{t,t+1}\left[p_{t+1}(n) - mc_{t+1}(n)\right] \frac{N_{A,t+1} + N_{E,t+1} + G_{N,t+1}}{N_{A,t} + N_{E,t} + G_{N,t}} \frac{\partial \Gamma_{PN,t+1}}{\partial p_t(n)} p_t(n) \end{aligned} \tag{31}$$

[19] It is worth emphasizing that the adjustment costs are related to changes in nominal prices. However, the maximization problem can be carried out in terms of relative prices. In fact, denote with $G_{PN,t}[P_t(n), P_{t-1}(n)]$ the adjustment cost as a function of nominal (i.e. non deflated by the CPI) prices $P_t(n)$ and $P_{t-1}(n)$, with $G_{PN,t}[P_t(n), P_{t-1}(n)] = \Gamma_{PN,t}\ [p_t(n), p_{t-1}(n)]$, and express the price-setting problem in nominal terms. It is easy to verify that the first order condition of the new problem coincides with (31) since $P_t(n)\partial G_{PN,t}/\partial P_t(n) = p_t(n)\partial \Gamma_{PN,t}/\partial p_t(n)$ and $P_t(n)\partial G_{PN,t+1}/\partial P_t(n) = p_t(n)\partial \Gamma_{PN,t+1}/\partial p_t(n)$.

Interpreting the previous equation, when prices are fully flexible ($\Gamma_{PN}=0$), the optimization problem collapses to the standard markup rule:

$$p_t(n) = \frac{\theta_{N,t}}{\theta_{N,t}-1} mc_t(n) \tag{32}$$

where the gross markup is a negative function of the elasticity of input substitution. Deviations from markup pricing occur if firms are penalized for modifying their prices in the short term. The speed of adjustment in response to shocks depends on the trade-off between current and future expected costs, making the price-setting process forward-looking.

The specific parameterization we adopt allows the model to reproduce realistic nominal dynamics:

$$\Gamma_{PN,t}(n) \equiv \frac{\phi_{PN}}{2}\left(\pi_{t-1,t}\frac{p_t(n)/p_{t-1}(n)}{\Pi_{t-4,t}^{0.25}} - 1\right)^2 \tag{33}$$

The adjustment cost is related to changes of the nominal price of nontradable n relative to the inflation target for the CPI, $\Pi_{t-4,t}$. The inflation target is specified in annualized terms (hence indexed by $t-4,t$), while changes in $p(n)$ occur at a quarterly frequency.[20] Underlying this specification is the notion that firms should not be penalized when their price hikes are indexed to some (publicly observable) benchmark such as the inflation target for the economy as a whole.

2.7 Price setting in the tradables sector and exchange rate pass-through

Consider now the price-setting problem in the tradables sector. To the extent that the four country blocs represent segmented markets in the global economy, each firm h has to set four prices, one in the domestic market and the other three in the export markets. Exports are invoiced (and prices are set) in the currency of the destination market. As we re-introduce export markets, once again our notation needs to make explicit the country indexes. In what follows we use the index CO for a generic country, and denote as H the country where the exporting firm h^H is located.

Accounting for (21), the four price-setting problem of firm h in country H can then characterized as follows:

$$\begin{aligned}&\max_{\sum_{CO}\{p_\tau^{CO}(h^H)\}_{\tau=t}^{\infty}} \sum_{CO} \mathsf{E}_t \sum_{\tau=t}^{\infty} D_{t,\tau}^H \pi_{t,\tau}^H g_{t,\tau}[\varepsilon_\tau^{H,CO} p_\tau^{CO}(h^H) - mc_\tau^H(h^H)] \\ &* \frac{s^{CO}}{s^H}\left(\frac{p_\tau^{CO}(h^H)}{p_{M,\tau}^{CO,H}}\right)^{-\theta_{T,t}^H}\left(M_{A,\tau}^{CO,H} + M_{E,\tau}^{CO,H}\right)\left(1-\Gamma_{PM,\tau}^{CO,H}(h)\right)\end{aligned} \tag{34}$$

When $H \neq CO$, recall that $p^{CO}(h^H)$ is the price of good h^H in country CO, $p_M^{CO,H}$ is the price of country CO's imports from country H, and $M_A^{CO,H} + M_E^{CO,H}$ are country CO's imports from country H. The term $\varepsilon^{H,CO}$ is the bilateral exchange rate between country H and country CO (an increase in $\varepsilon^{H,CO}$ represents a depreciation of country H's currency

[20] This specification implies that the inflation target is known at any point in time. More generally, the adjustment cost could be specified relative to any variable that converges asymptotically to the steady-state inflation rate.

against country CO)[21] and $\Gamma^{H,CO}_{PM}(h^H)$ are adjustment costs related to changes of the price of good h^H in country CO. These costs are the analogs of (33):

$$\Gamma^{CO,H}_{PM,t}(h^H) \equiv \frac{\phi^{CO,H}_{PM}}{2}\left(\pi^{CO}_{t-1,t}\frac{p^{CO}_t(h^H)/p^{CO}_{t-1}(h^H)}{\left(\Pi^{CO}_{t-4,t}\right)^{0.25}}-1\right)^2 \tag{35}$$

For the domestic prices of tradables $p^H(h^H)$ we still use (34) with $CO = H$, adopting the notational conventions $p^{H,H}_M = p^H_Q$, $M^{H,H}_A = Q^H_A$ and $M^{H,H}_E = Q^H_E$ as described in (12), and $\Gamma^{H,H}_{PM} = \Gamma^H_{PQ}$.

Despite its fastidiousness, the notation above is straightforward and the equations are self-explanatory. Profit maximization yields:

$$\begin{aligned}0 &= \left(1-\Gamma^{CO,H}_{PM,t}(h^H)\right)\left[\varepsilon^{H,CO}_t p^{CO}_t(h^H)\left(1-\theta^H_{T,t}\right)+\theta^H_{T,t}mc^H_t(h^H)\right]\\ &-\left[\varepsilon^{H,CO}_t p^{CO}_t(h^H)-mc^H_t(h^H)\right]\frac{\partial\Gamma^{CO,H}_{PM,t}}{\partial p^{CO}_t(h^H)}p^{CO}_t(h^H)-\mathsf{E}_t\{D^H_{t,t+1}\pi^H_{t,t+1}g_{t,t+1}\\ &*\left[\varepsilon^{H,CO}_{t+1}p^{CO}_{t+1}(h^H)-mc^H_{t+1}(h^H)\right]\left(\frac{M^{CO,H}_{A,t+1}+M^{CO,H}_{E,t+1}}{M^{CO,H}_{A,t}+M^{CO,H}_{E,t}}\right)\frac{\partial\Gamma^{CO,H}_{PM,t+1}}{\partial p^{CO}_t(h^H)}p^{CO}_t(h^H)\}\end{aligned} \tag{36}$$

If adjustment costs in the export market are highly relevant (that is, if the $\phi^{CO,H}_{PM}$ coefficient are relatively large), the prices of country H's goods in the foreign markets are characterized by significant stickiness in local currency. In this case, the degree to which exchange rate (and other shocks to marginal costs in country H) pass-through onto import prices in country CO is rather low. If instead the $\phi^{CO,H}_{PM}$ coefficients are zero worldwide, expression (36) collapses to a markup rule under the law of one price, and exchange rate pass-through is full:

$$p^{H,H}_t(h^H) = p^H_{Q,t} = \varepsilon^{H,CO}_t p^{CO}_t(h^H) = \varepsilon^{H,CO}_t p^{CO,H}_{M,t} = \frac{\theta_{T,t}}{\theta_{T,t}-1}mc_t \tag{37}$$

2.8 Consumer preferences

In each country there is a continuum of households indexed by $j \in [0, s]$, the same index of labor inputs. Some households have access to capital markets, some do not. The latter finance their consumption by relying exclusively on their labor incomes. We refer to the first type as 'Ricardian' or 'forward-looking'; they represent a share $(1 - s_{LC})$ of domestic households and are indexed by $j \in [0, s\,(1 - s_{LC})]$. We refer to the second type as 'non-Ricardian' or 'liquidity-constrained'; they represent a share s_{LC} of domestic households and are indexed by $j \in (s\,(1 - s_{LC})\,, s]$.

The specification of households' preferences adopts the Greenwood, Hercowitz and Huffman (1988) (GHH) utility function, adjusted for habit formation and preference shocks. Denoting with $\mathcal{W}_t(j)$ the lifetime expected utility of household j, we have:

$$\mathcal{W}_t(j) \equiv \mathsf{E}_t\sum_{\tau=t}^{\infty}\beta_{t,\tau}g^{1-\sigma}_{t,\tau}u_\tau(\,C_\tau(j),\ell_\tau(j)\,) \tag{38}$$

[21] All exchange rates are quoted in real terms, that is, in relative consumption units. Of course, $\varepsilon^{H,CO} = 1/\varepsilon^{CO,H}$ and $\varepsilon^{H,H} = 1$.

where the instantaneous felicity is a function of detrended consumption C and labor effort ℓ:

$$u_t\ (\ C_t(j), \ell_t(j)\ ) = Z_U(1 - \frac{b_c}{g_{t-1,t}})(\frac{1-b_\ell}{1-\sigma})$$
$$*[\frac{C_t(j) - b_c C_{j,t-1}/g_{t-1,t}}{1-b_c/g_{t-1,t}} - \frac{Z_V}{1+\zeta}(\frac{\ell_t(j) - b_\ell \ell_{j,\tau-1}}{1-b_\ell})^{1+\zeta}]^{1-\sigma} \tag{39}$$

In the expressions above $\beta_{t,\tau}$ is the discount rate between time t and time τ, possibly different across countries.[22] The term $g_{t,\tau}^{1-\sigma}$ in (38) implies that the disutility of labor effort increases with the common trend.[23] As customary, this feature can be interpreted as technological progress associated with home production activities, here related to the global trend. The parameter σ in (38) and (39) is the reciprocal of the elasticity of intertemporal substitution. The parameter ζ which affects the curvature of labor disutility is the reciprocal of the Frisch elasticity.

There is habit persistence in consumption with coefficient $0 < b_c < 1$. The term $C_{j,t-1}$ in (39) is past per-capita consumption of household j's peers, (i.e., either forward-looking or liquidity-constrained agents). Similarly, there is habit persistence in leisure with coefficient $0 < b_\ell < 1$.[24] The terms Z_U and Z_V are constants. Households' preferences are therefore symmetric within their respective categories but, because of different reference groups in habit formation, they are not symmetric across categories.

2.9 Budget constraint (Ricardian households)

The individual flow budget constraint for Ricardian agent $j \in [0, (1-s_{LC})\, s]$ is:

$$B_t(j) + \varepsilon_t B_t^*(j) \leq (1+i_{t-1})\frac{B_{t-1}(j)}{\pi_{t-1,t}\, g_{t-1,t}} + (1+i_{t-1}^*)\,[1-\Gamma_{B,t-1}]\,\frac{\varepsilon_t B_{t-1}^*(j)}{\pi_{t-1,t}^{US} g_{t-1,t}}$$
$$+ (1-\tau_{K,t})\, r_t K_t(j) + (1-\tau_{L,t})\, w_t(j)\ell_t(j)\ (\ 1-\Gamma_{W,t}(j)\ )$$
$$- C_t(j) - p_{E,t} I_t(j) + \Phi_t(j) - TT_t(j) \tag{40}$$

Households hold two nominal bonds, denominated in domestic and US currency, respectively.[25] In terms of our notation, $B_t(j)$ is (detrended) holdings of domestic bond by household j, expressed in terms of domestic consumption units, $B_t^*(j)$ is (detrended) holdings of the international bond, expressed in terms of US consumption units, and ε_t is the CPI-based real exchange rate, expressed as the price of one US consumption basket in terms of domestic consumption.[26]

The short-term nominal rates i_t and i_t^* are paid at the beginning of period $t+1$ and are known at time t. The two rates are directly controlled by their respective national

[22] If the quarterly rate of time preference RTP were constant over time, the discount rate would be $\beta_{t,\tau} = b^{\tau-t}$ where $b = 1/(1+RTP)$.

[23] The restriction $\beta_{t,\tau} g_{t,\tau}^{1-\sigma} < 1$ is imposed to ensure that utility is bounded.

[24] The instantaneous felicity is normalized such that in a steady state U, U_C and U_ℓ can all be written as $constant * f(C,\ell)$, where f is some function of steady-state consumption and labor effort, independent of the habit persistence coefficients.

[25] The choice of currency denomination of the international bond is arbitrary. With a simple re-definition of the relevant variables one could think of B^* in terms of any available currency, or basket of currencies.

[26] It is understood that ε is shorthand for $\varepsilon^{H,US}$, where H denotes the country under consideration.

governments. Only the US-currency bond is traded internationally: the US bond is in zero net supply worldwide, while the domestic bond is issued by the local government.[27] It follows that the net financial wealth of Ricardian household j at time t is:

$$F_t(j) \equiv (1 + i^*_{t-1}) [1 - \Gamma_{B,t-1}] \frac{\varepsilon_t B^*_{t-1}(j)}{\pi^{US}_{t-1,t} g_{t-1,t}} \tag{41}$$

A financial friction Γ_B is introduced to guarantee that international net asset positions follow a stationary process and the economies converge asymptotically to a well-defined steady state. Agents who take a position in the international bond market must deal with financial intermediaries who charge a transaction fee Γ_B on sales/purchases of the international bond.[28] This transaction cost is a function of the average net asset position of the whole economy. Specifically, we adopt the following functional form:

$$1 - \Gamma_{B,t} = \left(1 - \phi_{B1} \frac{\exp\left(\phi_{B2}\left[\varepsilon_t B^*_t - b^*_{FDES,t} GDP_t\right]\right) - 1}{\exp\left(\phi_{B2}\left[\varepsilon_t B^*_t - b^*_{FDES,t} GDP_t\right]\right) + 1} - Z_{B,t} \right) \frac{\beta^{US}_t}{\beta_t} \tag{42}$$

where $0 \leq \phi_{B1} \leq 1$, $\phi_{B2} > 0$, and $\varepsilon_t B^* \equiv (1/s)\, \varepsilon_t \int_0^{s(1-s_{LC})} B^*(j)dj$ represents the per-capita net asset position of the country in consumption units. The term b^*_{FDES} is the 'desired' net asset position of the country expressed as a ratio of GDP.[29] This variable measures the degree of international exposure that financial intermediaries consider appropriate for the economy, based on their assessment of the economic outlook.

To understand the role played by Γ_B, suppose first that $b^*_{FDES} = Z_B = 0$ and $\beta^{US} = \beta$. In this case, when the net asset position of the country is equal to its 'desired' level of zero, it must be the case that $\Gamma_B = 0$ and the return on the international bond is equal to $1 + i^*$. If the country is a net creditor worldwide Γ_B rises above zero, implying that the country's households lose an increasing fraction of their international bond returns to financial intermediaries. When holdings of the international bond go to infinity, the return on the international bond approaches $(1 + i^*)(1 - \phi_{B1})$. By the same token, if the country is a net debtor worldwide Γ_B falls from zero to $-\phi_{B1}$, implying that households pay an increasing intermediation premium on their international debt. When net borrowing goes to infinity, the cost of borrowing approaches $(1 + i^*)(1 + \phi_{B1})$. The parameter ϕ_{B2} controls the flatness of the Γ_B function: if $\phi_{B2} = 0$ then $\Gamma_B = 0$ regardless of the net asset position; if ϕ_{B2} tends to infinity then $1 - \Gamma_B = (1 - \phi_{B1})$ for any arbitrarily small net lending position, and $1 - \Gamma_B = (1 + \phi_{B1})$ for any arbitrarily small net borrowing position. An appropriate parameterization allows the model to generate realistic dynamics for net asset positions and current account.

Consider now the other components of (42). The variable $Z_{B,t}$ is a stochastic autoregressive process:[30] uncertainty in international financial intermediation plays in our framework the same role that 'uncovered interest parity shocks' or risk-premium fluctuations play in

[27] If the country under consideration is the US, $\varepsilon = 1$ and $i = i^*$.

[28] In our model it is assumed that all intermediation firms are owned by the country's residents, and that their revenue is rebated to domestic households in a lump-sum fashion. A simple variant of the model in which intermediation firms are owned by foreign residents leaves the basic results virtually unchanged. There are no intermediation costs for US residents entering the international bond market, that is, there is no difference between onshore and offshore US interest rates.

[29] The concept of GDP in our model will be discussed below with reference to (83).

[30] Fluctuations in Z_B cannot be large enough to push Γ_B above 1.

other open-economy models. Finally, when rates of time preference diverge across countries and $\beta^* \neq \beta$, the transaction cost is appropriately modified to account for asymmetries in real interest rates across countries.

The term b^*_{FDES} can be positive or negative. The above considerations are still valid after reinterpreting the concepts of 'net creditor' or 'net borrower' in terms of deviations from the desired levels. The desired net asset position in country H is characterized as follows:

$$b^{*H}_{FDES,t} = b^{*H}_{FNEUT} - \phi^H_{F1} \frac{B^H_t}{GDP^H_t} + \sum_{CO \neq H} \phi^{CO,H}_{F2} \frac{B^{CO}_t}{GDP^{CO}_t} \tag{43}$$

According to the previous expression, b^{*H}_{FDES} is a country-specific constant, b^{*H}_{FNEUT}, adjusted to account for changes in the debt-to-GDP ratios in either the domestic economy (B^H/GDP^H) or the rest of the world (B^{CO}/GDP^{CO}).

This specification provides a plausible link between debt imbalances and net asset positions. If the targeted debt-to-GDP ratio increased in the US, investors in the rest of the world would require a higher return on US securities, leading to a higher share of US assets in their portfolios or a reduction of net borrowing from the US. If however the target debt increased in the home country as well, the US premium would somewhat fall. Of course, our approach should be viewed only as a crude approximation to the actual determinants of cross-country spreads and interest rate premia in response to macroeconomic imbalances, whose endogenization should be eventually incorporated in a self-contained model. It remains unclear, however, whether a framework that incorporates a large amount of complications from which we abstract here would add much to our qualitative conclusions. Quantitatively, one could take b^*_{FDES} as a free variable and estimate the ϕ_{F1} and ϕ_{F2} parameters on the basis of empirical evidence on the link between net asset positions and debt levels. Alternatively, one could rely on cross-fertilization with respect to alternative theoretical models able to shed light on the structural determinants of these parameters, even though less useful in other dimensions. We will return on these considerations in the next sections.

Households accumulate physical capital which they rent to domestic firms at the after-tax rate $r\,(1-\tau_K)$. The law of motion of capital is:

$$K_{t+1}(j) g_{t,t+1} = (1-\delta)\, K_t(j) + \Gamma_{I,t} K_t(j) \qquad 0 < \delta \leq 1 \tag{44}$$

where δ is the country-specific depreciation rate of capital. To simulate realistic investment flows, capital accumulation is subject to adjustment costs. Capital accumulation is denoted $\Gamma_{I,t} K_t(j)$, where $\Gamma_I(.)$ is an increasing, concave, and twice-continuously differentiable function of the investment/capital ratio $I_t(j)/K_t(j)$ with two properties entailing no adjustment costs in steady state: $\Gamma_I(\delta+g-1) = \delta+g-1$ and $\Gamma'_I(\delta+g-1) = 1$. The specific functional form we adopt is quadratic and encompasses inertia in investment:

$$\Gamma_{I,t}(j) \equiv \frac{I_t(j)}{K_t(j)} - \frac{\phi_{I1}}{2} \left(\frac{I_t(j)}{K_t(j)} - (\delta+g-1) \right)^2 - \frac{\phi_{I2}}{2} \left(\frac{I_t(j)}{K_t(j)} - \frac{I_{t-1}}{K_{t-1}} \right)^2$$

where ϕ_{I1}, $\phi_{I2} \geq 0$, and g is the steady-state growth rate.

Each household j is the monopolistic supplier of a specific labor input and sets the nominal wage for its labor variety j accounting for (29). Labor incomes are taxed at the rate τ_L. There is sluggish wage adjustment due to resource costs that are measured in terms of the total wage bill. The adjustment cost is denoted $\Gamma_{WFL,t}$ (for Wage Forward-Looking) and its specification is the analog of (33) above, recalling that the real wage is expressed in detrended terms:

$$\Gamma_{WFL,t}(j) \equiv \frac{\phi_{WFL}}{2}\left(\pi_{t-1,t}g_{t-1,t}\frac{w_t(j)/w_{t-1}(j)}{\Pi_{t-4,t}^{0.25}g_{t-1,t}} - 1\right)^2 \tag{45}$$

Ricardian households own all domestic firms and there is no international trade in claims on firms' profits. The variable Φ includes all dividends accruing to shareholders, plus all revenue from nominal and real adjustment rebated in a lump-sum way to all Ricardian households, plus revenue from financial intermediation which is assumed to be provided by domestic firms exclusively.

Finally, agents pay lump-sum (non-distortionary) net taxes $TT_t(j)$ denominated in consumption units.

2.10 Consumer optimization (Ricardian households)

The representative Ricardian household chooses bond holdings, capital and consumption paths, and sets wages to maximize its expected lifetime utility (38) subject to (40) and (44), and taking into account (29).

For expositional convenience, it is worthwhile to write explicitly the maximization problem of agent $j \in [0, (1 - s_{LC})\, s]$ in terms of the following Lagrangian:

$$\begin{aligned}
&\max_{\{C_\tau(j), I_\tau(j), B_\tau(j), B^*_\tau(j), K_{\tau+1}(j), w_\tau(j)\}_{\tau=t}^{\infty}} \mathsf{E}_t \beta_{t,\tau} g_{t,\tau}^{1-\sigma} \{ \; u\left(\; C_\tau(j)\,, \;\; w_\tau^{-\psi_\tau}(j) w_\tau^{\psi_\tau} \ell_\tau, \;\; \right) \\
&+ \mu_\tau(j) \; (\; -B_\tau(j) - \varepsilon_\tau B^*_\tau(j) + \frac{(1+i_{\tau-1})B_{\tau-1}(j)}{\pi_{\tau-1,\tau} g_{\tau-1,\tau}} + \frac{(1+i^*_{\tau-1})(1-\Gamma_{B,\tau-1})\varepsilon_\tau B^*_{\tau-1}(j)}{\pi^{US}_{\tau-1,\tau} g_{\tau-1,t}} \\
&+ (1-\tau_{K,\tau})\, r_\tau K_\tau(j) + (1-\tau_{L,\tau})\, w_\tau(j)^{1-\psi_\tau} w_\tau^{\psi_\tau} \ell_\tau (1 - \Gamma_{W,\tau}[w_\tau(j), w_{\tau-1}(j)]) \\
&- C_\tau(j) - p_{E,\tau} I_\tau(j) + \Phi_\tau(j) - TT_\tau(j) \;\;) \\
&+ \lambda_\tau(j) \; (\; -K_{\tau+1}(j) g_{\tau,\tau+1} + (1-\delta)\, K_\tau(j) + \Gamma_{I,\tau}\left[I_\tau(j)/K_\tau(j)\right] K_\tau(j) \;) \; \}
\end{aligned} \tag{46}$$

where μ and λ are the multipliers associated with, respectively, the budget constraint and capital accumulation.

The first order conditions with respect to $C_t(j)$ and $I_t(j)$ yield:

$$\mu_t(j) = \partial u_t(j)/\partial C_t(j) = \lambda_t(j) \Gamma'_{I,t}(j)/p_{E,t} \tag{47}$$

In a symmetric setup, $\partial u_t(j)/\partial C_t(j)$ is the same across Ricardian agents j. Their stochastic discount rate and pricing kernel is therefore the variable $D_{t,\tau}$, which is defined as:

$$D_{t,\tau} \equiv \beta_{t,\tau} g_{t,\tau}^{1-\sigma} \frac{\mu_\tau}{\mu_t} \frac{1}{\pi_{t,\tau}} \frac{1}{g_{t,\tau}} \tag{48}$$

Accounting for the above expressions, the first order conditions with respect to $B_t(j)$ and $B^*_t(j)$ are, respectively:

$$1 = (1+i_t)\, \mathsf{E}_t D_{t,t+1} \tag{49}$$

$$1 = (1+i^*_t)\,(1-\Gamma_{B,t})\, \mathsf{E}_t\left(D_{t,t+1}\Delta_{t,t+1}\right) \tag{50}$$

where Δ denotes the rate of nominal exchange rate depreciation against the US, or:

$$\Delta_{t,\tau} = \frac{\varepsilon_\tau}{\varepsilon_t} \frac{\pi_{t,\tau}}{\pi^*_{t,t}} \tag{51}$$

In a non-stochastic steady state (49) implies $(1+i)/\pi = g^{\sigma}/\beta$, where π is the (gross steady-state quarterly) inflation rate, $(1+i)/\pi$ is the real interest rate, g is the (gross steady-state quarterly) rate of growth of the world economy, $1/\beta$ is the rate of time preference, and g^{σ}/β is the 'natural' rate of the economy.[31] Expressions (49) and (50) yield the risk-adjusted uncovered interest parity, recalling that the return on international bond holdings is modified to account for the costs of intermediation Γ_B. In a non-stochastic steady state the interest differential $(1+i)/[(1+i^*)(1-\Gamma_B)]$ is equal to the steady-state nominal depreciation rate of the currency vis-a-vis the US, and relative purchasing power parity holds.

The first order condition with respect to $K_{t+1}(j)$ is:

$$\frac{p_{E,t}}{\Gamma'_{I,t}(j)} \mathsf{E}_t g_{t,t+1} = \mathsf{E}_t \{ \, D_{t,t+1}\pi_{t,t+1}g_{t,t+1}(\; (1-\tau_{K,t+1}) \, r_{t+1} \\ + \frac{p_{E,t+1}}{\Gamma'_{I,t+1}(j)} \left[1-\delta+\Gamma_{I,t+1}(j)-\Gamma'_{I,t+1}(j)\frac{I_{t+1}(j)}{K_{t+1}(j)}\right] \;) \, \} \tag{52}$$

Expression (52) links capital accumulation to the behavior of the after-tax price of capital $(1-\tau_K)\,r$. In a non-stochastic steady state $1+(1-\tau_K)\,r/p_E$ is equal to the sum of the natural real rate g^{σ}/β and the rate of capital depreciation δ.[32]

Finally, the first order condition with respect to $w(j)$ determines wage dynamics for the wages of the Ricardian households:

$$-\,\psi_t \frac{u_{\ell,t}(j)}{u_{C,t}(j)} \frac{1}{w_t(j)} = (\psi_t - 1)\left[1-\Gamma_{WFL,t}(j)\right](1-\tau_{L,t}) + \frac{\partial \Gamma_{WFL,t}(j)}{\partial w_t(j)} w_t(j)\,(1-\tau_{L,t}) \\ + \mathsf{E}_t D_{t,t+1}\pi_{t,t+1}g_{t,t+1} \frac{(w_{t+1}(j)/w_{t+1})^{-\psi_{t+1}}}{(w_t(j)/w_t)^{-\psi_t}} \frac{w_{t+1}(j)}{w_t(j)} \frac{\ell_{t+1}}{\ell_t} \frac{\partial \Gamma_{WFL,t+1}(j)}{\partial w_t(j)} w_t(j)\,(1-\tau_{L,t+1}) \tag{53}$$

Different from (31) above, in expression (53) it is no longer true that the wage rate of the Ricardian household $w(j)$ is equal to the average wage rate in the economy w. In a non-stochastic steady state the real wage $w(j)$ is equal to the marginal rate of substitution between consumption and leisure, $-u_{\ell}/u_c$, augmented by the markup $\psi/(\psi-1)$ which reflects monopoly power in the labor market.

2.11 Consumer optimization (liquidity-constrained households)

Liquidity-constrained households have no access to capital markets. Their optimal choices are confined to labor supply. Similar to Ricardian households, they can optimally set their wages to exploit their market power. The maximization problem of agent $j \in ((1-s_{LC})\,s, s]$ can be written in terms of the following static Lagrangian:

$$\max_{C_t(j),w_t(j)} u_t \; (\; C_t(j), \ell_t(j) \;) + \mu_t(j) \; (\; -C_t(j) - TT_t(j) \\ + (1-\tau_{L,t})\,w_t(j)^{1-\psi_t} w_t^{\psi_t} \ell_t (1-\Gamma_{WLC,t}[w_t(j), w_{t-1}(j)]) \;\;) \tag{54}$$

[31] International differences in natural rates can arise from asymmetric rates of time preference. They are accounted for in the definition of Γ_B in (42)

[32] The expectation operator on the left hand side of (52) is needed as shocks to the trend $g_{t,t+1}$ are not part of the information set at time t. This is because variables are expressed as deviations from the current trend. An alternative specification which expresses variables as deviations from the lagged trend would make little difference.

It is assumed that redistributive policies rebate to these households the income losses associated with wage adjustment, so that their consumption level is:

$$C_t(j) = (1 - \tau_{L,t})\, w_t(j)\ell_t(j) \tag{55}$$

The first order conditions with respect to $C(j)$ and $w(j)$ determines partial adjustment of wages:

$$-\psi_t \frac{u_{\ell,t}(j)}{u_{C,t}(j)} \frac{1}{w_t(j)} = (1 - \tau_{L,t})\ \left[(\psi_t - 1)\left(1 - \Gamma_{WLC,t}(j) \right) + \frac{\partial \Gamma_{WLC,t}(j)}{\partial w_t(j)} w_t(j) \right] \tag{56}$$

Denoting w_{FL} the wage rate $w(j)$ that solves (53), and w_{LC} the wage rate $w(j)$ that solves (56), equation (27) determines the wage rate for the whole economy as:

$$w_t^{1-\psi_t} = s_{LC} w_{LC,t}^{1-\psi_t} + (1 - s_{LC})\, w_{FL,t}^{1-\psi_t} \tag{57}$$

2.12 Government

Public spending falls on nontradable goods, both final and intermediate. In per-capita terms, G_C is government consumption, G_I is government investment, and G_N denotes public purchases of intermediate nontradables. There are three sources of (net) tax revenue: taxes on capital income τ_K, taxes on labor income τ_L, and lump-sum taxes TT net of transfers to households. The government finances the excess of public expenditure over net taxes by issuing debt denominated in nominal currency, denoted B in per-capita terms. All national debt is held exclusively by domestic (Ricardian) agents. The budget constraint of the government is:

$$B_t \geq (1 + i_{t-1}) \frac{B_{t-1}}{\pi_{t-1,t} g_{t-1,t}} + G_t - G_{REV,t} \tag{58}$$

where:

$$G_t = G_{C,t} + p_{E,t} G_{I,t} + p_{N,t} G_{N,t} \tag{59}$$

and:

$$G_{REV,t} = \frac{1}{s} \left(\int_0^s TT_t(j)dj + \tau_{K,t} r_t \int_0^{s(1-s_{LC})} K_t(j)dj + \tau_{L,t} \int_0^s w_t(j)\ell_t(j)dj \right) \tag{60}$$

Define now the average tax rate for the economy τ as:

$$\tau_t \equiv G_{REV,t}/GDP_t \tag{61}$$

Similarly, define the deficit-to-GDP ratio as:

$$\frac{DEF_t}{GDP_t} = \left(B_t - \frac{B_{t-1}}{\pi_{t-1,t} g_{t-1,t}} \right) / GDP_t \tag{62}$$

From (58), in steady state we have:

$$\frac{B}{GDP} = \frac{\pi g}{\pi g - (1+i)} \left(\frac{G}{GDP} - \tau \right) = \frac{\pi g}{\pi g - 1} \frac{DEF}{GDP} \tag{63}$$

The previous equations define the relations between debt-to-GDP, average tax rate, and deficit-to-GDP ratio which are sustainable in the long term. In what follows we treat the long-run debt-to-GDP ratio as a policy parameter set by the government, and let τ and DEF/GDP be determined by (63).

The government is assumed to control lump-sum taxes, τ and τ_K directly, while τ_L is endogenously determined. The fiscal rule for τ is specified as:

$$\tau_t = (\tau_{t-1} + \tau_t + \mathsf{E}_t\tau_{t+1})/3 + \phi_{TAX1}(\frac{B_t}{GDP_t} - \phi_{TAX2}B_{TAR,t} - (1-\phi_{TAX2})\frac{B_{t-1}}{GDP_{t-1}})$$
$$+\phi_{TAX3}\left(\frac{DEF_t}{GDP_t} - \frac{DEF}{GDP}\right) + \phi_{TAX4}\left(\frac{G_t}{GDP_t} - \frac{G}{GDP}\right) \tag{64}$$

where B_{TAR} is an autoregressive process for the targeted debt-to-GDP ratio. The tax rate is a smoothed function of past and expected future rates, adjusted upward when: the current debt-to-GDP ratio is above the average of its current target and its past observed level; when the current deficit-to-GDP ratio is above its sustainable steady-state level; and when current government spending as a share of GDP is above its long-run level.

The government controls the short-term rate i_t. Monetary policy is specified in terms of annualized interest rate rules of the form:

$$(1+i_t)^4 = \omega_i (1+i_{t-1})^4 + (1-\omega_i)\left(1+i_t^{neut}\right)^4 + \omega_1 \mathsf{E}_t\left(\pi_{t-1,t+3} - \Pi_{t-1,t+3}\right) \tag{65}$$

The current interest rate i_t is an average of the lagged rate i_{t-1} and the current 'neutral' rate i_t^{neut}, defined as:[33]

$$1 + i_t^{neut} \equiv \frac{\Pi_{t-4,t}^{0.25}\left(g_{t-1,t}\right)^{\sigma}}{\beta_{t-1,t}} \tag{66}$$

This average is adjusted to account for the expected inflation gap three quarters in the future.[34] The rule (65) could be modified to include policy responses to a set of other variables (such as exchange rate or current account) expressed as deviations from their targets. In a steady state when all constant targets are reached it must be the case that:

$$1 + i = 1 + i^{neut} = \frac{\Pi^{0.25}g^{\sigma}}{\beta} = \frac{\pi g^{\sigma}}{\beta}. \tag{67}$$

2.13 Market clearing

The model is closed by imposing the following resource constraints and market clearing conditions, adopting explicit country indexes.

For every country H, the domestic resource constraints for capital and labor are, respectively:

$$\int_0^{s^H\left(1-s_{LC}^H\right)} K_t^H(j^H)dj^H \geq \int_0^{s^H} K_t^H(n^H)dn^H + \int_0^{s^H} K_t^H(h^H)dh^H \tag{68}$$

and:

$$\ell_t^H(j^H) \geq \int_0^{s^H} \ell_t^H(n^H,j^H)dn^H + \int_0^{s^H} \ell_t^H(h^H,j^H)dh^H \tag{69}$$

The resource constraint for the nontradable good n^H is:

$$N_t^H(n^H) \geq \int_0^{s^H} N_{A,t}^H(n^H,x^H)dx^H + \int_0^{s^H} N_{E,t}^H(n^H,e^H)de^H + G_{N,t}^H(n^H) \tag{70}$$

[33] Recall that $\Pi_{t-\tau,t-\tau+4}$ is the year-on-year gross CPI inflation target prevailing at time t for the four-quarter period between $t-\tau$ and $t-\tau+4$.

[34] We discuss this specification below. In the case of AS, we model an exchange rate targeting regime by introducing the component $\omega_2^{AS}\Delta_t^{AS}$ in (65), where Δ^{AS} is defined in (51) and we choose a very high value of ω_2^{AS} to peg the nominal bilateral exchange rate against the US.

while the tradable h^H can be used by domestic firms or imported by foreign firms:

$$T_t\left(h^H\right) \geq \int_0^{s^H} Q_{A,t}(h^H, x^H)dx^H + \int_0^{s^H} Q_{E,t}(h^H, e^H)de^H$$
$$+ \sum_{CO\neq H}\left(\int_0^{s^{CO}} M_{A,t}^{CO,H}(h^H, x^{CO})dx^{CO} + \int_0^{s^{CO}} M_{E,t}^{CO,H}(h^H, e^{CO})de^{CO}\right) \quad (71)$$

The final good A can be used for private (by both liquidity-constrained and forward-looking households) or public consumption:

$$\int_0^{s^H} A_t^H(x^H)dx^H \geq \int_0^{s^H(1-s^H_{LC})} C^H(j^H)dj^H + \int_{s^H(1-s^H_{LC})}^{s^H} C^H(j^H)dj^H + sG_{C,t} \quad (72)$$

and similarly for the investment good E:

$$\int_0^{s^H} E_t^H(e^H)de^H \geq \int_0^{\left(1-s^H_{LC}\right)s^H} I_t^H(j^H)dj^H + s^H G^H_{I,t} \quad (73)$$

All profits and intermediation revenue accrue to Ricardian households:

$$\int_0^{s^H(1-s^H_{LC})} \Phi_t^H(j^H)dj^H = \int_0^{s^H(1-s^H_{LC})} (1+i^*_{t-1})\Gamma^H_{B,t-1}\frac{\varepsilon_t^{H,US}B^{*H}_{t-1}(j^H)}{\pi^{US}_{t-1,t}g_{t-1,t}}dj^H$$
$$+ \int_0^{s^H(1-s^H_{LC})} \Gamma^H_{WFL,t}(j^H)\left(1-\tau^H_{L,t}\right)w_t^H(j^H)dj^H + \int_{s^H(1-s^H_{LC})}^{s^H} \Gamma^H_{WLC,t}(j^H)\left(1-\tau^H_{L,t}\right)w_t^H(j^H)dj^H$$
$$+ \int_0^{s^H}\left[p_t^H(n^H) - mc_t^H(n^H)\right]\left(\int_0^{s^H} N^H_{A,t}(n^H, x^H)dx^H + \int_0^{s^H} N^H_{E,t}(n^H, e^H)de^H + G^H_{N,t}(n^H)\right)dn^H$$
$$+ \int_0^{s^H}\left[p_t^H(h^H) - mc_t^H(h^H)\right]\left(\int_0^{s^H} Q^H_{A,t}(h^H, x^H)dx^H + \int_0^{s^H} Q^H_{E,t}(h^H, e^H)de^H\right)dh^H$$
$$+ \sum_{CO\neq H}\int_0^{s^H}\left[\varepsilon_\tau^{H,CO}p_\tau^{CO}(h^H) - mc_\tau^H(h^H)\right]$$
$$*\left(\int_0^{s^{CO}} M^{CO,H}_{A,t}(h^H, x^{CO})dx^{CO} + \int_0^{s^{CO}} M^{CO,H}_{E,t}(h^H, e^{CO})de^{CO}\right)dh^H \quad (74)$$

Market clearing in the asset market requires:

$$\int_0^{s^H(1-s^H_{LC})} B_t^H(j^H)dj^H = s^H B_t^H \quad (75)$$

for the four government bond markets, and:

$$\sum_{CO}\int_0^{s^{CO}(1-s^{CO}_{LC})} B_t^{*CO}(j^{CO})dj^{CO} = 0. \quad (76)$$

for the international bond market. Finally, aggregating the budget constraints across private and public agents after imposing the appropriate transversality conditions we obtain the law of motion for financial wealth:

$$\mathsf{E}_t D^H_{t,t+1}\pi^H_{t,t+1}g_{t,t+1}F^H_{t+1} = F_t^H + \Gamma^H_{B,t-1}\frac{\left(1+i^*_{t-1}\right)\varepsilon_t^{H,US}B^{*H}_{t-1}}{\pi^{US}_{t-1,t}g_{t-1,t}}$$
$$+ p^H_{N,t}N_t^H + p^H_{T,t}T_t^H - C_t^H - p^H_{E,t}I_t^H - G_t^H \quad (77)$$

where the total value of tradables is defined as:

$$p_{T,t}^{H}T_t^{H} \equiv p_{Q,t}^{H}\left(Q_{A,t}^{H}+Q_{E,t}^{H}\right)+\sum_{CO\neq H}\frac{s^{CO}}{s^{H}}\varepsilon^{H,CO}p_{M,t}^{CO,H}\left(M_{A,t}^{CO,H}+M_{E,t}^{CO,H}\right) \quad (78)$$

2.14 Measuring output and current account

Expression (78) can be written as:

$$CURBAL_t^{H}=\varepsilon_t^{H,US}\left(B_t^{*H}-\frac{B_{t-1}^{*H}}{\pi_{t-1,t}^{US}g_{t-1,t}}\right)=\frac{i_{t-1}^{*}\varepsilon_t^{H,US}B_{t-1}^{*H}}{\pi_{t-1,t}^{US}g_{t-1,t}}+TBAL_t \quad (79)$$

The left hand side of (79) is country H's current account, the first term on the right hand side are net factor payments from the rest of the world to country H and $TBAL$ is the trade balance. The latter can be thought of as:

$$TBAL_t^{H}=EX_t^{H}-IM_t^{H} \quad (80)$$

where total exports EX are:

$$EX_t^{H}=p_{T,t}^{H}T_t^{H}-p_{Q,t}^{H}\left(Q_{A,t}^{H}+Q_{E,t}^{H}\right) \quad (81)$$

and total imports IM are:

$$\begin{aligned}IM_t^{H}&=p_{MA,t}M_{A,t}^{H}+p_{ME,t}M_{E,t}^{H}\\&=\sum_{CO\neq H}p_{M,t}^{H,CO}\left(M_{A,t}^{H,CO}\frac{1-\Gamma_{MA,t}^{H,CO}}{1-\Gamma_{MA,t}^{H,CO}-M_{A,t}^{H,CO}\Gamma'^{H,CO}_{MA,t}}+M_{E,t}^{H,CO}\frac{1-\Gamma_{ME,t}^{H,CO}}{1-\Gamma_{ME,t}^{H,CO}-M_{E,t}^{H,CO}\Gamma'^{H,CO}_{ME,t}}\right)\end{aligned} \quad (82)$$

The adjustment terms in the previous equation reflects the fact that it takes time for imports to be fully productive in production, so that their effective costs are higher from the viewpoint of national producers and consumers of final goods than at the border level.

Finally, we define the model-based Gross Domestic Product (in consumption units) as:

$$GDP_t^{H}=A_t^{H}+p_{E,t}^{H}E_t^{H}+p_{N,t}^{H}G_{N,t}^{H}+EX_t^{H}-IM_t^{H}=p_{N,t}^{H}N_t^{H}+p_{T,t}^{H}T_t^{H} \quad (83)$$

so that:

$$CURBAL_t^{H}=TBAL_t^{H}+\frac{i_{t-1}^{*}\varepsilon_t^{H,US}B_{t-1}^{*H}}{\pi_{t-1,t}^{US}g_{t-1,t}}=GDP_t^{H}-\left(C_t^{H}+p_{E,t}^{H}I_t^{H}+G_t^{H}\right)+\frac{i_{t-1}^{*}\varepsilon_t^{H,US}B_{t-1}^{*H}}{\pi_{t-1,t}^{US}g_{t-1,t}} \quad (84)$$

While theoretically sound, this measure of output would bear little similarity with standard fixed-weight, constant-dollar measures of real GDP provided by national accounts. The problem is particularly severe for relatively open economies facing large swings in real exchange rates and relative prices. In the simulations that follow, we therefore adopt 'national accounts' concepts for GDP, $TBAL$ and their components, evaluating constant-dollar expenditures at any time t by using fixed steady-state prices instead of the corresponding relative prices at time t.

3 Model calibration

3.1 Initial considerations

The thorough quantification of the wealth of parametric features introduced in the model above represents an obvious (and possibly quixotic) challenge. For the purpose of this paper we suggest a plausible baseline calibration, discussing in some detail the reasons underlying our choices. In general, we rely on previous work done with the IMF's Global Economy Model (GEM), as well as estimates from the literature and our own empirical work.

As we adopt a multi-country model, some thought has been given to the composition of the regional blocs. We chose a four-region model — US (the United States), JE (Japan and the Euro Area countries), AS (Emerging Asia: China, India, Hong Kong, Malaysia, Philippines, Singapore, South Korea, Taiwan and Thailand) and RC (the Remaining Countries not otherwise considered). We have chosen to combine Japan and the Euro Area into one region since, from the vantage point of our project, they share similar structural characteristics — low productivity growth, very low inflation (or deflation), and structural rigidities, particularly in the labor market. Needless to say, Japan and the Euro Area have exhibited very different behaviors in the past regarding the accumulation of U.S. assets. However, our prior is that their role in the global rebalancing process will be comparatively less relevant in the coming years compared to Emerging Asia. The latter bloc consists mostly of the Asian countries which have strong growth and whose currencies exhibit limited flexibility against the US dollar. Moreover, their labor markets are rapidly growing and are flexible. In addition, the ongoing process of liberalization is expected to reduce barriers to entry for firms and enhance competition even for the major members of the bloc such as India and China. The Remaining Countries bloc is dominated by the other members of the EU (particularly the United Kingdom) and the other major OECD countries such as Canada, Australia, New Zealand and Mexico.

Keeping the composition of the four regions in mind, we take great care in providing a realistic description of the macroeconomic interdependencies of the various countries in the real world, particularly their trade linkages. We will first discuss the calibration of the domestic economies for our four regions, focusing on the newer elements of our model (such as non-Ricardian consumers). Next we will go through the calibration of the international linkages.

3.2 Parameterization of the regional blocs

Tables 1 through 5 document the parameterization we have adopted for the four regional blocs. For the most part, we use similar behavioral parameter values for all regions. When they differ, it is for reasons directly related to the analysis of current account dynamics on which our scenario simulations are focused.

Table 1 presents the parameters that are key for the consumers' optimization problem. Even though we consider two kinds of consumers, we calibrate the preferences of the liquidity-constrained and forward-looking households to be the same. We assume that in US, JE and RC the share of liquidity-constrained consumers (s_{LC}) is 25 percent. The share is much higher in Emerging Asia at 50 percent and reflects the nascent or underdeveloped capital markets for domestic consumers particularly in the cases of China, India, Indonesia and the Philippines.

The rate of time preference (the annualized inverse of β), when combined with trend real growth (g) of two percent per year is consistent with an annualized quarterly real world interest rate of three percent. US is the most impatient with the highest rate of time preference of 3.2 percent; AS is the most patient at 2.6 percent.

For all regions we assume a high degree of intertemporal substitution in consumption in the long run ($1/\sigma$) of 5. In the short run we achieve sluggish behavior in consumption through a high value for habit persistence (b_c) of 0.91. Conversely for labor we assume a low Frisch elasticity ($1/\zeta$) in the long run of 0.40, coupled with lower habit persistence (b_ℓ) of 0.75. These choices are similar to the assumptions found in Bayoumi, Laxton and Pesenti (2004), adjusted for our use of the GHH utility function.

For the firms' optimization problem, we also refer the reader to Table 1. The elasticity of substitution between labor and capital (ξ_T and ξ_N) is set at 0.75 in both the tradable and nontradable sectors, slightly lower than the conventional unit (Cobb-Douglas) assumption to help reducing the sensitivity of capital to changes in its relative price. The bias towards the use of capital (α_T and α_N) are calibrated to achieve a relatively high investment share of GDP in AS, and a low share in US (see Table 2). In all regions the nontradable sector is assumed to be less capital intensive than the tradable sector. The depreciation rate δ is assumed to be two percent per quarter across all regions (eight percent per year).

The dynamics of the model are governed by the nominal rigidities and real adjustment costs described in Table 3. The choice of 400 as the standard parameter for the quadratic adjustment costs is roughly equivalent to a four-quarter contract length under Calvo-style pricing. For real rigidities in investment, the parameterization is consistent with Juillard, Karam, Laxton and Pesenti (2004) for a Bayesian-estimated, closed economy DSGE model of the United States. For real rigidities in imports, a value of 0.95 approximates the expected sluggish reaction by volumes to movements in the real exchange rate.

There are separate markups on tradable and non-tradable goods (Table 4) since firms have some pricing power under monopolistic competition. We use estimates for the price markups from Martins, Scarpetta and Pilat (1996) in the case of US, JE and RC. For AS the markups are indicative of some (very) preliminary estimates done in the Research Department of the IMF for certain member countries of the AS bloc. US has the lowest price markups, indicating the greatest degree of competition while Japan and the Euro Area have the highest.

Similarly, in the labor market agents have some pricing power, resulting in the wage markups of Table 4. For US and JE the markups (16 percent and 30 percent respectively) are those found in Bayoumi, Laxton and Pesenti (2004).[35] We further assume that RC is somewhere in between US and JE, with a 20 percent wage markup, while we assume AS has a labor market as competitive as US.

Finally, to provide a nominal anchor for the domestic economy, we need to parameterize monetary policy (Table 5). US, JE and RC are all committed to price stability, and we assume they follow an inflation-forecast-based (IFB) rule.[36] We use a representative cal-

[35] Their determination of the wage markups is based, in turn, on Jean and Nicoletti (2002), who consider the wage differentials for a variety of industries in the United States and six member states of the Euro Area.

[36] IFB rules have been used extensively in central-bank models with Inflation-Targeting regimes in both advanced and emerging-market economies — see, for example, Laxton, Rose and Tetlow (1993), Batini and Haldane (1999), Hunt, Rose and Scott (2000), and Coats and others (2003). And they have also been used in empirical work to characterize monetary policy in other countries that do not have explicit Inflation-Targeting regimes, but have flexible exchange rates — see Orphanides (2003) and Julllard and others (2004). It is important to note that IFB rules are ad hoc. Svensson (1999).and Svensson and Woodford (2005) have proposed Inflation-Forecast-Targeting (IFT) rules based on optimizing loss functions and it is only a question of time before IFT rules are used extensively on linearized versions of the size and type of models considered

ibration of that class of rules, with a weight of 0.75 on the lagged short-term interest in order to impart a high degree persistence in the setting of the policy rate, and a weight of 2.00 on the three-quarter ahead gap between inflation and its target. The year-on-year CPI inflation target is assumed to be fixed at two percent for JE and RC, and somewhat higher at 2.5 percent for US. Emerging Asia is assumed to pursue a fixed exchange rate regime against the US dollar.[37] In one of the alternative scenarios presented below, Emerging Asia switches to an inflation-based rule, but starts with a high value for its inflation target and adopts a lower 2.5 percent target two years after the regime switch.

3.3 The international dimensions

The main features of interest in our model are highly dependent upon the calibration of each region's external sector in Table 6. For any given assumption on the steady-state net foreign asset positions of each region, we calculate the current account and trade balances consistent with long-term sustainability. In combination with the IMF's Direction of Trade Statistics on merchandise trade, the national accounts data on the level of imports of goods and services, and the United Nations' Commodity Trade Statistics (COMTRADE) data on each region's imports of consumption and investment goods, we derive our disaggregated steady-state trade matrix for all regions' exports and imports. We show it in a more aggregated form in Figure 2. On the basis of this trade matrix, we can derive all the bias parameters in the demand function for imports (ν_A and ν_E) and the regional composition of imports (b_A and b_E).

For the corresponding trade elasticities, we assume the elasticity of substitution between domestically-produced and imported tradable consumption goods (μ_A) and investment goods (μ_E) to be 2.5 as in Bayoumi, Laxton and Pesenti (2004). The elasticity of substitution between goods from different regions for imported consumption goods (ρ_A) and imported investment goods (ρ_E) is set at 1.5, consistent with existing estimates of import elasticities.

Lastly, we need to calibrate the behavior of net foreign assets, also in Table 6. The short-run speed of adjustment is governed by ϕ_{B1} and ϕ_{B2}, set at 0.05 and 0.10 respectively.[38] For the long-run behavior of net foreign assets (ϕ_{F1}) our prior is that a permanent increase in government debt by one percentage point of GDP is roughly associated with an increase in the net foreign liability position of the region by 0.5 percentage points of GDP, implying that ϕ_{F1} is equal to 1/2. As we discuss in detail below, overlapping generations models (particularly those which follow the Blanchard-Weil-Yaari formulation) provide theoretical underpinnings to evaluate this parameter. Quantitative simulations using models with such characteristics — specifically, the IMF's Global Fiscal Model (GFM) described in Botman, Laxton, Muir and Romanov (2005) and Multimod (Laxton *et al* (1998)) — are consistent with a value of ϕ_{F1} between roughly 0.40 and 0.80. Moreover, when the US expands its net foreign liabilities as a result of a permanent change in its public debt, we need to specify how

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here.

[37] This is a sensible approximation, given that China is the largest member of AS, and the limited flexibility of its currency against the US dollar is at the center of the current policy debate. Similarly, other members such as Hong Kong, Malaysia, South Korea, Singapore, Thailand, Phillippines and Indonesia either target explicitly stable exchange rates or attempt to manage the volatility of their currencies vis-a-vis the US dollar.

[38] This is consistent with most previous work based on GEM — Laxton and Pesenti (2003), Hunt and Rebucci (2004), and Bayoumi, Laxton and Pesenti (2004).

much of the new issuance will be absorbed by each region (ϕ_{F2}). Based on net foreign asset holdings in recent years, we assign 24 percent of new issuance by US to AS, and 38% to each of JE and RC. This calibration means that for a given one percent NFL-to-GDP shock in US, the AS net-foreign-asset-to-GDP rises the most — around 0.8 percent of GDP — while JE and RC see their ratios only rise by around 0.3 and 0.5 percent of GDP respectively.

4 A baseline scenario

4.1 The five component shocks

We now define a baseline scenario for the global rebalancing of current accounts, of interest not only *per se*, as a model-based quantitative assessment of macroeconomic adjustment paths in the global economy, but also as a benchmark against which we can analyze and discuss alternative scenarios. Our baseline scenario is an attempt to identify the sources of the current global disequilibrium, accounting for both the shocks emanating from the United States and the role played by other regions. The purpose of the baseline scenario is to answer questions such as: What are the key macroeconomic factors underlying the recent dynamics of current account imbalances and real exchange rates in the world economy? What assumptions about the size and persistence of the key underlying shocks are needed to fit the facts? What is the range of possible future trajectories for the relevant macroeconomic variables?

We are less interested in explaining and rationalizing current account dynamics over the past decades than in providing elements for an analysis of the current global outlook. Consistently, we formulate our baseline scenario based on the general premise that the current imbalances are mainly the reflection of savings behavior, by both private and public agents, not investment dynamics fueled by (excessively) optimistic growth expectations as observed in the second half of the 1990s.

Specifically, our suggestion is that the central tendencies underlying the global macroeconomic imbalances in the early 2000s can be attributed to a combination of five related but distinct 'shocks'. The first three shocks concern to a large extent the US economy:

1. A negative US government debt shock (with initial tax cuts followed by future tax hikes) centered around the announced plans of the U.S. federal government.

2. A permanent decrease in the United States' private savings rate.

3. An increase in the demand for US assets abroad, particularly in Emerging Asia

The remaining two shocks reflect productivity trends in the rest of the world. Even though general worldwide convergence in productivity growth rates is taken as the dominant feature of our economy in the long term, prolonged deviations from balanced growth can play a key role in the unfolding of medium-term rebalancing scenarios, in line with the asymmetric tendencies that we have observed across regions in the past decade. The shocks are:

4 A very persistent positive shock to productivity growth in Emerging Asia with a central tendency of one percent per year

5 A very persistent negative shock to productivity growth in Japan and the Euro Area with a central tendency of 0.75 percent per year

We now consider each of these shocks in turn, by outlining their central tendencies and discussing their effects on the regional economies.

4.1.1 Government debt in the US

For the public savings shock in the US, we couple a sustained increase in the government deficit for the next five years with a steady-state government debt shock of 11.5 percent of GDP (Figures 3 and 4).[39] The steady-state government deficit of the US rises from 2.5 to 2.7 percent. We observe lower taxes today, but higher taxes in the future to meet the interest payment obligations on the debt. The increased borrowing by the fiscal authority crowds out the trade balance, thereby worsening the current account deficit relative to the initial steady state. We also observe a real exchange rate appreciation in the short run, but a depreciation in the long run.

The increase in government debt increases US net foreign liabilities by 6.25 percent of GDP, which is financed by the rest of the world. Relative to each region's GDP, Emerging Asia sees the largest effect, as its NFA position increases by 4.25 percent of GDP in the long run, which means it must be financed now by a large current account surplus of 0.4 percent of GDP and 0.2 percent of GDP in the long run. There are similar effects in JE and RC, but they are smaller.

4.1.2 The private savings rate in the US

The reduction in US consumers' desire to save is represented by a increase in the rate of time preference in the US relative to the rest of the world of 20 basis points, as well as a risk premium shock of 30 basis points for 25 years (Figures 5 and 6).[40] At the same time, we assume AS is more patient than JE or RC — they have a lower rate of time preference at 2.6 percent versus 3 percent. So a negative private savings shock in the United States results in an increase in the real interest rate, and a reduction in domestic demand.

In the short run there is a deterioration of the current account balance of 0.4 percent. of GDP However, there is a long run depreciation, which means there is an improvement in the steady-state trade balance. The spillover effects are relatively minor, their magnitudes depending entirely upon the extent of US trade linkages with AS, JE and RC.

4.1.3 Demand for US assets abroad

The third major component of the baseline scenario is an increase in the demand for US assets in the rest of the world (Figures 7 and 8).[41] The major consumer of US assets in

[39] Technically, we implement the government debt shock as follows. We increase the steady-state government-debt-to-GDP ratio in the United States by 11.5 percentage points. We implement the shock in the short run by setting a deficit-to-GDP ratio for the United States of 4.5 percent in 2005, 4.3 percent in 2006 and 4.0 percent in 2007, and then declining to the steady-state value of 2.7 percent of GDP. In parallel, we also increase the rate of time preference ($1/\beta^4$) in US permanently by 20 basis points to account for a potential shift in the world real interest rate.

[40] The private savings shock has both a temporary and permanent component. The permanent component is the rate of time preference shock. Relative to the initial world rate of time preference ($1/\beta^4 - 1$) of 2.7 percent, AS is more patient at 2.6 percent (a negative 10 basis point shock) while US is much more impatient at 3.1 percent (a positive 40 basis point shock). For the temporary component, we increase the risk premium Z_B for all regional blocs by one percent for 25 years.

[41] For the technical implementation, we rely on the autonomous holdings (b^*_{FNEUT}) in the desired net foreign asset position equation (43). In order to finance the increase in US net foreign liabilities by 20 percentage points of GDP, AS increases its steady-state holdings of net foreign assets by 20 percentage

this shock is AS (and to a lesser extent, JE, as Japan behaves much like the rest of Asia in its demand for US assets). We see that AS saves more and increases its net foreign asset holdings by 20 percentage points of GDP permanently, with lesser increases in JE and RC (5.2 and 9.0 percentage points of GDP respectively). This results in an increase in the US net–foreign-liability-to-GDP ratio by 20 percentage points.

As a counterpart to its asset accumulation, AS runs a current account surplus that shows up as a US current account deficit of 3.5 percent in the short run and one percent in the long run. In the short run, households in US consume more but in AS consume less. The converse is true in the long run. Output growth in AS is also positive, once the sharp negative effects of the sudden real appreciation wears off. The short-run appreciation of the AS real effective exchange rate is the result of adjusted uncovered interest parity, since higher real interest rate differentials are necessary in the future to maintain its nominal exchange rate peg *vis-à-vis* the US.

4.1.4 Productivity growth in Emerging Asia

Emerging Asia faces a long run positive shock to its productivity growth (Figures 9 and 10). We assume that productivity grows at three percent per year for eight years, instead of the world trend rate of two percent. Relative to the initial steady state, we see a large increase in output. Because of the increase in the marginal product of capital, there is a sustained increase in investment to achieve a new higher capital-output ratio. Since the productivity shock is generalized across the entire economy, we see a long-term real depreciation. There is also a small sustained deflation as productivity expands.

Internationally, most of the spillover effects occur in JE, which has the strongest trade linkages with AS. However, the productivity shock in AS also contributes to our formulation of the baseline scenario in US, where we see a current account deficit opening up in the short to medium term.

4.1.5 Productivity growth in Japan and the Euro Area

This shock basically has the same effects as the shock in Emerging Asia, but with all the signs of the responses reverted (Figures 11 and 12). JE faces productivity growth of 1.25 percent per year for 13 years, which is slower than the world trend rate of two percent. The responses are slightly higher than the ones for the AS shock, given the lower degree of flexibility in price setting for the labor and goods markets in JE and the fact that monetary policy pursues an inflation target rather than defending an exchange rate peg. The spillover effects also differ because JE is 34.6% of world GDP in the initial equilibrium (whereas AS is merely 9.4%) and the nature of their trade linkages with the world. Since Japan and the Euro Area's strongest links are with AS and RC, the effects on US are smaller relative to what we observe from the AS productivity shock.

4.2 The integrated scenario

The five aforementioned shocks are the basis for our integrated baseline scenario. As we have already alluded to, the shocks are the central tendencies of the baseline scenario we present below, which instead is presented as a range of outcomes.

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points of GDP; JE increases its steady-state holdings of net foreign assets by 5.2 percentage points of GDP; and RC increases its steady-state holdings of net foreign assets by nine percentage points of GDP.

Our motivation is simple. Over time, there has been considerable uncertainty about the evolution and correction of the U.S. current account imbalance, and there is no basis to assume that this will not be case in the future. Figure 13 easily visualizes this point by showing the evolution of the IMF's forecasts in its World Economic Outlook, from 1999 to the present. In the later forecasts we see the same basic story as the one we are proposing. Earlier forecasts put more weight on the priors that the U.S. current account deficit was caused by high investment rates, rather than low private savings and large public dissaving. We can also observe that consumption continues to trend upwards over time, but in later forecasts there is a need for a notable correction toward the end of the forecast horizon.

When presenting our baseline scenario, we therefore consider a range of possibilities by generating a range that accounts for a degree of uncertainty around the central tendency of the five component shocks already outlined. We assign a high degree of uncertainty as to the outcome for shocks related to private savings in the United States, rest of world preferences for holdings of US assets, and the positive productivity shock in Emerging Asia. For the outcome of shocks related to the US fiscal scenario and to the magnitude of the negative productivity shock in Japan and the Area we assume a lesser degree of uncertainty.

Figure 14 presents the baseline scenario in the United States. The key features for US are a gradual build up in government debt and a decline in net foreign assets. The exchange rate needs to depreciate gradually to allow the net asset position to stabilize. This generates the trade surplus required to finance the interest obligations resulting from the increase in net foreign liabilities. Consumption as a share of GDP is higher in the short run but is eventually crowded out as US becomes more indebted. In addition, investment is crowded out by the persistent government deficits. Overall, the dynamics in the United States are driven by the current account deficit moving from 5 percent of GDP to a sustainable level in 10 years time.

Emerging Asia's most important role in the baseline scenario is its role in absorbing the increased supply of US assets (Figure 15). It runs a large current account surplus which continues to grow until 2010. The trade balance is negative in the long run to support the large increase in the net foreign asset position. To absorb the inflows from the interest payments on its net foreign asset position, its real effective exchange rate roughly appreciates between 10 and 20 percent in the next five years. Because of the fixed exchange rate regime, there is an increase in the real interest rate necessary to defend the peg. There is also a sustained increase in domestic inflation while the government deficit falls. Overall, GDP growth weakens in the short run — high interest rates hurt investment and the appreciation hurts imports. However consumption increases a share of GDP in the medium term from higher wealth (and lower savings requirements) in the long run.

Japan and the Euro Area experience few effects as Emerging Asia absorbs most of the increased US demand for goods and the increase in the US supply of assets (Figure 16). JE is mostly stable going forward with only a temporary current account improvement until it stabilizes around 0.5 percent of GDP in about 10 years time.

The Remaining Countries bloc is not a key part of either our baseline scenario, or the alternative scenarios we present below. It behaves much like Emerging Asia since it has strong links with the United States (mainly Canada and Mexico). RC absorbs less US debt as there is no large underlying positive shock to its preference for US assets. Furthermore, it experiences relatively little inflation and has a smaller movement in its real effective exchange rate than Emerging Asia because it conducts its monetary policy by targeting inflation rather than a nominal exchange rate peg.

5 Elements for an analysis of alternative scenarios

This section has two objectives. First, we consider some scenarios that are designed to highlight the potential risks of large current account imbalances. Second, we discuss some possible solutions that may mitigate these risks by gradually reducing the magnitude of these global imbalances over time. In summary, we argue that the short-run output costs for the U.S. economy that would be associated with a sudden loss in appetite for U.S. assets are likely to be the same order of magnitude as a large credible fiscal consolidation that would make a significant contribution to reducing these imbalances over time and making both the US and world economy less susceptible to shocks. We also consider the effects of competition-friendly structural policies aimed at reducing distortions in the product markets in Europe and Japan. Our analysis suggests that such policies could play a prominent role in reducing current account imbalances on a sustainable basis if they were associated with a sustained increase in growth and a permanent downward shift in the net foreign asset positions of these countries.

5.1 Scenarios involving a loss in appetite for US assets

Among the major risks associated with the large buildup in U.S. net foreign liabilities, there has been considerable discussion that a sudden loss in appetite for these assets by the rest of the world could precipitate a large and abrupt depreciation in the U.S. dollar and cause significant second-round negative effects on other countries. We attempt to evaluate these predictions.

Initially, we consider the effects of a sudden portfolio reshuffling in the rest of the world (Emerging Asia, the Euro Area, Japan, and the RC blocs) under the assumption that the exchange rate in Emerging Asia is pegged to the US currency. The effects of this first scenario are reported as solid lines in Figure 17. Next, we consider the same scenario, but in this case we assume that central banks in Emerging Asia gradually adopt a flexible exchange rate regime.[42] The effects of this second scenario are reported as dashed lines in Figure 17 and serve to illustrate how flexibility in the exchange rate can help reduce variability in both output and inflation variability in Emerging Asia.

These scenarios result in higher real interest rates in the United States and a significant depreciation in the US dollar in effective terms. The depreciation in the dollar improves the trade balance, but has a contractionary effect on US GDP growth as higher real interest rates have a larger depressing effect on domestic demand than the effect of the real exchange rate depreciation. Interestingly, this analysis suggests a fairly benign scenario where growth falls temporarily in Japan and the RC bloc, but then rises in response to lower real interest rates in these countries.

These scenarios seem consistent with a view that adjustment in relative prices and real interest rates may not have enormous implications for the world economy as a whole, as long as the adjustment process is orderly and does not result in a persistent increase in real interest rates in the rest of the world. It is important to note that these simulations assume relatively high elasticities of substitution between domestically-produced tradables and importables. Reducing these elasticities to one approximately doubles the real depreciation in the US dollar, but has much smaller effects on the other results reported in Figure 17 as

[42] Technically, this is made operational by shifting the parameters in the reaction function for Emerging Asia gradually over time to be consistent with the parameters in the other country blocks of the model.

the exchange rate simply has to do more work to re-equilibrate the economies to move US dollar asset holdings toward their new desired levels.[43]

Benefits of exchange rate flexibility in Emerging Asia While the effects look rather benign for the world economy as a whole, they would be anything but benign for some economies in Emerging Asia that exhibit all the symptoms of overheating. In this scenario one can see the potential benefits of allowing greater exchange rate flexibility in Emerging Asia as a way to reduce variability in both output and inflation. Indeed, a comparison of the solid lines and the dashed lines in Figure 17 shows the pressure on inflation and output that would be associated with a reduction in demand for US assets by AS central banks if they kept trying to peg their exchange rates to the US dollar.

In the first case attempting to maintain the peg would create significant overheating and a large increase in inflation, as inflation would be the only method to appreciate their real exchange rates to be more in line with underlying fundamentals. In the second case, we allow the weight on the exchange rate in the Emerging Asia reaction function to fall gradually over time and at the same time increase the weight on inflation. Consequently, the real exchange rate depreciates by less in Emerging Asia and this results in less variability in output and inflation.[44]

Are these scenarios too benign to be believable? Perhaps. These scenarios suggest that there may be small risks for the global economy associated with a loss in appetite for US assets. However, with interest rates currently at low levels relative to historical standards, there is a risk that real rates may even rise in other countries if a large US dollar depreciation and a significant real interest rate hike in the United States were to precipitate a reassessment of global risks. This could also trigger adjustments in the prices of other assets (such as housing and equities) and bring into play confidence effects that are not included in our analysis.

Concern about potential scenarios where the adjustment process could be much more costly to both the US and the world economy has motivated several policymakers and analysts to demand credible and swift action to help mitigate these types of risks. An important question then is what policies would be successful in mitigating such risks by reducing the magnitude of these imbalances. We do not evaluate the full range of policies that have been suggested to reduce imbalances, but instead focus our effort on evaluating what are likely to be two of the most important.

[43] Our baseline elasticities are in line with estimates used in NOEM models, but they are significantly higher than the mid-point of the range of econometric estimates, which falls closer to one. For example, Bergin (2004) finds evidence for a unitary elasticity. See Corsetti and Pesenti (2001) for a stylized model with a unit elasticity of substitution between home and foreign goods, complete pass-through, and home bias in government spending. More complex models such as Erceg, Guerrieri and Gust (2005) and Bayoumi, Laxton and Pesenti (2004) employ estimates of 2.5 and 3.0, respectively. Imposing higher estimates is based on general-equilibrium considerations as well as the assumption that econometric estimates based on aggregate data are probably biased downward. It is important to note that estimates around 2.5 combined with adjustment costs on imports results in dynamic reponses for imports that are not inconsistent with typical impulse response functions over 1-2 year horizons. As well known, estimates of long-run elasticities based on disaggregated data are substantially higher.

[44] We acknowledge that the difference between the scenarios is not large. It would be much larger if we assumed there was an immediate move to a flexible exchange rate regime. We show some results below for a US fiscal experiment that better contrast the differences between a pure exchange rate peg and a pure flexible exchange rate regime in the EA bloc.

5.2 Reducing government deficits in the United States

In a recent model-based analysis of current account imbalances, Erceg, Guerrieri and Gust (2005) suggest that fiscal deficits do not have very significant effects on current account deficits.[45] The implication is that a large reduction in the US government deficits would not play a major role in correcting current account imbalances. Other theoretical frameworks — and other models — reach rather different conclusions. This is the case, for instance, with simulation results based on the Global Fiscal Model (GFM), a multi-country choice-theoretic model that has been developed specifically to study the medium- and long-term consequences of alternative fiscal policies that involve permanent changes in government debt.[46]

The theoretical framework adopted in this paper provides a synthesis between alternative modeling strategies, by considering the link between government debt and net asset positions in relation to the technology of financial intermediation. This allows us to provide simulation results when this link is switched off, to show why the effects of fiscal deficits on current account deficits can be very small if no allowance is made for the possibility that permanent changes in government debt can result in a permanent shift in the desired level of net foreign liabilities. It also allow us to predict a rather different path for current account rebalancing when the link is explicitly and realistically taken into account.

Effects of a permanent reduction in government debt through tax hikes Figure 18 reports the results for a US fiscal consolidation scenario where the government-debt-to-GDP ratio is reduced by 60 percentage points in the long run by increasing taxes by 3 percent of GDP over fifteen years. The tax hike is assumed to fall entirely on labor income, but after the 15th year of the simulation, the tax rate is allowed to fall in order to stabilize the government debt ratio at a value that is 60 percentage points below baseline.

The solid line in Figure 18 reports the results when the Emerging Asian currencies are assumed to be pegged to the dollar while the dashed lines are for the case where they are assumed to have a flexible exchange rate regime. In both cases output growth falls in the United States and the current account balance improves significantly. The contractionary effects on real GDP are moderated significantly by a real depreciation in the US dollar and decline in real interest rates which allows US inflation to rise by about 1 percentage point higher than baseline. These simulations show clearly that US fiscal consolidation would not be achieved without some short-run costs for output growth and inflation, but unlike the results by Erceg et al. (2005) they suggest that a large and credible fiscal consolidation could have large and durable benefits by reducing current account imbalances.

The dashed lines report the results when the AS countries no longer 'import' an inappropriate monetary stance by pegging their exchange rates to the US dollar. In the case of a peg their real exchange rates depreciate with the US dollar and real interest rates decline. This

[45] Erceg, Guerrieri, and Gust (2005) add rule-of-thumb consumers to a model based on the representative agent paradigm and then use the model to study the effects of recent US fiscal deficits on the current account deficit. Not surprisingly, they find much smaller effects than in models that allow for the possibility that permanent increases in government debt can have permanent consequences for the stock of net foreign liabilities. Faruqee and Laxton (2000) show that liquidity-constrained consumers by themselves do not result in significant long-term crowding-out effects associated with permanent increases in government debt.

[46] The Global Fiscal Model has been developed at the IMF. For an introduction to the structure and properties of GFM see Bottman and others (2005) and Kumhof, Laxton and Muir (2005). It assumes that prices and wages are perfectly flexible, but has a well-defined steady state where private and public sector preferences determine if countries are net creditors or debtors.

results in a significant expansion in demand in the short run and higher inflation. In the case where they are assumed to follow a flexible exchange rate regime there is substantially less variability in output and inflation as the real exchange rate is allowed to appreciate in line with fundamentals. Note that the rest of the world (Japan, Europe and RC) benefits from fiscal consolidation in the United States as the rise in world savings results in lower real interest rates and higher investment.

The fiscal scenarios reported above allow the desired level of net foreign liabilities to fall by 1/2 of the decline in government debt while in Erceg et al. (2005) this mechanism does not exist. To see the importance of this assumption for our results we have constructed two alternative scenarios, one that employs a lower estimate of 1/4 and another that employs an estimate of 3/4 — see Figure 19. Not surprisingly, this parameter has a significant effect on the path of the current account balance. In the limiting case when it is assumed to be zero, the effects on the current account balance over the medium term become insignificant. Indeed, in the long run the effects would be absolutely zero as the relationship between current account deficit and fiscal deficit, measured as ratios of nominal GDP, will be exactly the same as the relationship between the stocks of net foreign liabilities and government debt.

In models where the long-run desired level of net foreign liabilities is always zero (or constant), permanent shifts in government debt have by assumption no effect on the stock of net foreign liabilities and the sustainable long-term current account balance[47]. In our framework, a permanent reduction in government debt by 60 percentage points of GDP reduces net foreign liabilities by 30 percentage points in the long run. Assuming a steady state growth rate of nominal GDP of 5.0 percent, this reduction on the stock of government debt would result in a reduction in the government deficit and current account deficit of 3.0 and 1.5 percentage points, respectively, in the long run.

Alternative views about the link between government debt and net foreign liabilities As a check of the reliability of our simulations, it is worthwhile to investigate what assumptions may point to larger or smaller estimates in models where the relationship between government debt and net foreign liabilities is modeled endogenously and falls directly out of assumptions about behavior. The Global Fiscal Model is based on an overlapping generations framework with finite lives and potential myopia in consumer spending decisions because the planning horizon can be set smaller than the expected lifetime of an average consumer. An important consequence of these assumptions is that there will be a strong link in the long run between government debt and the stock of net foreign liabilities. Figure 20 presents the GFM results for the same fiscal consolidation experiment that was considered above using GEM. We consider two cases. The first assumes a planning horizon of 10 years (solid lines) while the second assumes a planning horizon of 20 years (dashed lines). Note, that in both cases there are significant effects on the current account balance from permanently reducing government debt. In the first case the current account balance improves by about 2.0 percentage points, about 2/3 of the 3 percentage point improvement in the primary balance, while in the second case when the planning horizon is 20 years it improves by about 1/2 of the magnitude in the primary balance. The effects on the government defiit are even larger because of interest savings.

It is important to emphasize that the improvements in the current account balance

[47] The link between steady-state net assets and sustainable current account can be derived by considering (79) in steady state: $CURBAL^H/GDP^H = \left[\left(\pi^{US}g - 1\right)/\pi^{US}g\right]\varepsilon^{H,US}B^{*H}/GDP^H$.

are durable to the extent that there is a permanent reduction in net foreign liabilities of over 40 percentage points in both scenarios. Kumhof, Laxton and Muir (2005) show that the long-run elasticity between the stock of government debt and net foreign liabilities in GFM ranges from a low of 0.50 to a high of 0.75 for plausible assumptions about structural parameters such as: the planning horizon of agents; the type of fiscal consolidation.(labor taxes, corporate income taxes, or government absorption); or key elasticities such as the intertemporal elasticity of substitution.

Does the effect on the current account depend on the type of fiscal consolidation? Yes. The effects on the current account balance will generally be larger if the fiscal consolidation is a result of a cut in government absorption rather than an increase in taxes. Figure 21 compares the same tax-induced fiscal consolidation reported earlier with an alternative fiscal consolidation where government absorption is cut by 3 percentage points of GDP for 15 years. As is typically the case there will be much stronger contractionary effects on real GDP for expenditure cuts in the short run, as well as larger effects on the current account balance. It is important to note that in this case the reaction function is not consistent with reducing real interest rates sufficiently aggressively in the short run to moderate the decline in real activity and perhaps even to allow inflation to rise in the short run.

5.3 How much would higher growth in Europe and Japan contribute?

It has been suggested that part of the US current account deficit is a result of slower growth in Europe and Japan, and that one solution that would help reduce current account imbalances would be to raise growth in Europe and Japan through structural policies aimed at improving competition, raising capital accumulation, and reducing distortions in labor and product markets. To study this scenario we follow Bayoumi, Laxton and Pesenti (2004) and assume that price markups in both the tradables and nontradables sectors in Europe and Japan decline gradually to US levels over a 10 year period — see Figure 22. Growth rises significantly in Europe and Japan with some small spillover effects on the rest of the world. Notice however that, while such policies have a significant effect on the current account balances, the effects are smaller than the fiscal consolidations presented earlier.[48]

The simulations presented in Figure 22 both assume that there would be a permanent 6 percentage point reduction in the desired net foreign asset to GDP ratios in Europe and Japan as well as an increase in desired NFA positions in other countries. The solid lines are based on the shifts in the long-run desired NFA positions when we perform the same simulation experiment on GFM, while the dashed lines assumes that more financing would come from the United States to help finance the increase in investment in Europe and Japan. Obviously, if the effects on growth were more sustained and trend productivity growth were to increase to US rates there could be even larger changes in the desired NFA positions.

6 Conclusion

(To be added)

[48] We do not consider the effects of a reduction in wage markups in Europe and Japan so these estimates should be considered to be a lower bound of the potential benefits of structural reforms.

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Table 1: Baseline Parameterization of the Regional Blocs

Parameter	US	AS	JE	RC
Rate of time preference $\left(1/\beta^4 - 1\right) * 100$	3.2	2.6	2.7	2.7
Depreciation rate δ	0.020	0.020	0.020	0.020
Intertemporal elasticity of substitution $1/\sigma$	5.00	5.00	5.00	5.00
Habit persistence in consumption b_c	0.91	0.91	0.91	0.91
Inverse of the Frisch elasticity of labor ς	2.50	2.50	2.50	2.50
Habit persistence in labor b_ℓ	0.75	0.75	0.75	0.75
Tradable Intermediate Goods				
Substitution between factors of production ξ_T	0.75	0.75	0.75	0.75
Bias towards capital α_T	0.67	0.72	0.76	0.67
Nontradable Intermediate Goods				
Substitution between factors of production ξ_N	0.75	0.75	0.75	0.75
Bias towards capital α_N	0.62	0.66	0.71	0.62
Final consumption goods				
Substitution between domestic and imported goods μ_A	2.5	2.5	2.5	2.5
Bias towards domestic goods ν_A	0.96	0.07	0.39	0.15
Substitution between domestic tradables and nontradables ε_A	0.5	0.5	0.5	0.5
Bias towards tradable goods γ_A	0.35	0.37	0.37	0.32
Final investment goods				
Substitution between domestic and imported goods μ_E	2.5	2.5	2.5	2.5
Bias towards domestic goods ν_E	0.98	0.05	0.78	0.17
Substitution between domestic tradables and nontradables ε_E	0.5	0.5	0.5	0.5
Bias towards tradable goods γ_E	0.77	0.82	0.80	0.76

Table 2: Steady-state National Accounts Decomposition in the Baseline Scenario

Ratio of GDP	US	AS	JE	RC
Total Consumption	79.6	68.9	76.8	77.0
Private C	67.1	57.9	56.3	62.7
Liquidity-constrained consumers C_{LC}	5.1	9.5	3.0	4.3
Forward-looking consumers C_{FL}	62.1	48.4	53.3	58.4
Public $G_C + P_N G_N$	12.5	11.0	20.5	14.3
Total Investment $P_E E$	19.6	31.6	23.3	23.4
Private $P_E I$	17.1	29.6	20.3	20.9
Public $P_E G_I$	2.5	2.0	3.0	2.5
Trade balance $TBAL$	0.7	-0.5	-0.2	-0.3
Imports IM	11.4	25.7	14.7	22.2
Consumption Goods $P_{MA} MA$	7.5	12.5	12.6	11.8
Investment Goods $P_{ME} ME$	3.9	13.2	2.1	10.4
Government Debt B	61.5	24.0	67.0	30.0
Net Foreign Assets B^*	-53.5	43.1	17.4	23.7
Share of World GDP (percent)	30.4	10.2	33.9	26.0

Table 3: Real Adjustment Costs and Nominal Rigidities

Parameter	US	AS	JE	RC
Real Adjustment Costs				
Capital accumulation ϕ_{I1}	1.00	1.00	1.00	1.00
Investment changes ϕ_{I2}	78	78	78	78
Imports of consumption goods ϕ_{MA}	0.95	0.95	0.95	0.95
Imports of investment goods ϕ_{ME}	0.95	0.95	0.95	0.95
Nominal Rigidities				
Wages for liquidity-constrained consumers ϕ_{WLC}	400	400	400	400
Wages for forward-looking consumers ϕ_{WFL}	400	400	400	400
Price of domestically-produced tradables ϕ_{PQ}	400	400	400	400
Price of nontradables ϕ_{PN}	400	400	400	400
Price of imported intermediate goods ϕ_{PM}	400	400	400	400

Table 4: Price and Wage Markups

Parameter	US	AS	JE	RC
Tradables				
Markup $\theta_T/(\theta_T-1)$	1.15	1.14	1.21	1.17
θ_T	7.67	8.00	5.70	6.73
Nontradables				
Markup $\theta_N/(\theta_N-1)$	1.28	1.27	1.40	1.33
θ_N	4.58	4.75	3.50	4.04
Wages				
Markup $\psi/(\psi-1)$	1.16	1.16	1.30	1.20
ψ	7.30	7.30	4.30	6.00

Table 5: Monetary Policy

Parameter	IFB Rule	Fixed Exchange Rate Regime
Lagged interest rate at t-1 ω_i	0.75	1.00
Inflation gap at t+3 ω_1	2.00	0.00
Change in the nominal exch. rate at t ω_2	0.00	1000000 (proxy for ∞)

Table 6: Calibrating the International Linkages

Parameter	US	AS	JE	RC
Substitution between imports from different regions ρ_A	1.5	1.5	1.5	1.5
Bias towards imported consumption goods b_A from				
United States (US)	...	0.33	0.27	0.57
Emerging Asia (AS)	0.10	...	0.11	0.01
Japan / Euro Area (JE)	0.32	0.45	...	0.42
Remaining Countries (RC)	0.58	0.22	0.62	...
Substitution between imports from different regions ρ_E	1.5	1.5	1.5	1.5
Bias towards imported investment goods b_E from				
United States (US)	...	0.28	0.83	0.56
Emerging Asia (AS)	0.20	...	0.05	0.06
Japan / Euro Area (JE)	0.30	0.46	...	0.38
Remaining Countries (RC)	0.50	0.26	0.12	...
Net Foreign Liabilities				
Short-run dynamics ϕ_{B1}	0.05	0.05	0.05	0.05
Short-run dynamics ϕ_{B2}	0.10	0.10	0.10	0.10
% related to domestic government debt ϕ_{F1}	0.50	0.50	0.50	0.50
% related to US government debt ϕ_{F2}	...	0.24	0.38	0.38

Figure 1: The Structure of the Model

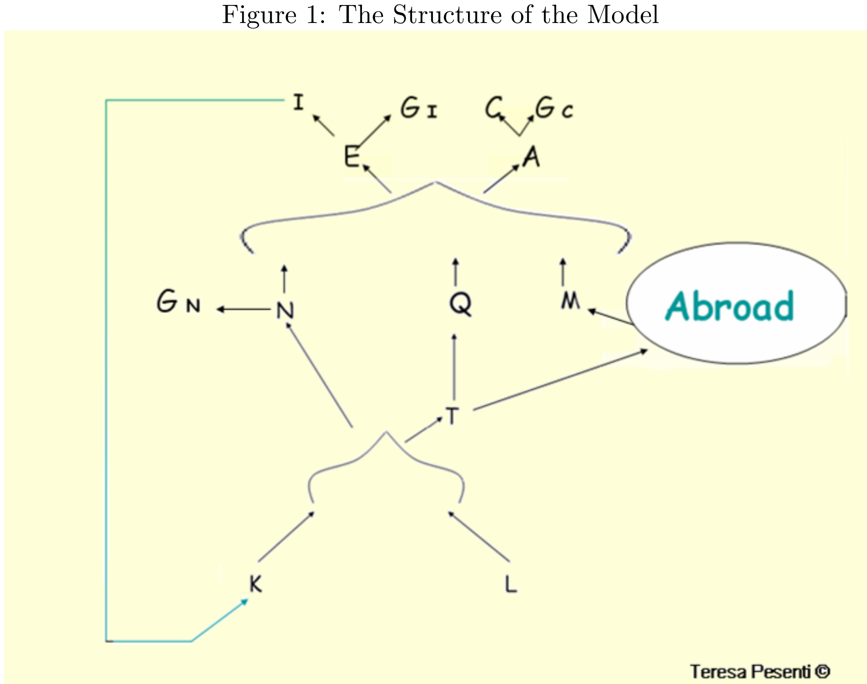

Figure 2: International Trade Linkages

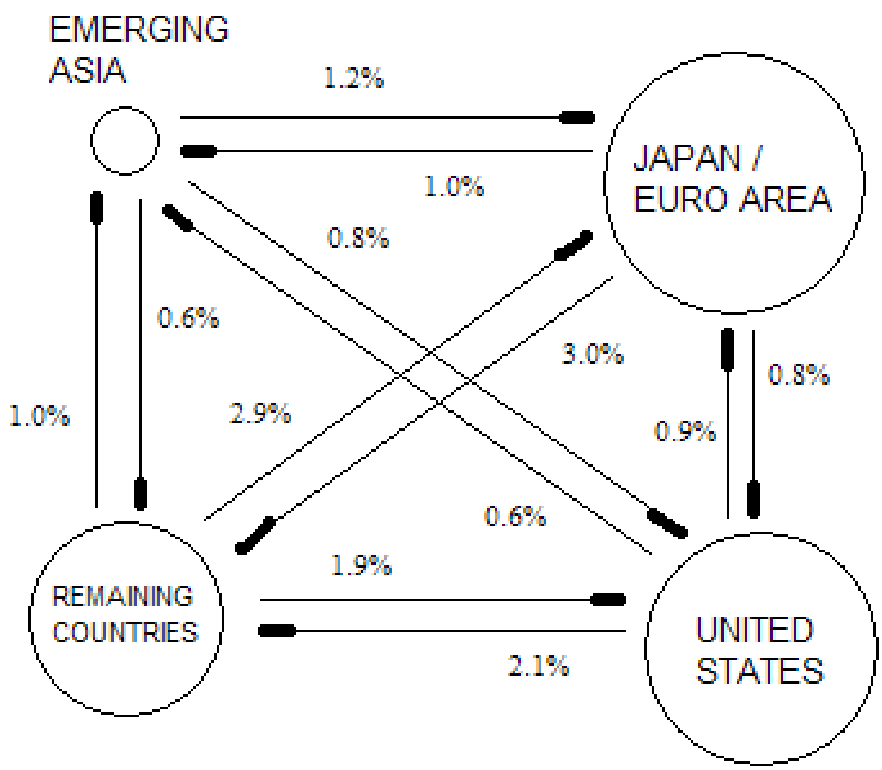

Figure 3: United States

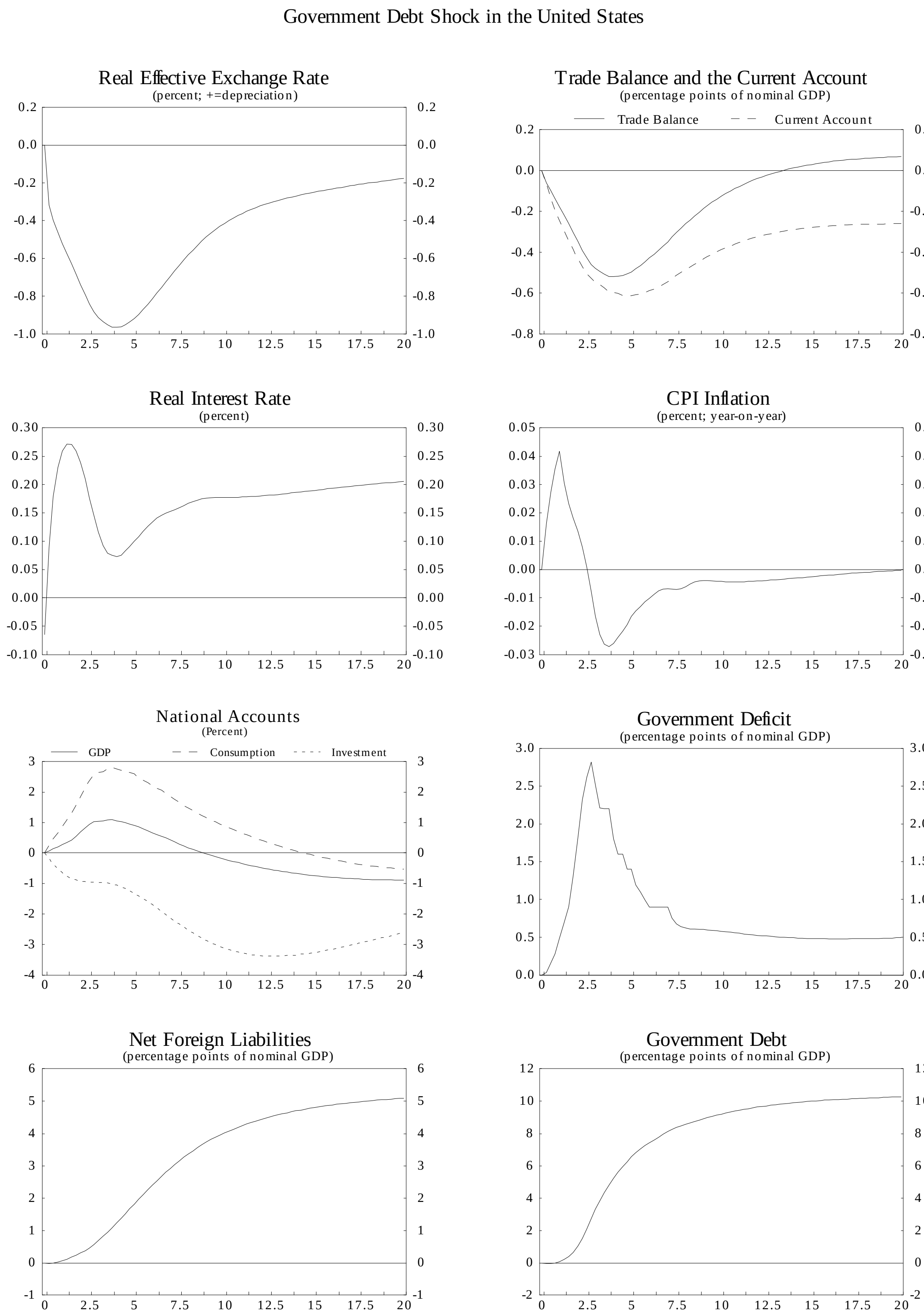

Figure 4: Rest of the World

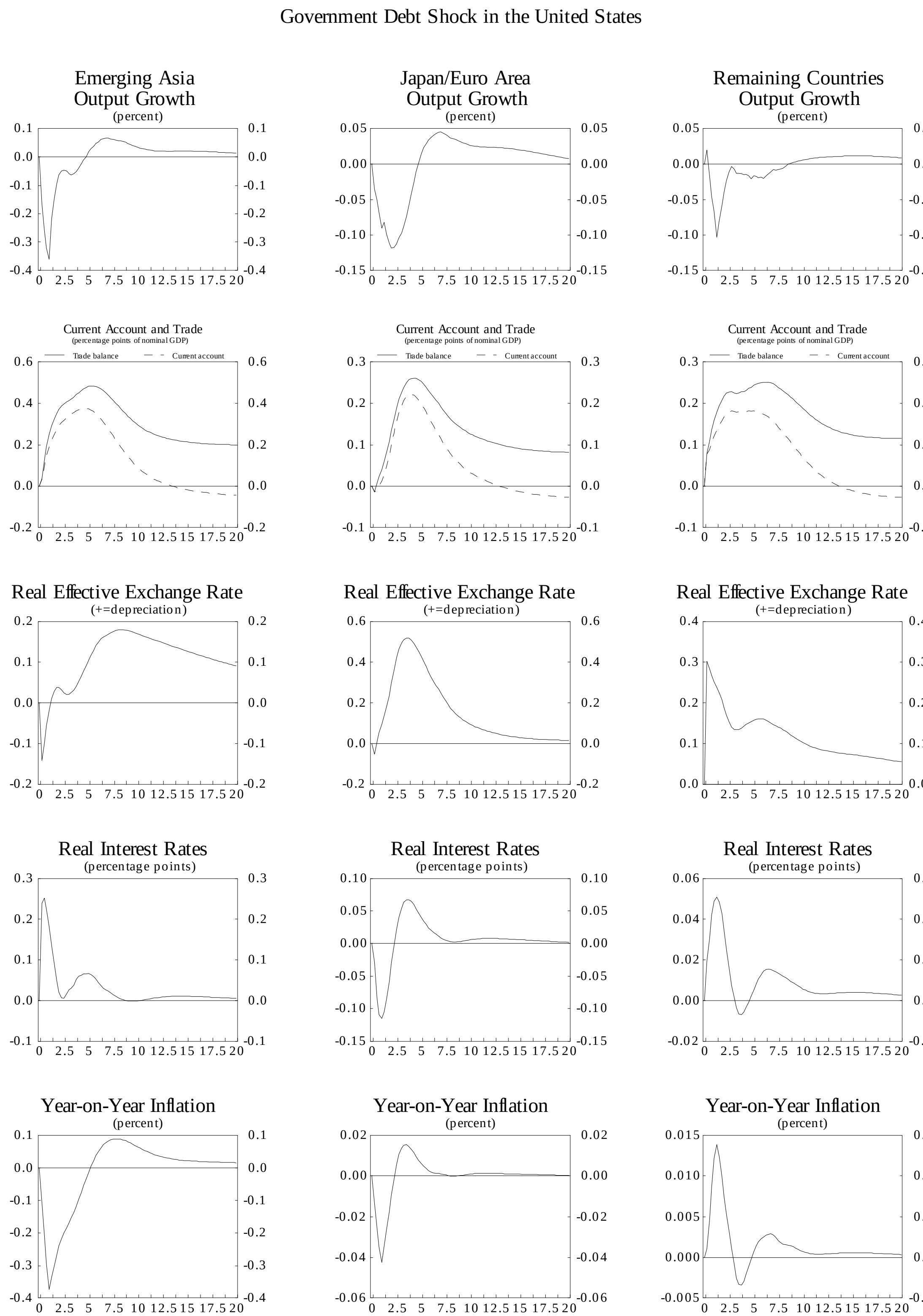

Figure 5: United States

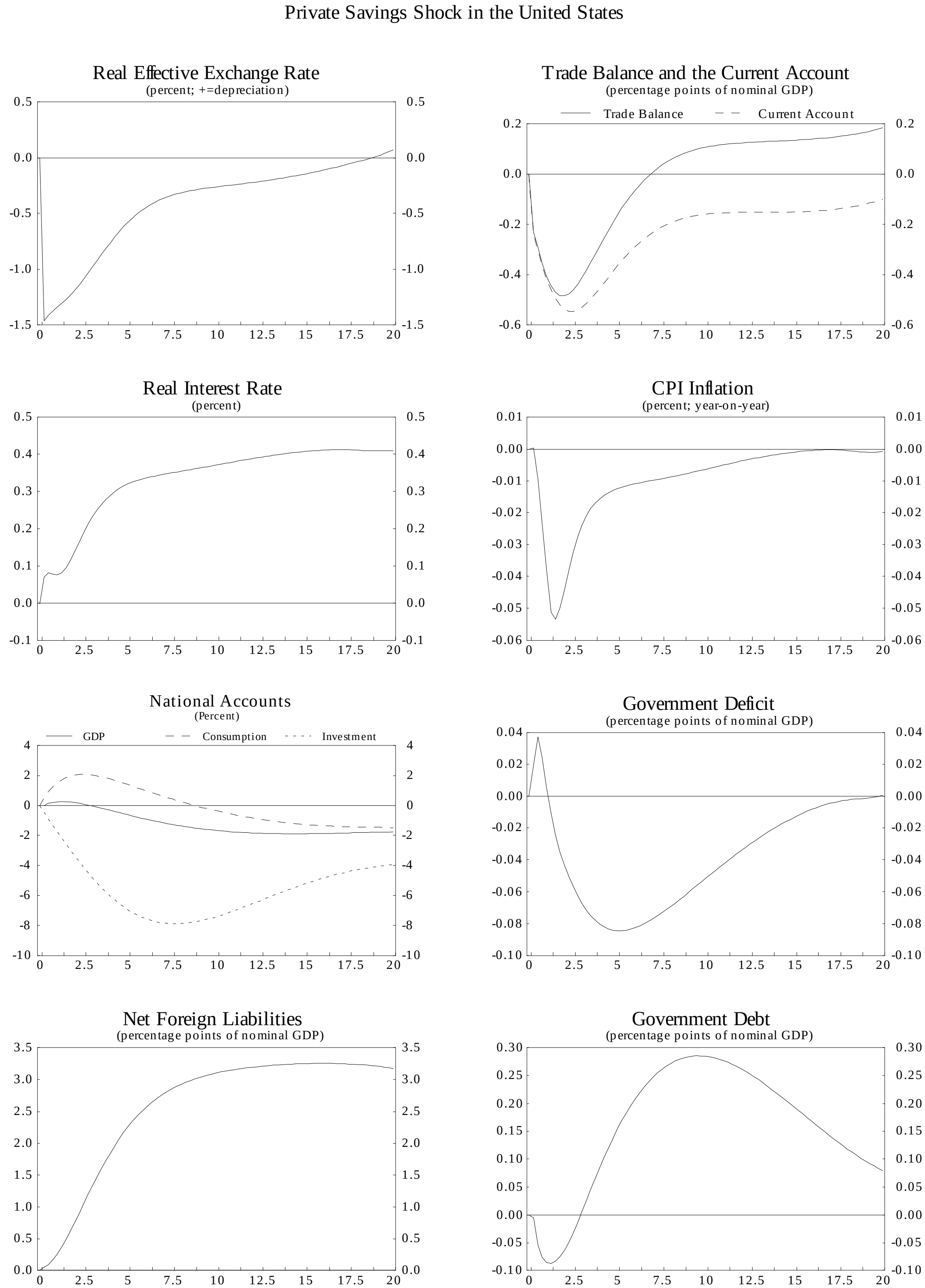

Figure 6: Rest of the World

Private Savings Shock in the United States

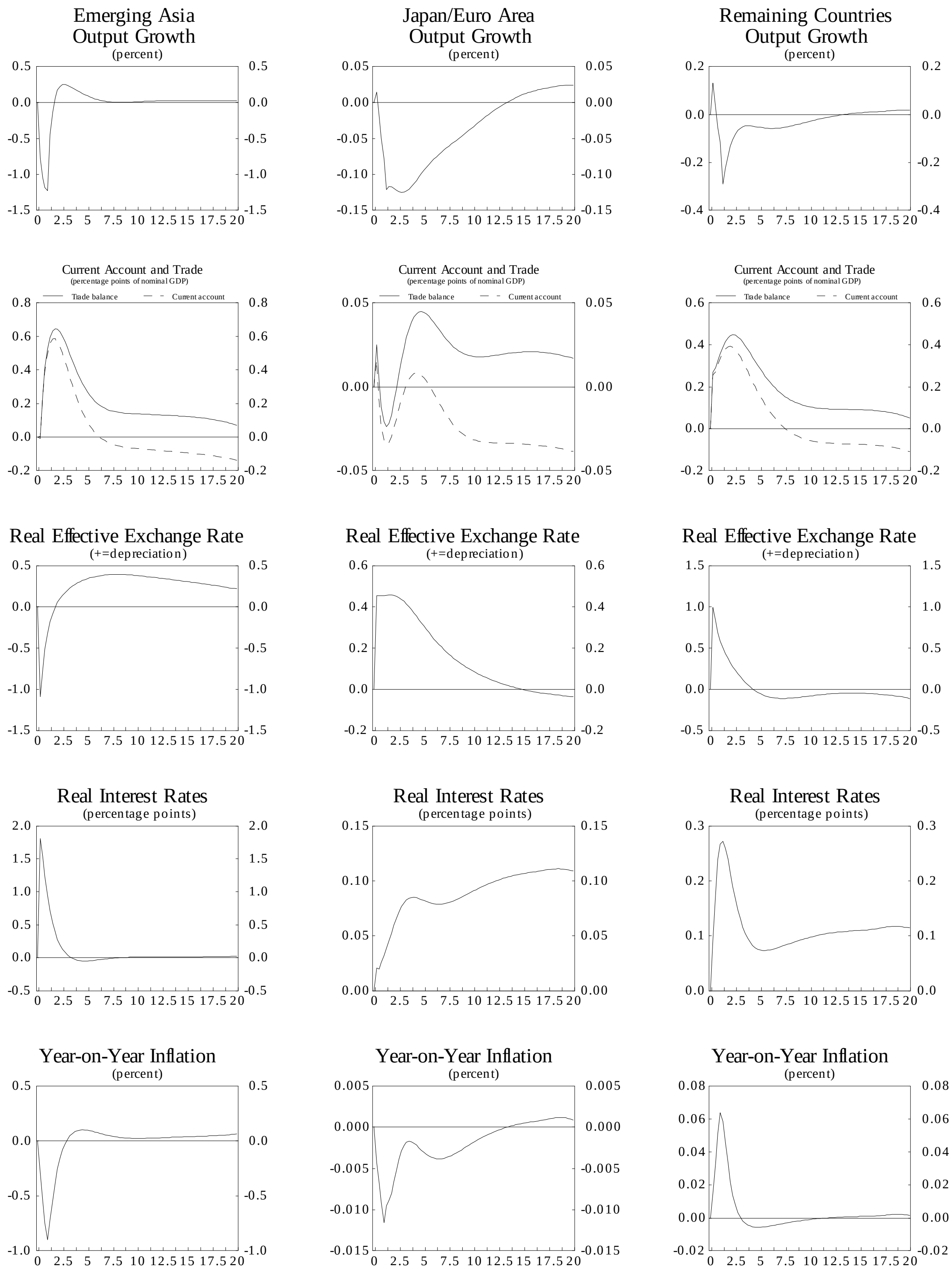

Figure 7: United States

Preference for US Assets Shock in the Rest of the World

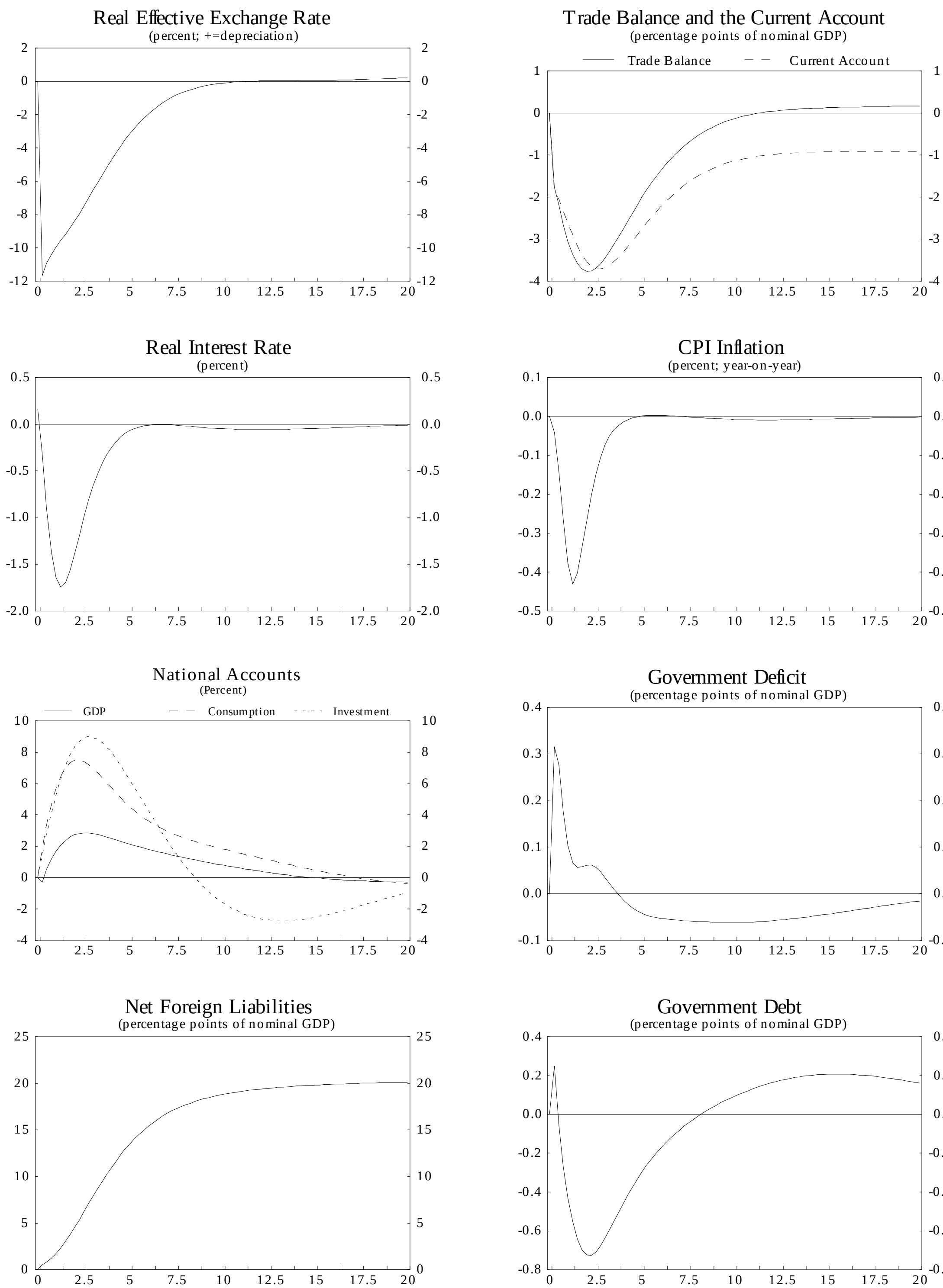

Figure 8: Rest of the World

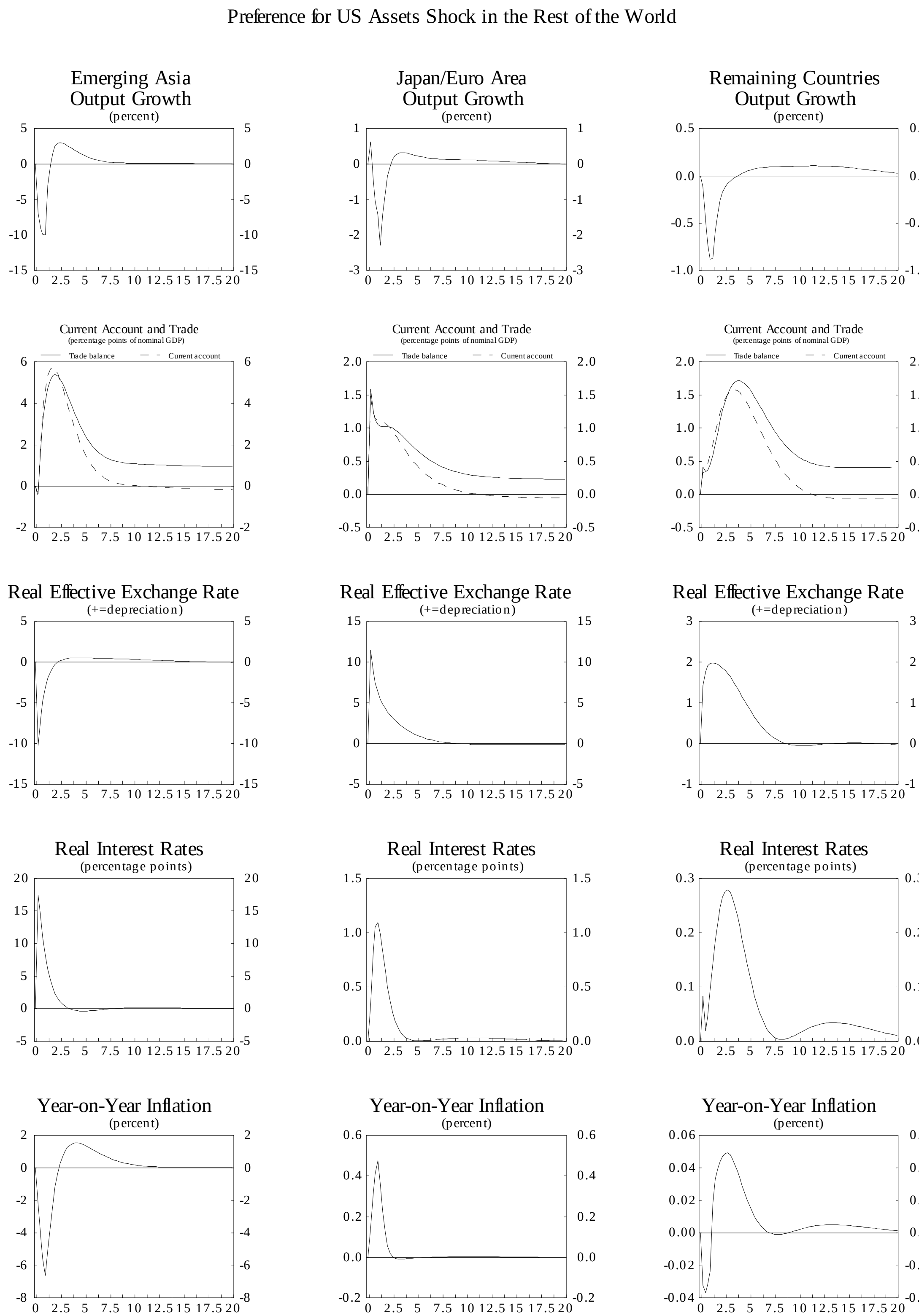

Figure 9: Emerging Asia

Positive Productivity Shock in Emerging Asia

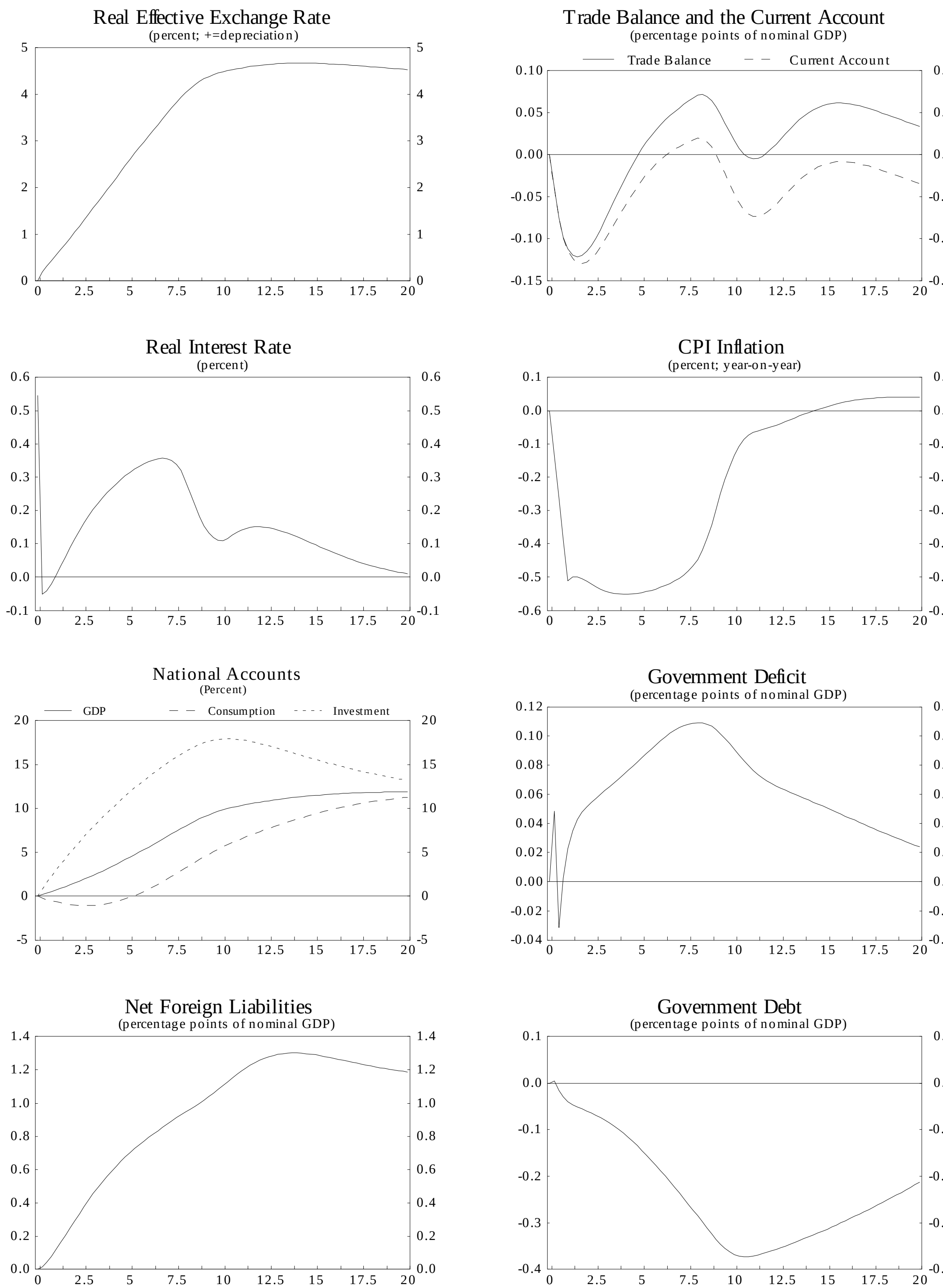

Figure 10: Rest of the World

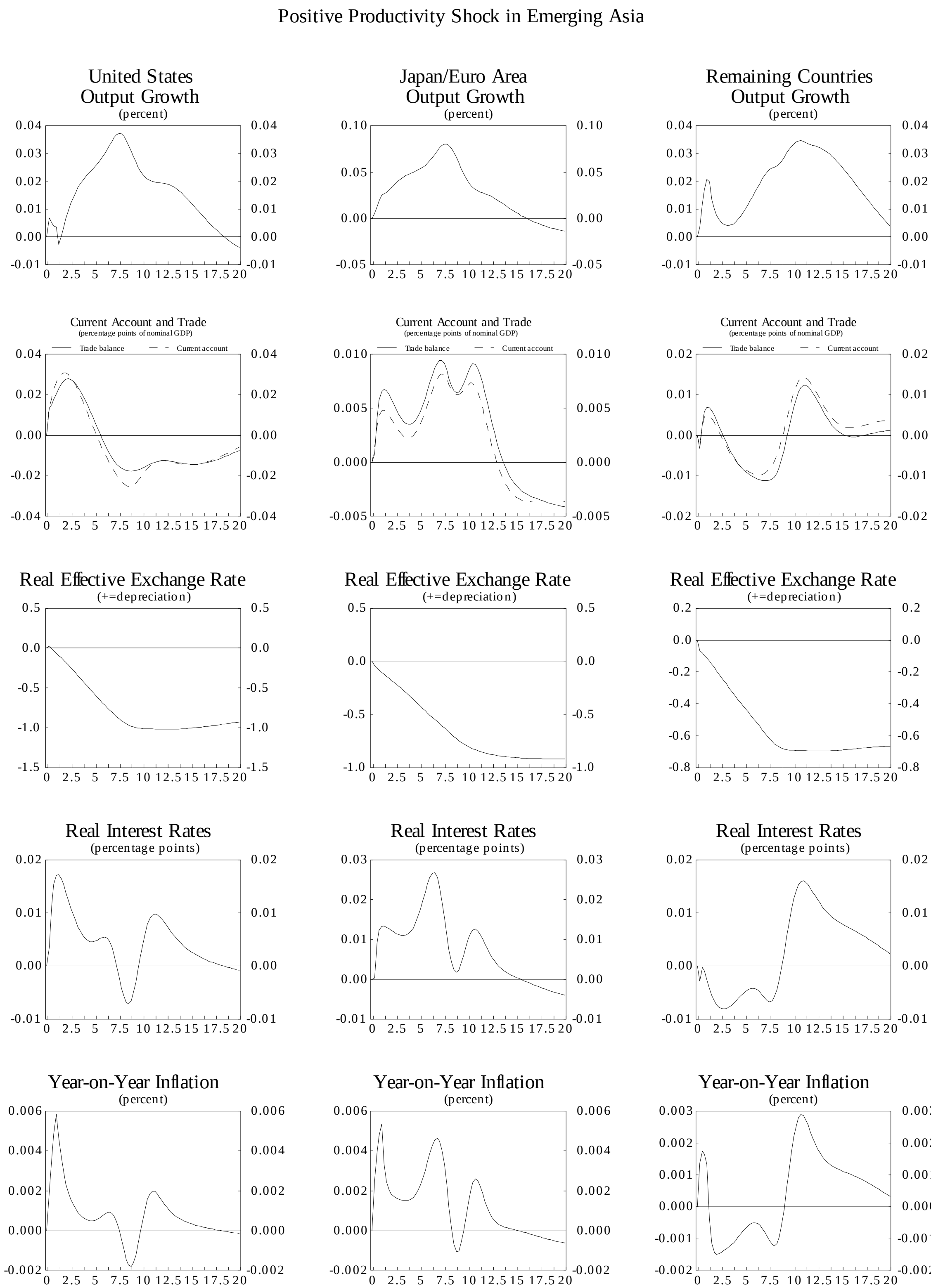

Figure 11: Japan and the Euro Area

Negative Productivity Shock in Japan and the Euro Area

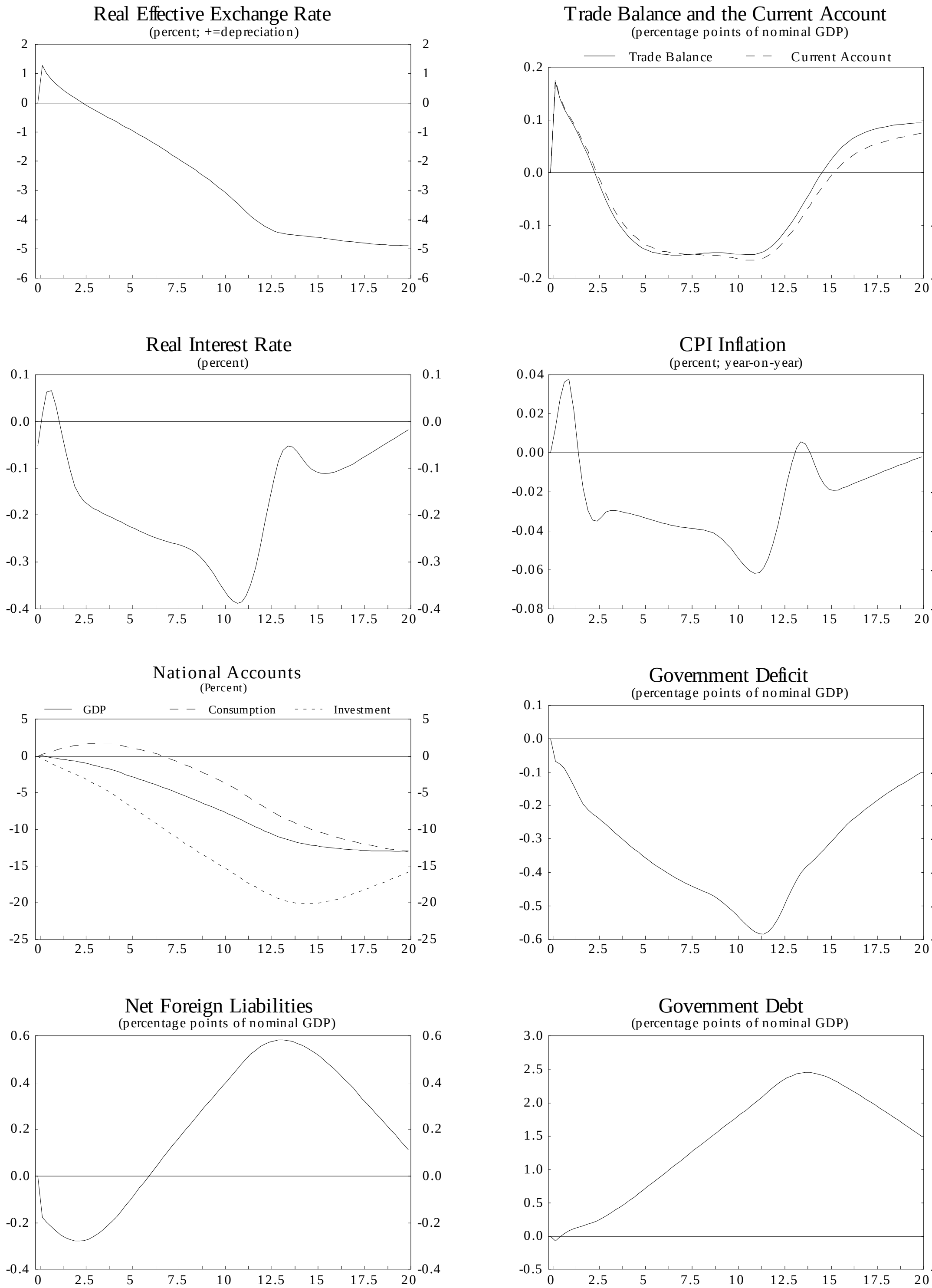

Figure 12: Rest of the World

Negative Productivity Shock in Japan and the Euro Area

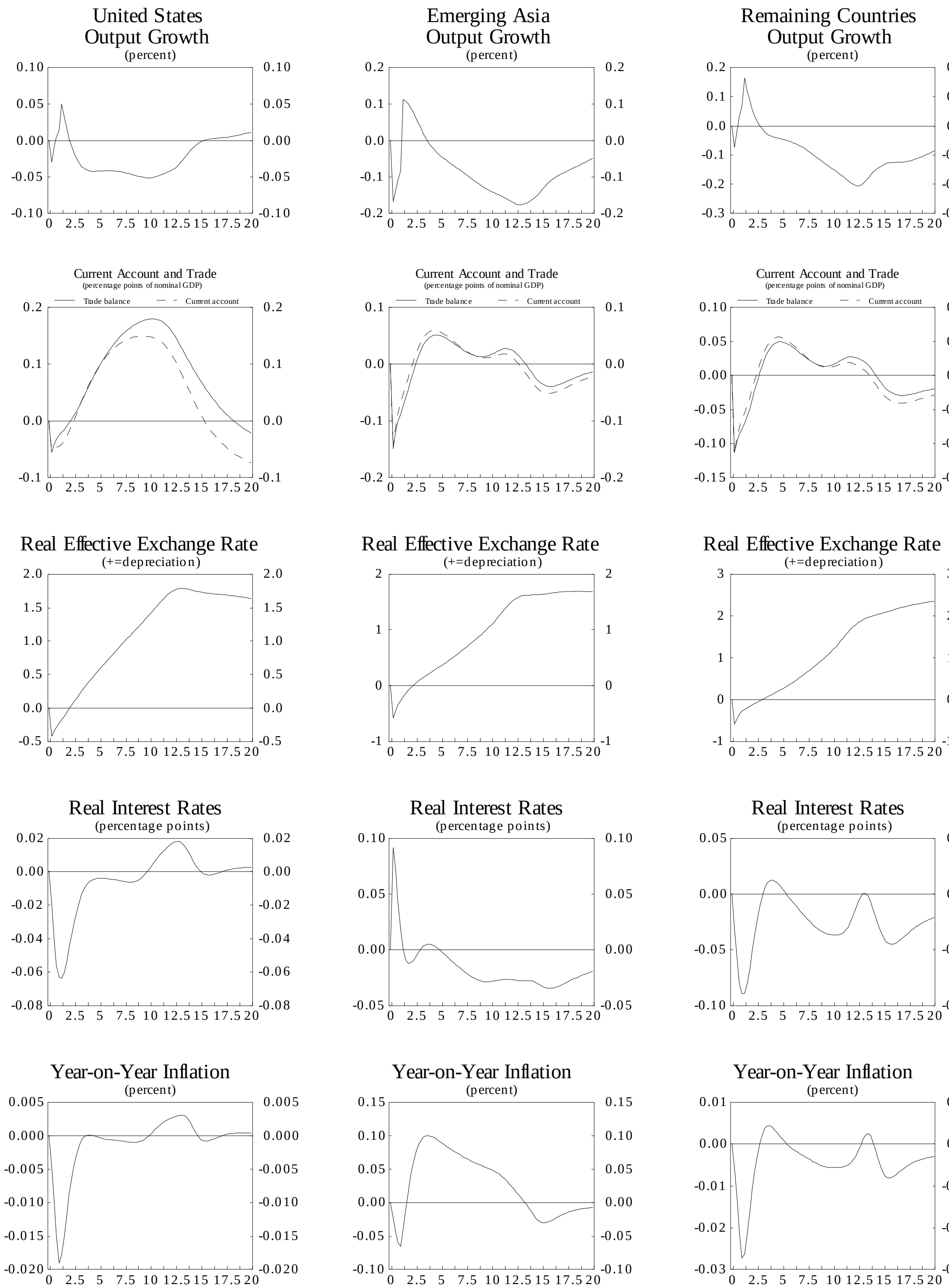

Figure 13: Forecasts from the IMF's World Economic Outlook, 1999 to 2005

United States

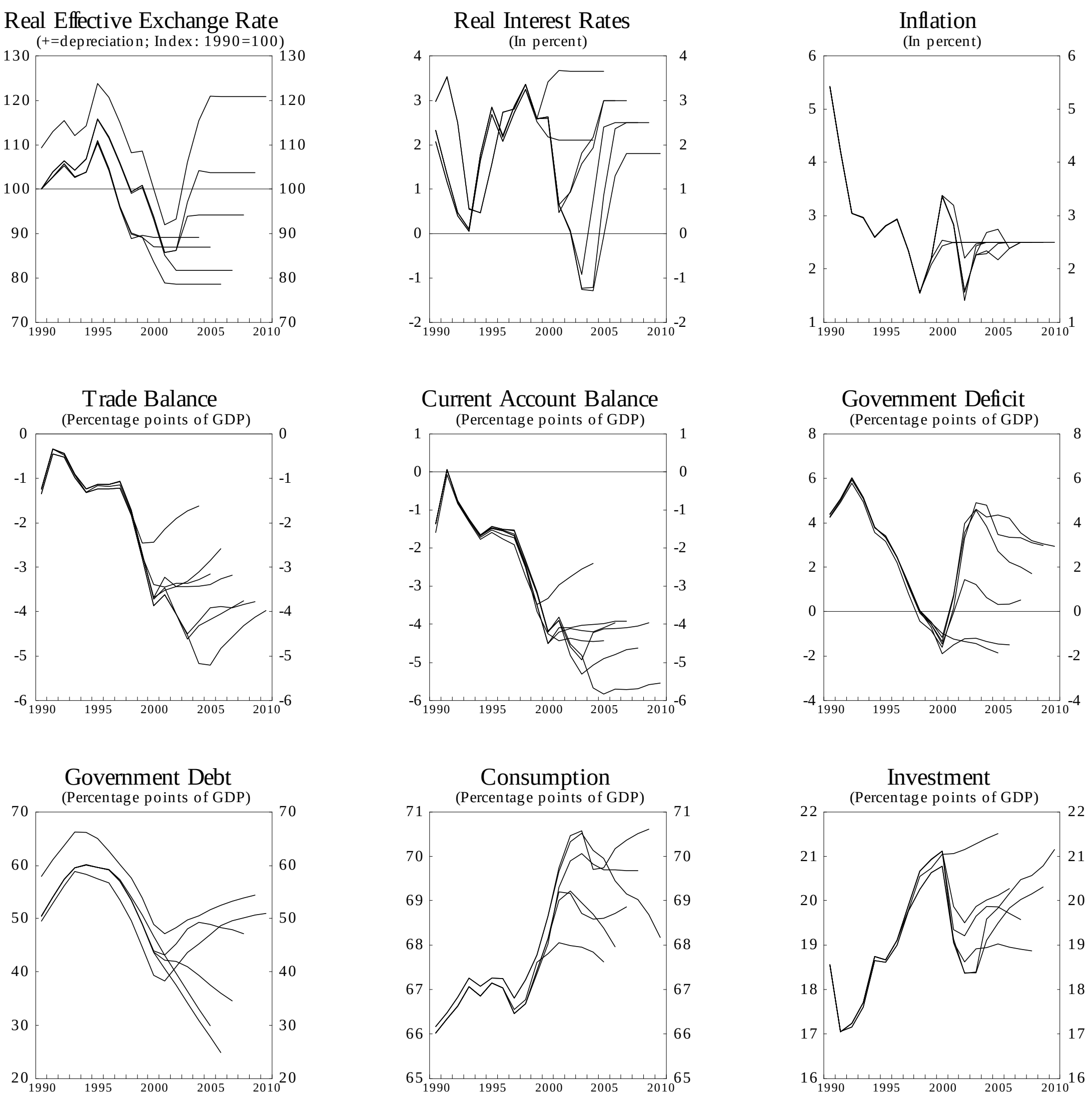

Figure 14: The Baseline Scenario - United States

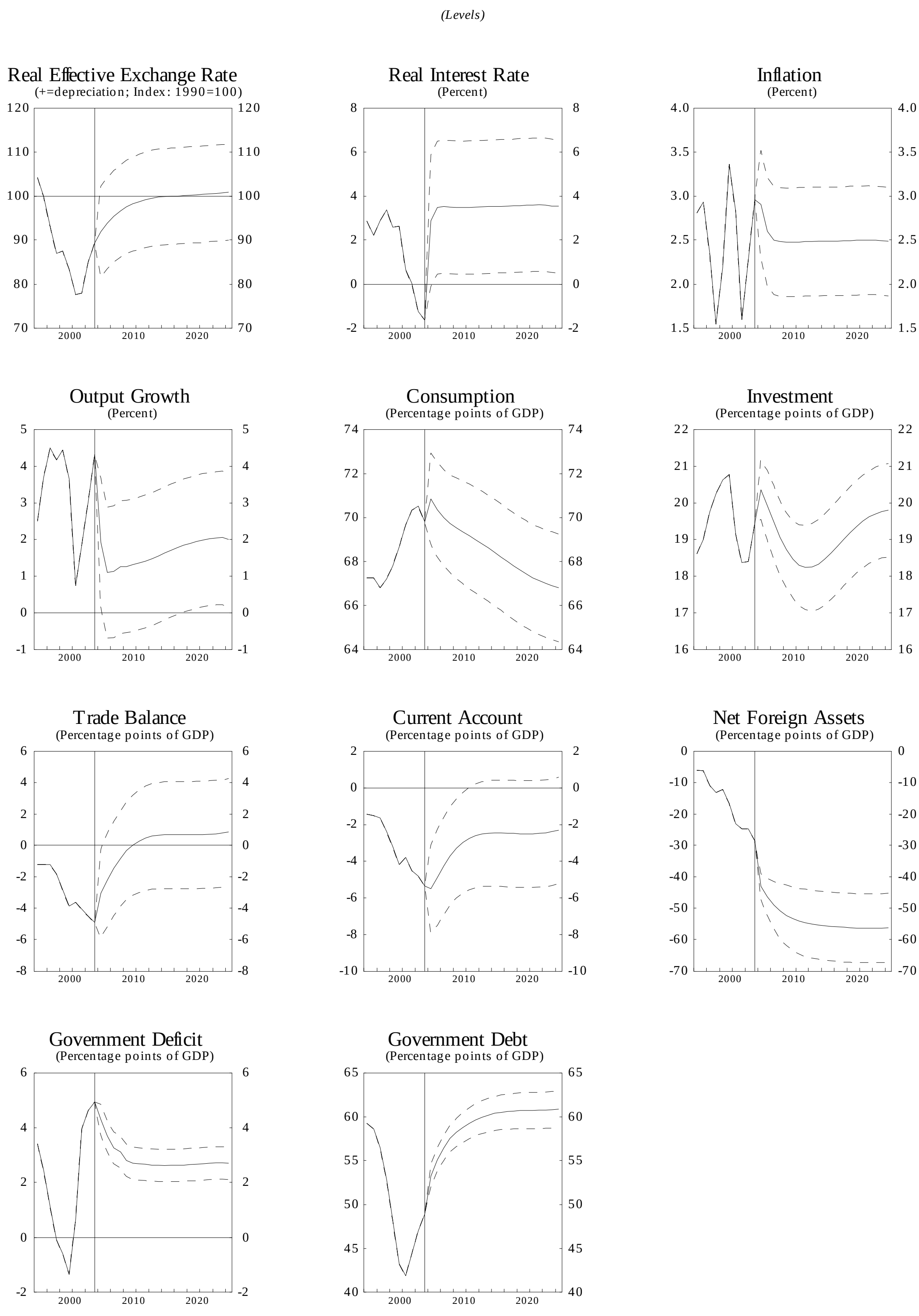

Figure 15: The Baseline Scenario - Emerging Asia

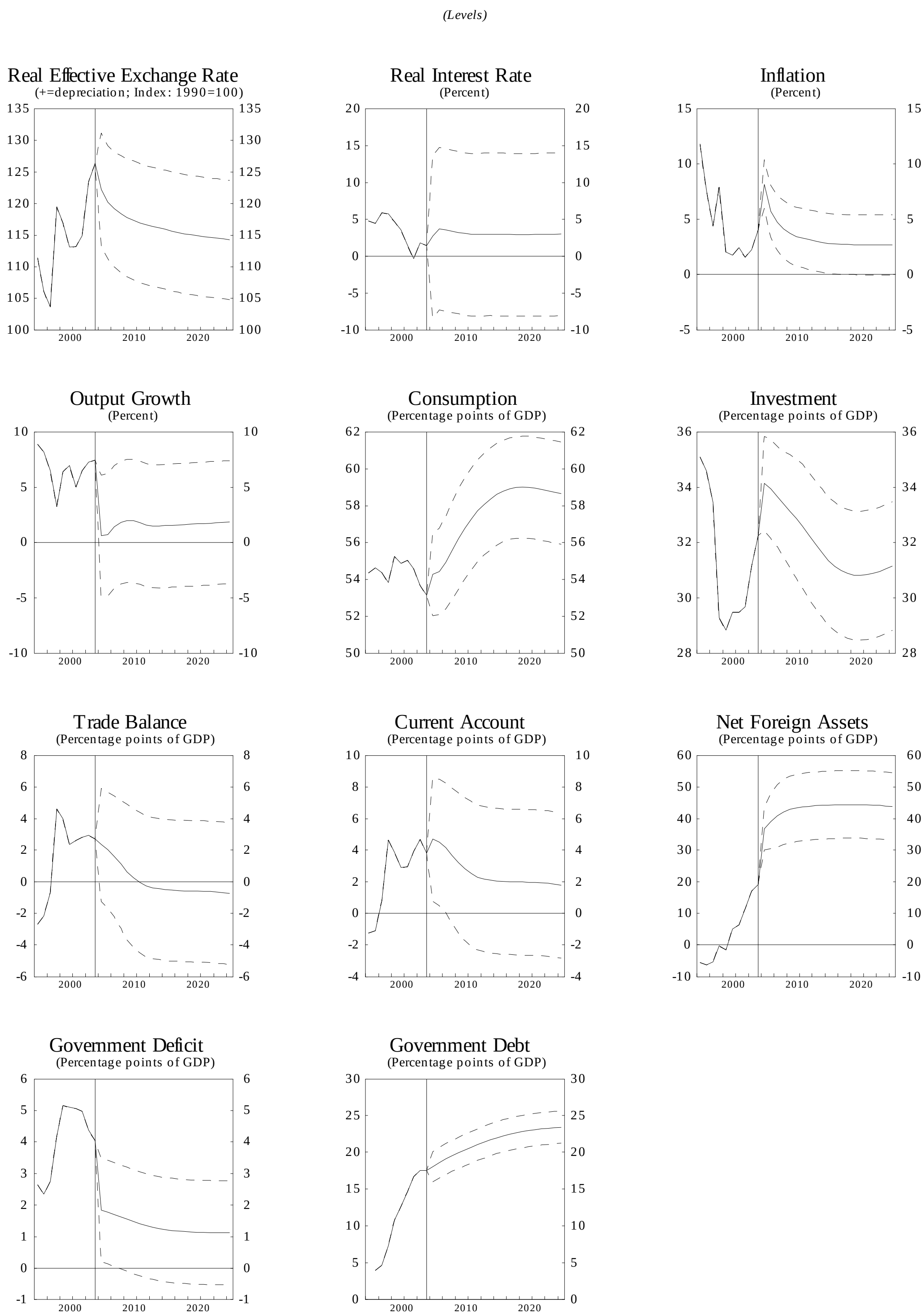

Figure 16: The Baseline Scenario - Japan and the Euro Area

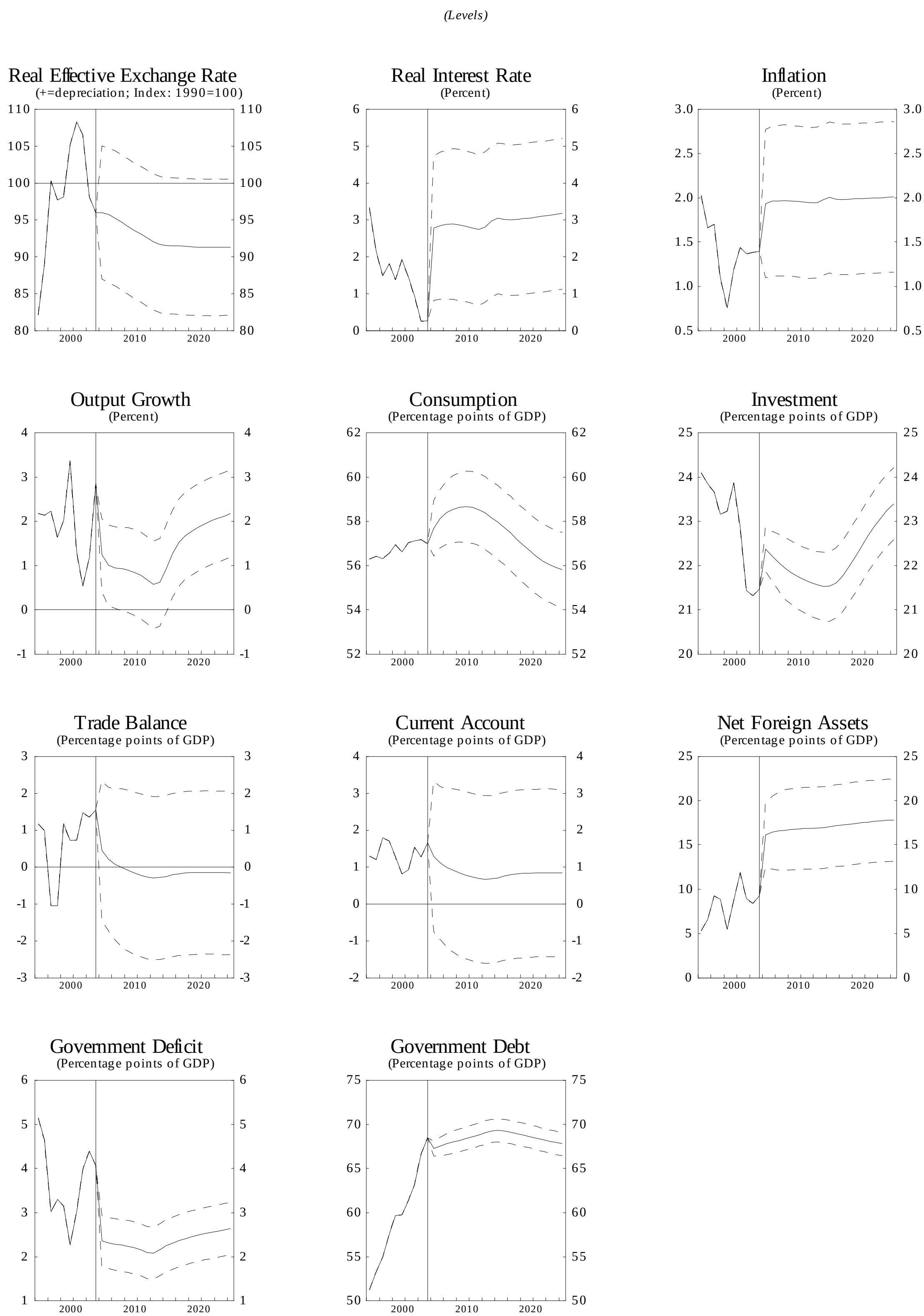

Figure 17: Loss of Appetite for US Assets: Exchange Rate Peg in Emerging Asia (Solid Lines) and Move to Flexible Exchange Rates in Emerging Asia (Dashed Lines) [Deviation from baseline]

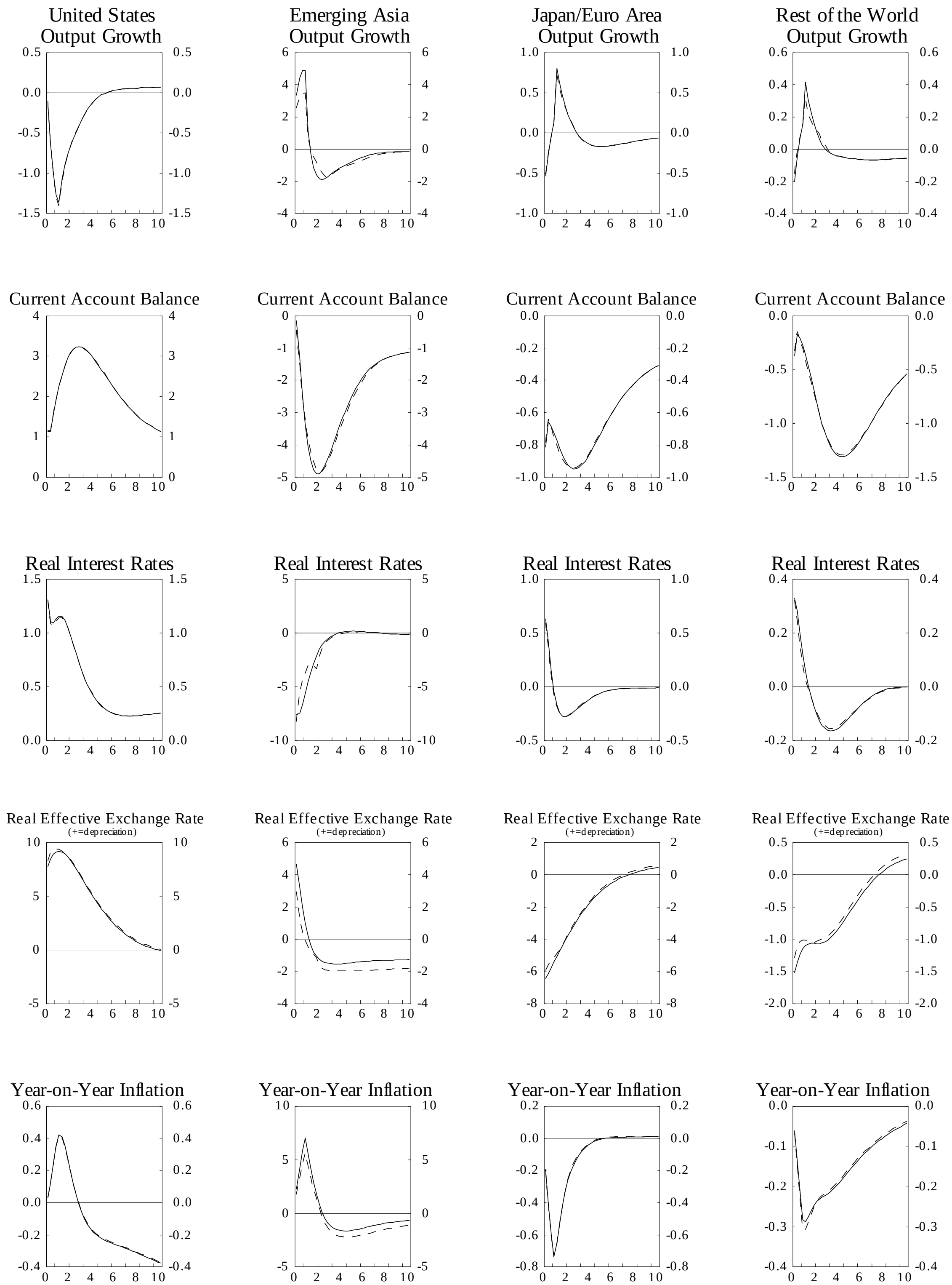

Figure 18: Effects of a Permanent Reduction in Government Debt through Tax Hikes: Exchange Rate Peg in Emerging Asia (Solid Lines) and Move to Flexible Exchange Rates in Emerging Asia (Dashed Lines) [Deviation from baseline]

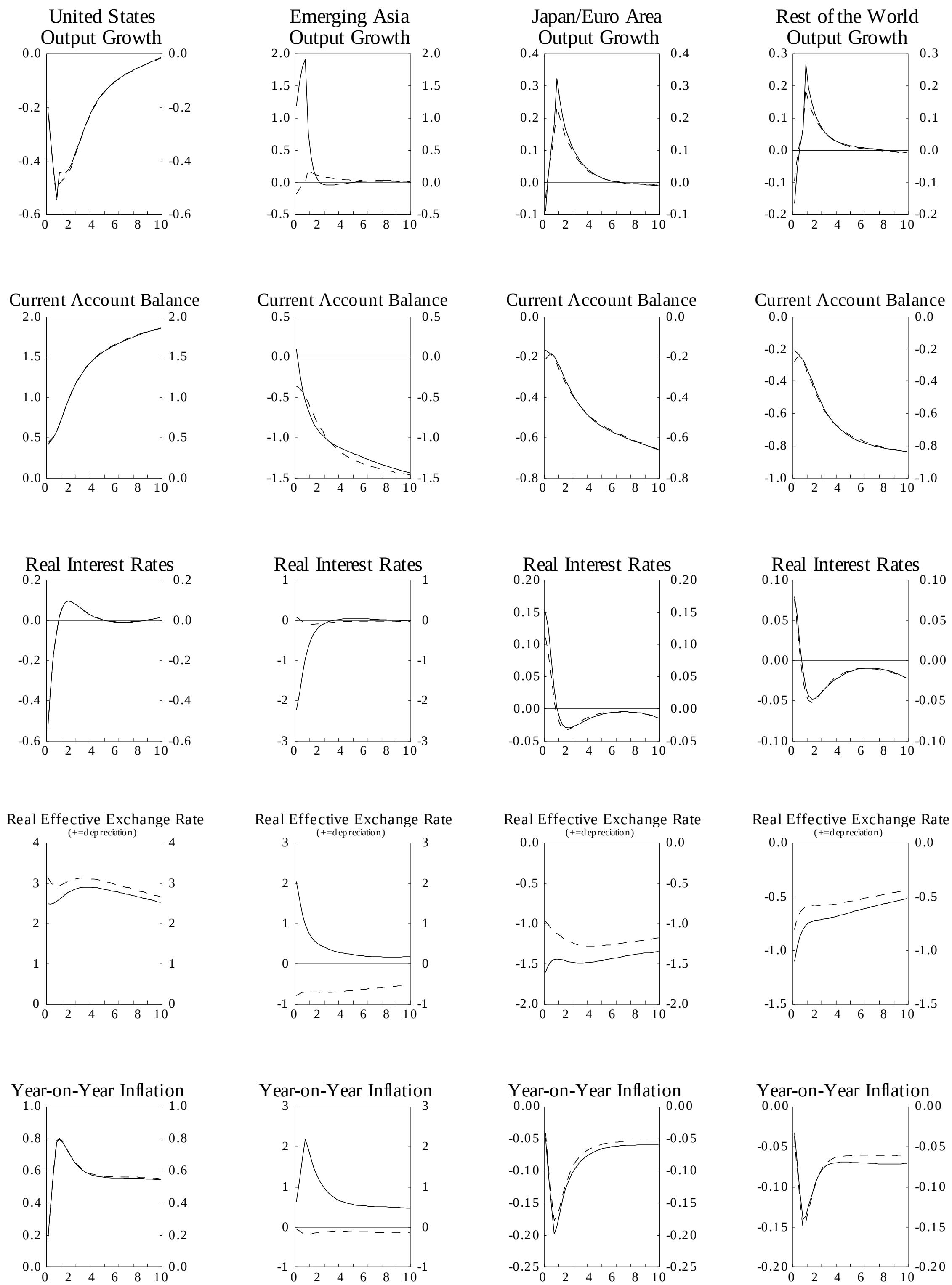

Figure 19: Effects of a Permanent Reduction in Government Debt through Tax Hikes: Sensitivity Analysis with Alternative Assumptions on the Link Between Government Debt and Net Foreign Liabilities [Deviations from baseline]

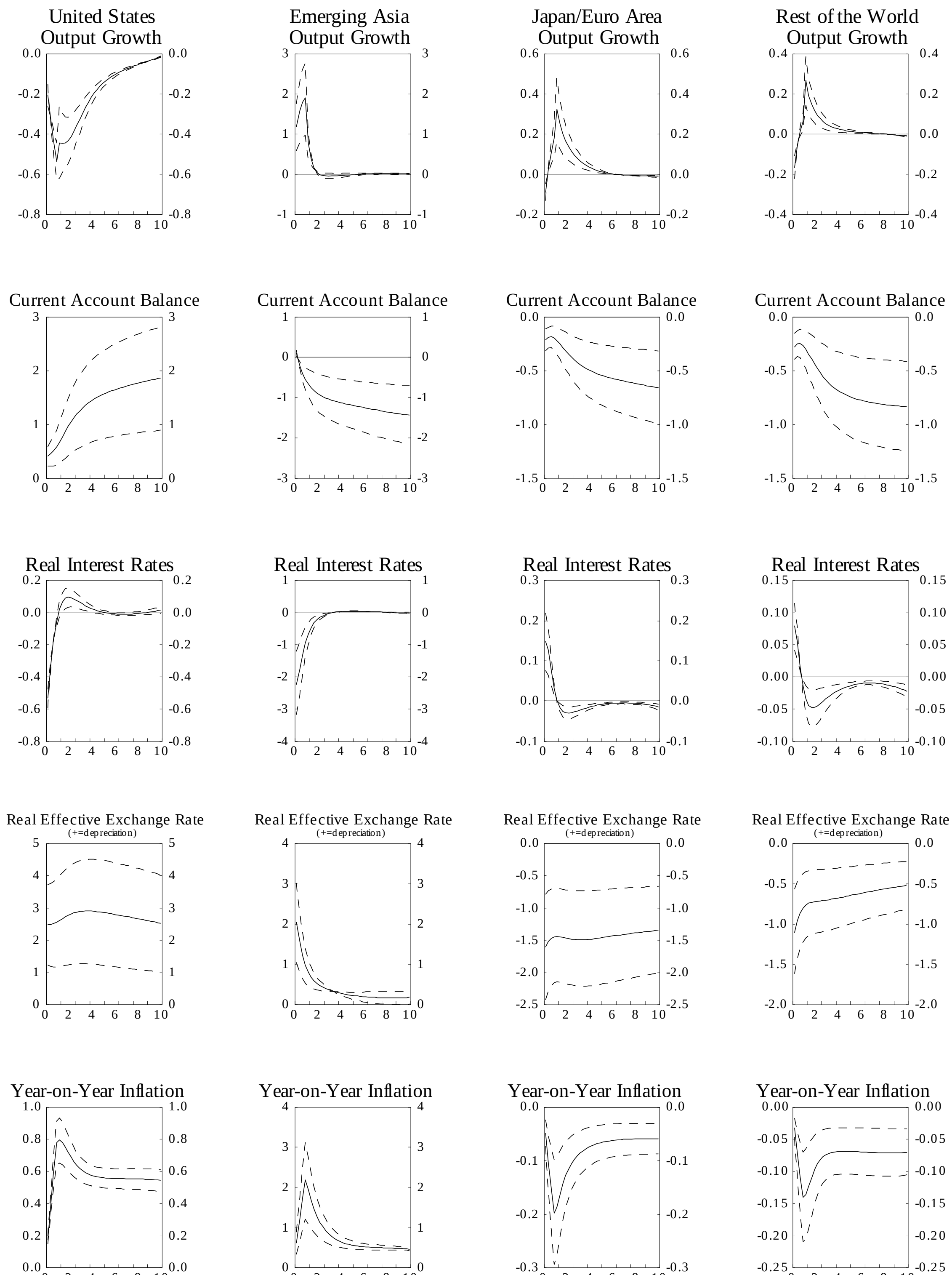

Figure 20: Effects of a Permanent Reduction in Government Debt through Tax Hikes: Sensitivity Analysis using GFM Comparing a Planning Horizon of 10 Years (Solid Lines) with a Planning Horizon of 20 Years (Dashed Lines) [Deviations from baseline]

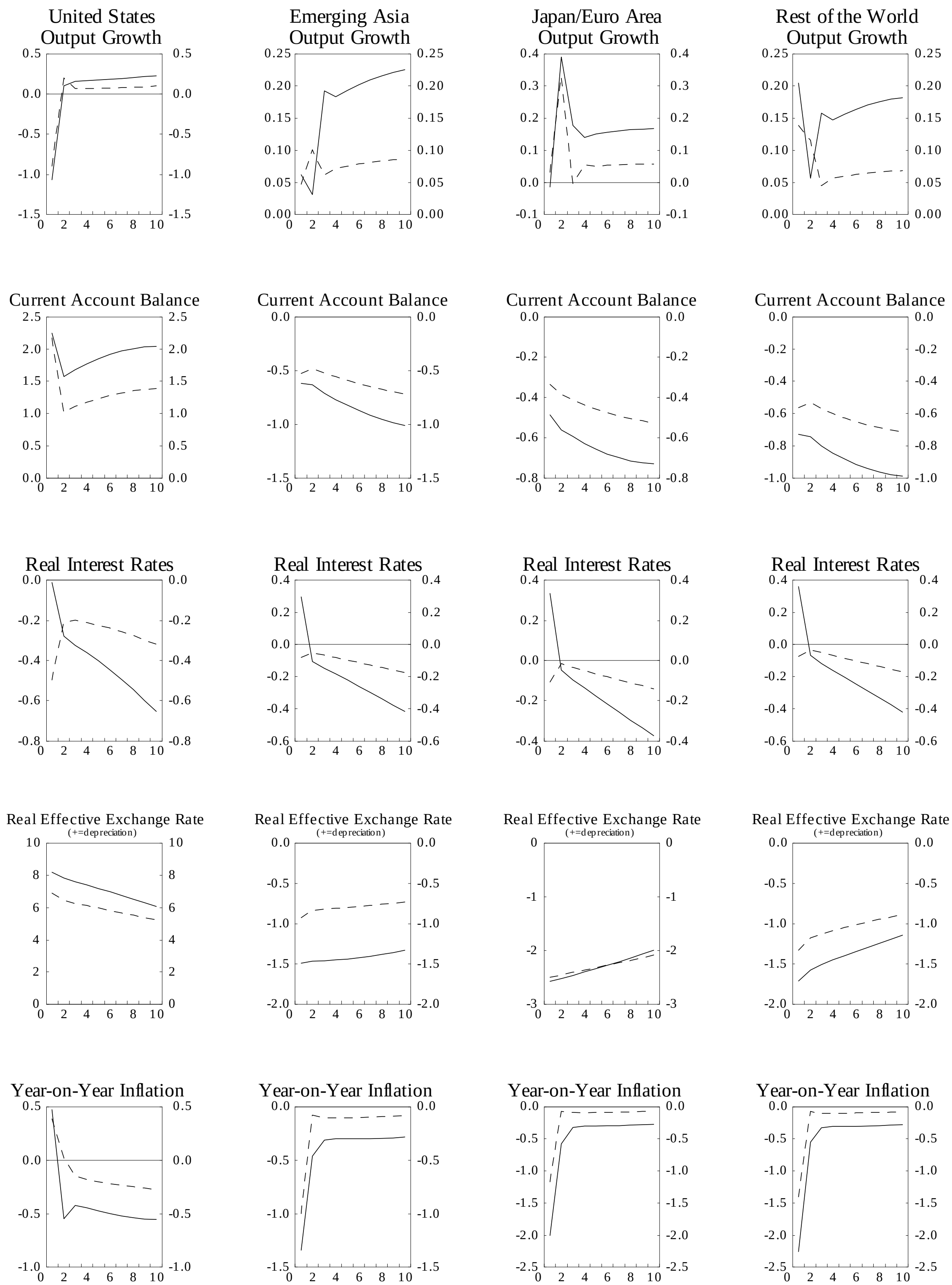

Figure 21: Effects of a Permanent Reduction in Government Debt through Tax Hikes (Solid Lines) and Expenditure Cuts (Dashed Lines) [Deviations from baseline]

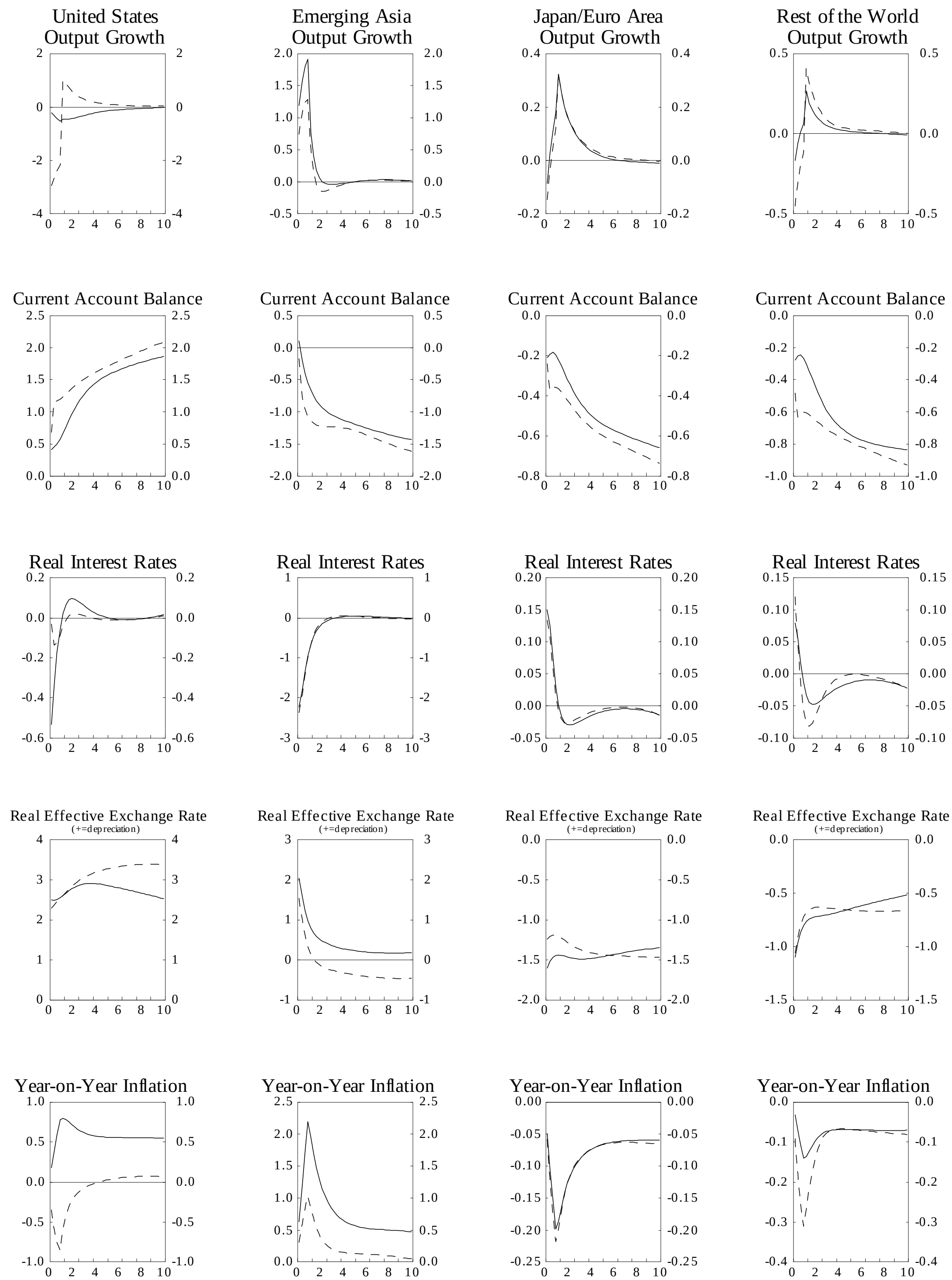

Figure 22: Estimated Effects of More Competition-Friendly Policies in Europe and Japan (Deviations from baseline)