Would protectionism defuse global imbalances and spur economic activity? A scenario analysis*

Hamid Faruqee
International Monetary Fund

Douglas Laxton
International Monetary Fund

Dirk Muir
Bank of Canada

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

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Abstract

In the evolving debate and analysis of global imbalances, a commonly overlooked issue pertains to rising protectionism. This paper attempts to fill that gap, examining the macroeconomic implications of trade policy changes through the lens of a dynamic general equilibrium model of the world economy encompassing four regional blocs. Simulation exercises are carried out to consider the imposition of uniform and discriminatory tariffs on trading partners as well as the case of tariff retaliation. We also discuss a scenario in which a 'globalization backlash' lowers the degree of competition in import-competing sectors, and compare the implications of higher markups in the product and labor markets.

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"Should globalization be allowed to proceed and thereby create an ever more flexible international financial system, history suggests that current imbalances will be defused with little disruption.... I say this with one major caveat. Some clouds of emerging protectionism have become increasingly visible on today's horizon...The costs of any new such protectionist initiatives, in the context of wide current account imbalances, could significantly erode the flexibility of the global economy." — Former Federal Reserve Chairman Alan Greenspan.[1]

1 Introduction

Unprecedented global imbalances have stirred an ongoing and lively policy debate. Can they be sustained, and for how long? If not, can an orderly rebalancing be achieved without severely disrupting international trade and finance or global growth? Past episodes tell a cautionary tale regarding the implications of very large deficits (and their reversals).[2] Guided by lessons of history, mainstream views worry about the 'inevitable' external adjustment and the prospect of large swings in the value of the dollar.[3] Others believe that concerns are overblown and question the instructiveness of past experiences, noting that an expanding universe of current accounts, declining correlations between saving and investment, and accumulating gross (as well as net) foreign asset positions[4] signify a rapidly shifting global landscape.[5]

But attention and concern attached to external balances have, in fact, increased not decreased in recent years. In particular, persistent and widening trade and payments imbalances have fuelled rising protection sentiment and posturing in a number of countries. In the United States, for example, several congressional bills concerning trade imbalances have been written.[6] At the heart of the controversy are sizable trade surpluses in emerging Asia, paired with substantial foreign reserve accumulation and large-scale intervention in the currency market to limit exchange rate flexibility. In fact, roughly three-quarters of the vast global reserve build-up between 1999 and 2004 is attributable to Asia. During that time, key Asian central banks — including India, South Korea, Taiwan, Hong Kong, Singapore and Malaysia — as a group have more than doubled their official holdings of foreign securities, mostly U.S. Treasuries, to over $2 1/2 trillion. Japan and China account for the bulk of these holdings, although oil exporting countries have more recently played a larger role in foreign reserve accumulation.[7]

Central to their 'new Bretton Woods' hypothesis, Dooley, Folkerts-Landau and Gar-

[1] Greenspan (2003).

[2] See Milesi-Ferretti and Razin (2000), Edwards (2004) and Freund (2005).

[3] See, for example, Obstfeld and Rogoff (2000, 2006), International Monetary Fund (2002).

[4] See Lane and Milesi-Ferretti (2001, 2003, 2004), Tille (2003), Faruqee and Lee (2006). See also International Monetary Fund (2005a).

[5] Hausmann and Sturzenegger (2006) argue that the U.S. is effectively neither a deficit nor a debtor country once the value of foreign assets is appropriately assessed (i.e., taking the so-called 'dark matter' into account). Buiter (2006) criticizes this logic. Gourinchas and Rey (2006) suggest that the current account itself is becoming a less relevant concept, given ever-increasing valuation effects, which can facilitate external adjustment.

[6] For a survey of U.S. congressional trade bills related to China see Hufbauer and Wong (2004).

[7] See Garton (2004), Higgins and Klitgaard (2004).

ber (2004, 2006) emphasize how these policy actions are deliberately related to export-led growth and development strategies — strategies that could remain in place for a very long time.[8] Undervaluation of Asian currencies — which Goldstein (2004) estimates to be 15 to 25 percent in the case of China — obviously does not help to unravel rising trade frictions. And beyond exchange rate policies, another contentious issue is implicit export subsidies, including inter-alia tax advantages and other government preferences, state-owned enterprises, and export 'zones',[9] whose trade implications are often not dissimilar to those of an undervalued currency.[10]

But 'scapegoating' often emanates from domestic economic woes, and the recent situation may not be an exception. In the recent past job growth in the United States has been below previous economic recoveries, particularly in sectors exposed to foreign competition. Wages have also reacted slowly to changing business conditions. Not surprisingly, politicians and business leaders alike are tempted to support protectionism as an appealing and politically costless recipe to address internal and external problems.

What seems to be missing — or severely overlooked — in this debate is the quantitative assessment of the implications for the world economy of a potential resurgence in protectionism. Questions such as the one in the title of this paper cannot be satisfactorily addressed without a coherent analytical framework to guide scenario analysis and simulation exercises. This paper is a preliminary step in this direction.

First, we set up and calibrate a general-equilibrium, dynamic model of the world economy encompassing four regional blocs, one of which is emerging Asia. The model represents — we believe — a fair compromise between the two extreme poles of realism and complexity versus stylization and tractability.[11] While its scale is larger and its structure more detailed than most academic dynamic general-equilibrium models, our model shares with the relevant literature the adoption of solid choice-theoretic foundations, and closely builds on recent theoretical developments in international macroeconomics.

The model converges to a well-defined non-stochastic steady-state, where all relevant macroeconomic variables are determined as functions of structural parameters and policy variables. We carry out comparative statics exercises by comparing the steady-state properties of the model before and after the imposition of import tariffs. We consider the effects of protectionist policies undertaken by each importing country both when tariffs are imposed on imports from the rest of the world as a whole and when they discriminate across exporters.

Next, we construct a 'baseline' scenario as follows. We take a specific point in time (namely, 2006Q1) at which the economy is assumed not to be in a steady state due to the occurrence of several country-specific macroeconomic shocks sometime in the past. The shocks have different sizes and different degrees of persistence. Judgemental assumptions about these shocks are made to guarantee that, at the beginning of the simulation horizon, the model generates values for the relevant endogenous variables which are broadly consistent with the observed levels at the end of 2005. The propagation mechanism intrinsic to the

[8] See Eichengreen (2004), Roubini and Setser (2005) for a critique.

[9] See, for example, Hufbauer and Wong (2004) and Morrison (2005).

[10] Morgan Stanley, for example, estimates that removing China's explicit and implicit export subsidies would be equivalent to a 16 percent appreciation of the currency against the dollar (quoted in Laura D'Andrea Tyson, "Stop Scapegoating China – Before It's Too Late", *Business Week*, May 2, 2005).

[11] The model is a variant of the Global Economy Model (GEM) developed at the International Monetary Fund.

model generates dynamic paths for all endogenous variables converging to the new steady-state world equilibrium levels. We refer to these paths as the baseline scenario in our analysis. While it is not meant to provide a macroeconomic forecast for the world economy, our baseline provides plausible quantitative elements to asses the extent of price and quantity adjustment associated with global rebalancing.

Finally, we reconsider the above scenario modified to account for the unanticipated imposition of import tariffs at the beginning of the simulation horizon, and study how the new scenario deviates from the previous baseline. According to our estimates, a generalized 10 percent hike against emerging Asia improves the US current account balance as a share of GDP by a mere 0.1 percentage point. The effect disappears after about two years, and in the absence of further adjustment in net saving, it may even revert sign. Similar effects hold in the rest of the world. All in all, our analysis strongly suggests that the answer to the question in the title of this paper is a resounding no.

The paper is structured as follows. Section 2 briefly provides a non-technical overview of the model and discusses the calibration. The baseline scenario is introduced in Section 3. Section 4 considers the effects of tariff hikes, both uniform and selective, and discusses the case in which protectionist pressures take the form of a backlash against competition-friendly reforms in import-competing sectors. Section 5 concludes.

2 A model of the global economy

2.1 The theoretical structure

The simulation model we adopt in this paper builds upon Faruqee, Laxton, Muir and Pesenti (hereinafter FLMP) (2006), appropriately modified. In this section we limit ourselves to a very synthetic overview of the theoretical framework, highlighting a few formal features of particular relevance for the simulation exercises.[12]

The world economy consists of four regional blocs ('countries'): US (United States),[13] JE (Japan and euro area), AS (Emerging Asia), and RC (Remaining Countries). In each country, there are households, firms, and a government. The overall structure of the model is illustrated in Figure 1, and each sector is described in turn below.

Each household consumes a non-tradable final good (C in Figure 1), and is the monopolistic supplier of a differentiated labor input (ℓ) to all domestic firms. Some households are liquidity-constrained and do not have access to capital markets. They finance their consumption exclusively through disposable labor incomes. The remaining households own domestic firms and the domestic capital stock (K), which they rent to domestic firms. They 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 transacting in the international bond market.[14] Labor and capital are immobile internationally. The

[12] Technical details are extensively discussed in the Appendix to the working paper version of this article.

[13] 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.

[14] Like most open-economy general-equilibrium models, the assumption that all current-account transactions are settled in terms of a unique international bond is made for parsimony reasons. We leave to future developments the extension of the model toward a more realistic financial market structure which includes trade in equities as well.

market for capital is competitive, and capital accumulation is subject to adjustment costs. In the labor market wage contracts are subject to nominal rigidities.

On the production side, perfectly competitive firms produce two final goods — a consumption good (A) and an investment good (E). The consumption good is consumed either by domestic households or by the government (G_C). Similarly, demand for the investment good is split between private agents (I) and the public sector (G_I). Final goods are produced by using all available intermediate goods as inputs. Intermediate goods are either non-traded (N) or traded internationally (T). Domestic tradables used by domestic firms are denoted Q, imports from all other country blocs are denoted M. To model realistic dynamics of trade volumes, we assume that imports are subject to short-term adjustment costs that temporarily lower the response of import demand to changes in relative prices.

Intermediate goods are available in different varieties, each produced by a single firm under conditions of monopolistic competition worldwide. The prices of intermediate goods are subject to adjustment costs (nominal price rigidities). These goods are produced with domestic labor inputs and domestic capital.

Finally, the government purchases the two national final goods, as well as nontradable services G_N. As treasury, the government finances the excess of its expenditures over net taxes by borrowing from the domestic private sector, although its net tax rate is set in such a way as to achieve a stable long-run target debt-to-GDP ratio. As central bank, the government manages the national short-term nominal interest rate. Monetary policy is specified in terms of a credible commitment to an interest rate rule that either targets inflation or the exchange rate.

2.2 Parameterization of the regional blocs

We refer the reader to FLMP (2006) for a detailed account of the calibration of the model. 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.

Given the importance of a multi-country setting, some thought has been given to the composition of the regional blocs: US (the United States), JE (Japan and the euro area countries), AS (Emerging Asia: China, India, Hong Kong, Malaysia, Philippines, Singapore, South Korea, Taiwan province of China and Thailand) and RC (the Remaining Countries not considered elsewhere). The steady-state shares of world GDP of the four blocs are, respectively, 27.9, 32.2, 15.5 and 24.4 percent.

The decision to combine Japan and the euro area into one region reflects, from the vantage point of our project, their overlap in key 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 and foreign exchange intervention policy. However, our prior is that their role in the global rebalancing process will become comparatively less relevant in the years ahead, especially when compared to Emerging Asia.

This latter bloc groups Asian countries with strong growth and whose currencies have recently exhibited limited flexibility against the U.S. dollar. Moreover, their labor markets tend to be rapidly growing and fairly flexible. In addition, the ongoing process of market liberalization is expected to reduce entry barriers and enhance competition, including in the major constituents such as India and China.

The Remaining Countries bloc is dominated by the other members of the European Union (particularly the United Kingdom) and the other major OECD countries such as

Canada, Australia, New Zealand and Mexico.

We assume that in US, JE and RC the share of liquidity-constrained consumers is 25 percent. The share is much higher in Emerging Asia at 50 percent, reflecting the nascent or underdeveloped financial markets for domestic consumers — particularly, in the cases of China, India, Indonesia and the Philippines.

The rates of time preference underlying steady-state real interest rates are initially set at 2.7 percent but can differ across countries over the simulation exercise: in the new steady state US, the most impatient region, has the highest rate of time preference at 3.2 percent; AS, the most patient, has a rate of 2.6 percent.

The elasticity of substitution between labor and capital is set at 0.75 in both the tradable and nontradable sectors. The share of capital in the production functions is calibrated to achieve a relatively high investment share of GDP in AS, and a low share in US, in line with their respective historical averages. In all regions, the nontradable sector (e.g., services) is assumed to be less capital intensive than the tradable sector (e.g., manufacturing). The depreciation rate is assumed to be two percent per quarter across all regions.

There are separate markups on tradable and non-tradable goods 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. The US bloc has the lowest price markups, indicating the greatest degree of competition, while Japan and the euro area have the highest. 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.

Similarly, in the labor market agents have some pricing power. For US and JE the wage markups (16 percent and 30 percent respectively) correspond to Bayoumi, Laxton and Pesenti (2004).[15] 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.

Monetary policy is parameterized as follows. US, JE and RC are all committed to price stability, and we assume they follow an inflation-forecast-based rule.[16] A representative calibration is used, with a weight of 0.75 on the lagged short-term interest in order to impart a high degree of smoothing in the setting of policy rates, 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 currency.[17]

The main results of the model rely heavily upon the calibration of each region's external sector. For given steady-state net foreign asset positions for each region, it is straightforward to calculate the current account and trade balances consistent with long-term stock-

[15] 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.

[16] Inflation-Forecast-Based rules have been used extensively in central-bank models with inflation-targeting regimes in both advanced and emerging-market economies. See however the discussion in Svensson and Woodford (2005).

[17] This should be interpreted as a sensible approximation rather than in literal terms, given that China is the largest member of AS, and the limited flexibility of its currency against the U.S. dollar is at the center of the current policy debate. Similarly, other members such as Hong Kong, Malaysia, South Korea, Singapore, Thailand, Philippines and Indonesia attempt to manage the volatility of their currencies vis-a-vis the U.S. dollar.

flow equilibrium. Using the IMF's Direction of Trade Statistics on merchandise trade, the national accounts data on the imports of goods and services, and the United Nations' Commodity Trade Statistics (COMTRADE) data on each region's imports of consumer and capital goods, we derive a disaggregated steady-state matrix delineating the pattern and composition of trade for all regions' exports and imports. A more aggregated form is found in Figure 2. On the basis of this trade matrix, we derive all the weight coefficients in the demand function for imports and the regional composition of imports.

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

Lastly, we need to calibrate the behavior of net foreign liabilities (NFL). For the long-run behavior of net foreign assets 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. Moreover, when the United States expands its net foreign liabilities as a result of a permanent change in its public debt, the absorption of new issuance by each region is calibrated (on the basis of net foreign asset holdings in recent years) by assigning 24 percent of new issuance by US to AS, and 38 percent to each of JE and RC. This calibration implies that for a 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.

3 The baseline scenario

The first step in our analysis is the construction of a baseline scenario of current account rebalancing for the world economy. The 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 other regions. The purpose of the baseline is to coherently guide our thinking about the central questions surrounding external developments: 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?

Our baseline is constructed in a similar way as the baseline presented in FLMP (2006) and International Monetary Fund (2005b, Appendix 1.2), although it is revised and updated to account for 2005 data. As in our previous work, our working hypotheses are that the central tendencies underlying the global macroeconomic imbalances in the early 2000s can be attributed to a combination of six related but distinct 'shocks'. The first three shocks center around the United States economy:

1. Higher US government debt (with initial tax cuts followed by future tax hikes) centered around the announced plans of the United States federal government.[18]

[18] In our simulation the steady-state government-debt-to-GDP ratio in the US increases by 11.5 percentage points. In the short run the deficit-to-GDP ratio for the US peaks at 5 percent after two years, and then declines to the steady-state value of 2.7 percent of GDP.

2. A permanent decline in the private savings rate in the United States relative to the rest of the world.[19]

3. An increase in the demand for US assets abroad, particularly in the AS bloc.[20]

The next two shocks reflect relative productivity trends in the rest of the world. In the model, worldwide convergence of productivity growth rates is taken as the anchoring feature of the economy in the long term. However, prolonged deviations from balanced growth can play a key role in the unfolding of medium-term rebalancing scenarios, in line with the asymmetric tendencies observed across regions in the past decade. The shocks are:

4. Very persistent and rapid productivity growth in AS with a central tendency starting at 5.5 percent per year.[21]

5. Very persistent and lagging productivity growth in JE with a central tendency of 0.75 percent per year.[22]

The final shock attempts to capture structural changes in the pattern of world trade, including strategies of export promotion in Emerging Asia[23] leading to upward shifts in the range and quality of AS exported varieties, as well as preference shifts toward AS goods in world demand. The specific way these competitiveness-friendly strategies are introduced is through:

6. A short-run and temporary positive shock to AS fiscal policy to promote exports with a magnitude of 33 percent, associated with an increase in the rest of the world demand for AS exports by 5 percentage points.[24]

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[19]The private savings shock has both a temporary and permanent component. The permanent component is represented by an increase in the rate of time preference in the US relative to the rest of the world of 50 basis points. For the temporary component, we reduce the risk premium on US assets for all regional blocs by one percent for 25 years.

[20]The shock is implemented as a change in desired net foreign asset positions. 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 20.5 percentage 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.

[21]Technically, the productivity growth rate in AS differs between the tradable and nontradable sectors. For the nontradables sector, productivity grows at three percent per year for eight years. The shock in the tradable sector is much larger, and much longer. On average, the productivity growth rate in Emerging Asia is close to 5.5 percent a year at the beginning of the simulation, declining steadily to around 2.25 percent after 30 years and returning to the trend two percent growth rate two years later.

[22]To be more precise, we assume that productivity grows at 1.25 percent per year for 13 years in Japan and the euro area for both the tradable and nontradable sectors, instead of at the world trend growth rate of two percent.

[23]This includes tax rebates, accelerated depreciation allowances, and tax holidays.

[24]This shock is implemented as a positive increase in the AS fiscal deficit above 4 percent of GDP in the first year, which declines to 1.0 percent of GDP by the end of the ninth year. Afterwards it reverts to the deficit consistent with the original long-run debt target of 24 percent of GDP. At the same time, world preferences for Asian imports shift up by 5 percentage points of their total imports over roughly three years. For example, the bias of US consumers for imported goods from Emerging Asia increases from 0.11 to 0.16, with a corresponding decrease in demand for imported goods from RC from 0.58 to 0.53. This implies that in the long run, for every additional one hundred units of imports in JE, RW or US, five of those units now come from AS rather than from the other trading partners.

The six aforementioned shocks form the components for our integrated baseline scenario. As mentioned earlier, the shocks should be viewed as the central tendencies of the scenario, while the latter is presented more broadly as a range of potential outcomes.

In presenting the baseline scenario, we consider a range of possibilities that accounts for the degree of uncertainty around the central tendency of the six component shocks. A high degree of uncertainty, in particular, surrounds the outcome of 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 U.S. fiscal policy and lagging productivity in Japan and the euro area, the uncertainty bounds are more narrow.

The baseline scenario begins in 2006Q1. As mentioned in the introduction, at the beginning of the simulation horizon the model is not in a steady state. Rather, the aforementioned shocks are assumed to have materialized during the 12 quarters preceding 2006Q1, and at the beginning of the simulation horizon the world economy is already on a transition path toward the new steady state. We believe that using this time frame for the combination of the six shocks (with minor modifications to smooth demand and monetary policy) is the best strategy to represent our baseline view of the world economy at the beginning of 2006.

Figure 3 presents the baseline scenario in the United States. The pre-2006 time series are historical data. After 2006Q1 we plot our model-based projections, with the solid lines referring to the central tendencies and the dotted lines quantifying risks to the basic scenario. The key features are a gradual build up in US government debt and a decline in net foreign assets. The exchange rate depreciates 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 heavily indebted. In addition, investment is crowded out by persistent budgetary deficits. Overall, the dynamics in the United States are driven by the current account deficit moderating from about 6 percent of GDP to a sustainable level in 10 years' time.

To a significant extent the increased supply of US assets is absorbed by Emerging Asia (Figure 4). Initially AS runs a large and growing current account surplus. Eventually, the trade balance turns negative 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, the AS real effective exchange rate roughly strengthens between 10 and 20 percent over the next five years, an appreciation achieved in real terms through higher inflation. Because of limited exchange rate flexibility, there is an increase in the real interest rate necessary to defend the stability of the currency. Overall, the economy cools down in the short run, as higher interest rates dampen investment and real appreciation affects net exports. However, consumption increases as a share of GDP in the medium term in anticipation of higher wealth (and lower saving) in the long run.

Japan and the euro area are relatively stable in terms of adjustment, experiencing few effects as Emerging Asia absorbs most of the increased US demand for goods and the increased supply of US assets (Figure 5). The JE external account is broadly stable going forward, with only a temporary and small current account improvement until it stabilizes around 0.5 percent of GDP in about 10 years time.

The Remaining Countries bloc behaves much like Emerging Asia since it has strong links with the United States (mainly Canada and Mexico). But 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 exhibits a smaller movement in its real effective exchange rate than Emerging Asia because in the simulations it conducts its monetary policy by targeting inflation rather than the nominal exchange rate.

4 Scenarios involving protectionist policies

In this section we run a set of simulation exercises on the macroeconomic effects of trade policies in the global economy. Using a dynamic general-equilibrium model as the analytical framework of our simulation exercises allows us to consider both the long-term implications of higher tariffs and their dynamic effects in the short and medium term, as well as what implications they might have for monetary and fiscal policies. Since in this venue we are not concerned with a detailed sectoral account of trade distortions, our methodology lumps together the myriad of potential protectionist barriers and considers an hypothetical average tariff on imports as the only trade policy instrument.[25] We allow however for discrimination across exporters, in order to track down the effects of selective intervention against specific countries, in particular the Emerging Asia (AS) bloc.

We first use our four-region steady-state model to estimate the long-run effects of tariffs, obtaining results which are consistent with the optimal tariff argument. Second, to assess whether or not tariffs would be an effective policy initiative for alleviating current account imbalances, we examine both the comparative static and dynamic effects of higher tariffs imposed on imports from emerging Asia. Finally, because the process of globalization may have been an important factor in increasing competition throughout the world, we complete our analysis by studying the implications of protectionist pressures toward a partial reversal of these trends (a 'globalization backlash' leading to higher markups in the tradables sector), and compare these results with similar scenarios of higher markups in the labor and product markets.

4.1 A world protectionist surge: Long-term effects of a hike in tariff rates against all other countries

A considerable amount of research on the impact of tariff and non-tariff barriers has been carried out in the trade and industrial organization literature, using computational general-equilibrium models to estimate the effects predicted by the theory. In this section we build on this body of work while focusing on a macroeconomic perspective.[26] The obvious starting point in our analysis is to use our model to estimate what would be the long-term response of key macroeconomic variables to a permanent change in the degree of protectionism worldwide. These effects depend on the interaction between the distortions associated with the imposition of the tariff itself and other distortions in the macroeconomy, either related to structural factors (e.g. whether the country is 'large' enough to have monopoly power on its terms of trade) or policy choices (e.g. whether the increased tariff revenue compensates for a reduction in distortionary taxation on capital and labor incomes for an unchanged level of government spending, or rather finances additional public absorption G_C and G_I).

[25] A summary of several studies on the (static) general equilibrium impact of trade liberalization, in the context of examining the effects of the Uruguay Round, can be found in Whalley (2000). The cited studies are based on multi-sector, multi-region models that uniformly assume Armington-type (CES) trade structures to examine the long-run trade policy effects in more detail as well as their global impact.

[26] Among the classic contributions in this literature see Torrens (1833), Mill (1844), Edgeworth (1894), and Bickerdike (1907). More recent contributions include Graaf (1950), Johnson (1961), Hamilton and Whalley (1983), Gross (1987), Markusen and Wigle (1989), Grossman and Helpman (1995) and Frensch (2002).

The important insight from the optimal tariff literature posits that for a single large country it may be optimal to raise tariffs, but when all countries do so they may all lose. The basic intuition for this result dates back at least to Torrens (1833) and Mill (1844), whose analysis suggested that a tariff reduces welfare by distorting consumption and production decisions but can lead to a terms of trade improvement if foreigners reduce their prices facing lower demand for their exports. This terms-of-trade gain amounts to a transfer of wealth towards the country imposing the tariff, which tends to appreciate its currency. Whether a country gains or loses as a whole thus depends on the strength of the terms-of-trade effect, which in turn depends on the elasticity of substitution between imported goods and domestically produced tradables.

Table 1 reports estimates of the long-run domestic and spillover effects of a 10 percentage point hike in tariffs in each of the regions. The tariff hikes are assumed to apply to all imports, regardless of country of origin. For example, the first column in Table 1 refers to the effects of a 10 percent hike in US tariffs against imports from AS, JE and RC, the second column refers to a tariff in AS against imports from US, JE and RC, etc. The last column refers to a scenario in which each country simultaneously raises its import barriers against all other countries (illustrating the effects of a 'trade war'). The results in Table 1 assume that the additional revenue from the tariff hikes is used to reduce the tax rate on labor income.

The general pattern that emerges from these simulations is that the tariff hike has a contractionary spillover on the rest of the world (where welfare falls for all consumers) but an expansionary impact in the protectionist country (who has an increase in welfare), at least as long as no other country follows suit and 'retaliates'. Consider for instance a scenario in which the United States raises its tariffs against foreign imports (first column). In the United States itself, real GDP rises permanently by 1.1 percent, consumption by 1.4 percent and labor effort by a half percentage point, while the real exchange rate appreciates by 6.3 percent. On impact, the tariff alters the relative price of imported versus domestically-produced goods. Because of the relatively high elasticity of substitution between domestically-produced and imported goods, there is a strong shift into domestic production, leading to an increase in labor demand. Higher consumption reflects these labor income gains as well as the wealth effect from the change in the terms of trade, discussed above. Conversely, in the rest of the world there is a generalized output fall (1.0 percent in Emerging Asia, 0.4 percent in the JE bloc, and 1.1 in the rest of the world) with real exchange rate depreciations.

Similar considerations hold for the next three columns, showing the effects of protectionist hikes in AS, JE and RC respectively. The largest expansionary effect on the domestic economy is found in the AS case, the smallest in the US case. This is not surprising, as the direct effects of tariffs are highly related to the degree of openness of the respective economies, and we should expect them to be larger in regions that have greater exposure to trade. In fact, as shown in the very last row of Table 1, imports represent about 26 percent of GDP in Emerging Asia, 24 percent in the Remaining Countries bloc, 16 percent in Japan and the euro area, and only 12 percent in the United States. Obviously, tariff revenue as a share of GDP is higher in the countries that have greater openness.

The size of the protectionist spillovers to the rest of the world differ from case to case. For instance, a tariff hike in the United States has a large contractionary impact in Emerging Asia (1.0 percent GDP reduction), but a tariff hike in Emerging Asia has relatively small repercussions on the US economy (0.3 percent GDP reduction). The worst GDP spillovers are found in the JE bloc when the Remaining Countries hike their tariffs (output falls by

1.4 percent) and in the Emerging Asia bloc as a result of protectionism in Japan and the euro area.

In sum, our results are suggestive that terms of trade effects may be quantitatively relevant and each country may be tempted to raise tariffs.[27] Note, however, that when all countries hike tariffs by equal amounts, these terms-of-trade effects work to offset each other, so that the only macroeconomic effects left are the distortions in consumption and production decisions. In other words, nobody wins when protectionism surges worldwide. As the last column of Table 1 reports, if all countries hike their tariff rates simultaneously, we see a fall in welfare of 0.1 percent for the majority of consumers (i.e. the forward-looking consumers).[28] Interestingly, the liquidity-constrained consumers actually see an increase in their welfare of 0.4 percent, but this result stems partially from the fact that, by construction, the increase in tariffs has the positive effect of reducing distortionary taxation in the labor market, thus boosting labor effort and employment in steady state (and the consumption of liquidity-constrained agents, whose wealth depends solely on labor income). Moreover, output contracts everywhere. Emerging Asia, Japan and the euro area are the main victims (-1.1 percent), while the United States remains almost unscathed (-0.2 percent).[29] Again, the muted output effects are attributable to the reduction in the level of labor taxation resulting from the new revenue stream from the imposition of tariffs.

To control for these labor-supply effects, in Table 2 we consider the case in which higher tariff revenue increases government absorption that does not contribute directly to either productive capacity or the welfare of consumers. Once again, in all cases the country that imposes the tariff benefits from a real exchange rate appreciation and higher output whenever it is the only country that raises the tariff. And in all cases this increase in output comes at the expense of a contraction in those countries that face the higher tariff rates and a real depreciation in their exchange rate. Welfare also falls for both types of consumers. But in Table 2 there are significant negative crowding-out effects on private consumption, investment and output relative to Table 1. Labor effort falls everywhere in the world economy, no matter which country adopts a protectionist posture. Not surprisingly, the implications of a trade war (last column) worsen significantly. Welfare falls worldwide by 2.4 percent for forward-looking consumers and 2.7 percent for liquidity-constrained consumers. In the AS bloc, consumption falls by 6.2 percent in Table 2 (as opposed to only 0.4 percent in Table 1). In Japan and the euro area consumption falls by 4.5 percent (as opposed to 0.8 percent). Even in the United States, consumption now falls by 2.4 percent (it was virtually unchanged in Table 1).

In both Tables 1 and 2 there are very small effects on the long-run current account balance as a share of GDP. This should be expected: even though our model allows for steady-state budgetary non-neutralities, in our simulation exercises tariffs do not affect in-

[27] The size of the optimal tariff may well differ across importers. In the theoretical trade literature it has been shown that the optimal tariff rate is inversely related to the export supply elasticities — see Bickerdike (1907) and Grossman and Helpman (1995). Broda, Limao and Weinstein (2006) provide some empirical support for this view by showing that countries with higher market power have higher average tariff rates.

[28] Welfare here is derived from the two utility functions, one for each type of consumer: forward-looking ones, who own all bonds and the capital stock, and liquidity-constrained ones. Welfare is measured in terms of consumption equivalents, defined as the amount of consumption required to achieve a certain level of utility, holding labor supply (leisure) at the pre-tariff steady-state level.

[29] In Whalley (2000), the cited trade policy effects or gains in that case (in terms of global output) range from 0.2 to 1.4 percent from the Uruguay Round liberalization—whereby developed countries reduce average tariffs by 36 percent over 6 years, and developing countries by 24 percent over 10 years.

tertemporal decisions and therefore have no significant and permanent effects on current account balances. However, this result should be accompanied by the *caveat* that in alternative scenarios import tariffs may play some role as long as the additional tax revenue is used to reduce the government-debt-to-GDP ratio and the level of national savings in the economy where the tariff is imposed.

4.2 Selective trade policies: Long-term and dynamic effects of a hike in tariff rates against Emerging Asia

The next set of experiments consider both the comparative static and dynamic effects of imposing tariffs exclusively on imports from emerging Asia. In all cases the increase in tariff revenue is used to reduce the tax rate on labor income, as in Table 1.

The first three columns in Table 3 report the comparative-static effects under the assumption that these policies are implemented by each country bloc separately. The last column reports the results when all regions impose higher tariffs on imports from emerging Asia. The results of these simulations are similar to the previous findings in Table 1 above, but the orders of magnitudes are smaller as only imports from AS are now affected by the protectionist surge. Output, consumption and employment expand in the country that imposes the tariff. AS is worse off, more when the JE trading partners hike their tariffs (AS consumption falls by 1.6 percent) than when US does so (AS consumption falls by 1.1 percent). Again the main channel through which such beggar-thy-neighbor policies are effective is through a real appreciation in the country that imposes the tariff and a depreciation in the country that is subjected to the higher tariff.

There are also some interesting third country effects. In general, the real exchange also tends to depreciate in the two other countries that are not affected by the tariff hikes. For example, an increase in tariffs in the United States on imported goods from emerging Asia results in a depreciation of the real effective exchange rate not only in emerging Asia (1.4 percent), but also in the Japan-euro area bloc (0.2 percent) and the Remaining Countries bloc (0.2 percent). These third country effects can be significant in some cases, suggesting that other regions can lose — or possibly even benefit depending on their openness and trade patterns — when two regions engage in a trade war.

Moving now to a more detailed assessment of the short-run implications of trade protection against emerging Asia, Figures 6 to 9 report the dynamic effects of a generalized (US/JE/RC) 10 percent tariff hike against AS on GDP, consumption, investment, the trade balance and the current account balance (both as a percentage of GDP), the short-term interest rate, inflation and the real effective exchange rate in each country bloc. Besides the change in trade policies, the scenario is exactly as described in Section 3 above, and the time series charts are plotted as percentage deviations from the aforementioned baseline. The long-run endpoints of these charts are consistent with the last column of Table 3.

Emerging Asia experiences a large contraction in consumption, investment and GDP in both the short run and long run (Figure 6, second chart). The real effective exchange rate depreciates over time and is 4.5 percent higher in the long run (Figure 9, second chart). This results in both a trade and current account deficit (relative to baseline) that is over one percent of GDP in the short run (Figure 7, second chart). This effect is only temporary and disappears over time, as AS consumers do not adjust their saving behavior in response to changes in the relative prices affected by higher tariffs. As indicated earlier, if the tariff hike was used to reduce government debt, the non-Ricardian properties of the model would result in an increase in both national and world savings, thus a permanent increase in the current account balance for the country that imposed the tariff. However, these effects would be true for any tax or expenditure instrument and are not directly attributable to the change in one instrument or another; rather, they would be simply a consequence of the permanent change in the target level of government debt.

The responses in the other regions go in the opposite direction. These countries benefit from consumption and GDP increases both in the short and long run (Figure 6), and their real exchange rates appreciate (Figure 9). Trade policy is the main factor underlying price dynamics, as the countries that impose the tariff witness a positive inflationary impulse in the short run and short-term interest rates rise to bring inflation closer to desired levels (Figure 8). In emerging Asia, instead, inflation falls by over 3 percentage points below baseline in the short run. Underlying this result is the assumption that emerging Asia maintains a regime of limited exchange rate flexibility against the US currency, and consequently the depreciation in its real effective exchange rate can only be brought about by lower inflation and not the weakening of its nominal exchange rate.

In the protectionist countries there is a temporary improvement in both the trade and current account balances (Figure 7). Given their relevance for the ongoing rebalancing debate, these results are worth emphasizing in some detail. According to our projections, a generalized 10 percent hike against emerging Asia improves the US current account balance as a share of GDP by a mere 0.1 percentage point. The effect disappears after about two years, and in the absence of further adjustment in net saving, it may even revert sign. Similar effects hold in JE and the RC blocs. Even if one was willing to consider a world tariff hike three times as large as the one considered in our simulations (and a 30 percent hike certainly represents an upper bound under current circumstances), a surge in world protectionism would at best improve current accounts by half percentage points of GDP over a business-cycle horizon. This hardly sounds like the ultimate recipe to defuse global imbalances.

In Figures 10 to 13 we repeat the analysis above, except this time the tariff hike is assumed to take place exclusively in the US bloc. The tariff has a similar small and temporary positive effect on the US trade and current account balances (Figure 11), but what is more interesting is that it results in negative spillover effects on economic activity in the two 'bystander' regions (Japan, euro area and remaining countries) even though tariffs are only raised on imported goods from emerging Asia. Indeed, for more open economies such as the RC bloc these effects are significant on both consumption, investment and GDP (Figure 10, bottom chart).

The previous analysis focused on tariff hikes on imported goods from emerging Asia and showed that such policies are unlikely to be quantitatively successful in reducing current account imbalances on a sustainable basis. More importantly, because trade policies can only enhance welfare at the expense of the country against which the tariff hike is being levied, such policies are likely to result in retaliation and protectionist escalades. To quantify this point, we consider the long-term effects of tariffs being imposed on imported goods from the United States — see Table 4. As expected the real exchange rate depreciates in the United States and appreciates in the countries that are imposing the tariffs. This results in a permanent reduction in US consumer welfare, consumption and GDP. Interestingly, there are also significant third-country effects. For example, when the Remaining Countries bloc imposes a tariff on imports from the United States, this has significant negative spillover effects on emerging Asia.

4.3 A globalization backlash: Long-term effects of a reversal of competition-friendly policies

Among the purported benefits of the process of globalization is the increase in competition and the resulting reduction of markups in both product and labor markets worldwide. An important risk going forward is that protectionist policies induced by trade imbalances could reverse this trend and result in higher market power in import-competing sectors. This is a different but related protectionist threat relative to the ones considered above, whose quantitative relevance needs to be assessed in the context of our analysis. This can be motivated by the recognition that often times protectionist measures do not take the explicit form of (say) *ad valorem* tariffs but less transparent or even hidden non-tariff barriers (NTBs). By erecting such trade barriers or frictions, these insular policies can effectively reduce market access and, thus, the degree of competition in the marketplace. Although there is less agreement on how this should be precisely modeled, a reasonable formulation pursued here is via a reversal of competition-friendly policies.[30]

Extending previous work in this area, in this section we take wage and price markups as proxies for the degree of competition in domestic labor and product markets, and consider the implications of changes in markups and their spillover effects to other regions of the world.[31] In particular, we consider a scenario in which a 'globalization backlash' leads to a moderate increase in markups by 5 percentage points in the tradables sector T (Table 5). We compare these results with similar scenarios leading to changes in markups in the nontradables sectors N (Table 6) as well as in the market for labor (Table 7).

The key message is that in every case there are fairly large real income and consumption losses (mirrored in consumer welfare, particularly for the liquidity-constrained consumers), and in most cases significant negative spillover effects to the rest of the world. Consider first Table 5. A markup increase in the US tradables sector (first column) reduces welfare by 0.9 percent for forward-looking consumers, and 3.5 percent for liquidity-constrained consumers in the United States (and a reduction between 0.1 percent and 0.3 percent for both types of consumers in the rest of the world). Furthermore, there are reductions in US output by 1.3 percent and US consumption by 1 percent, causing output losses between 0.1 and 0.2 percent in the other regions. The negative spillover effects are even larger when the increase in markups occurs in the Japan and euro area bloc (third column) or the Remaining Countries bloc (fourth column). The reduction in purchasing power associated with higher markups can result in a fall in consumption by as much as 0.5 percent in regions such as emerging Asia. A generalized 5 percent increase in price markups worldwide (last column) reduces AS output by more than 3 percent, JE output by 2.2 percent and US output by 1.7 percent.

Higher markups in the nontradables and labor markets may have even larger domestic effects, but not surprisingly the negative spillover effects tend to be smaller than when the increases occur in the markets for tradable goods and services. For example, a 5 percent increase in markups in the tradables sector of the United States (Table 5, first column) reduces its consumption by 1.0 percent, but also results in a reduction in consumption of

[30] Unlike the case of tariffs, treatment of NTBs has been hampered by a lack of common methodological approaches to evaluate them, both conceptually and empirically. See UNCTAD (2005) for a list of possible NTBs and a review of the issues surrounding their scope, identification, classification, and impact.

[31] Bayoumi, Laxton, and Pesenti (2005) use a simpler but similar model to study the effects of competition-friendly reforms in the euro area. The most relevant difference with respect to their approach is that our model encompasses a nontradables sector.

0.3 percent in both emerging Asia and the Remaining Countries blocs. When the same increase materializes in the nontradables sector (Table 6, first column), it results in a 1.5 percent reduction in consumption in the United States, a 0.1 percent fall in emerging Asia and no significant effects in the other regions. When the increase occurs in the US labor market (Table 7, first column), US consumption falls by 1.5 percent and by 0.1 percent everywhere else in the global economy.

The long-term effects on the current account balance are insignificant, for precisely the same reason why they were not significant in the case of a hike in tariffs, as such changes do not result in a shift in desired saving behavior. However, changes in markups can have significant short-term effects on the current account balance as consumption and investment take time to adjust to their new equilibrium levels.

The long-term effects on the real exchange rate can be quite significant, with responses similar to the ones associated with sector-specific shocks to productivity. In all cases a positive shock to the markup results in a depreciation of the country's real exchange rate when the shock is in the tradables sector, and an appreciation when the shock is in the nontradables sector. This is consistent with the standard Balassa-Samuelson effects in multi-sector open economy models.

5 Conclusion

While the apparent ability of the global economy to finance large global imbalances may comfort some, rising protectionism — in response to years of persistent and widening external imbalances — is a clear and present danger. The temptation for countries to resort to beggar-thy-neighbor policies to remedy protracted current account deficits through trade and commercial policies — including hiking import tariffs or their equivalent trade barriers — is understandable, but short-sighted.

The scenario analysis in this paper shows that a country acting unilaterally may stand to gain through improving its terms of trade, at the expense of others, as the optimal tariff literature would suggest. This is true with either uniform or discriminating tariff increases. But the trade balance improvements are short-lived (given public and external indebtedness), and the prospect of trade retaliation underscores the potentially deleterious consequences for the overall global economy.

According to our projections, a generalized 10 percent hike against emerging Asia improves the US current account balance as a share of GDP by a mere 0.1 percentage point. The effect disappears after about two years, and in the absence of further adjustment in net saving, it may even revert sign. Similar effects hold in the rest of the world. Moreover, there are unintended third-country effects on 'bystander' countries, opening the likely possibility that any such actions would be matched by countervailing trade policy actions in partner countries, undermining the initial gains and leaving the world worse off than before. And the world contraction would be even more substantial if protectionist pressures took the form of a backlash against competition-friendly reforms in import-competing sectors. At the end of the day, a protectionist surge would lower global growth leaving global imbalances unresolved.

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Figure 1: The Structure of the Model

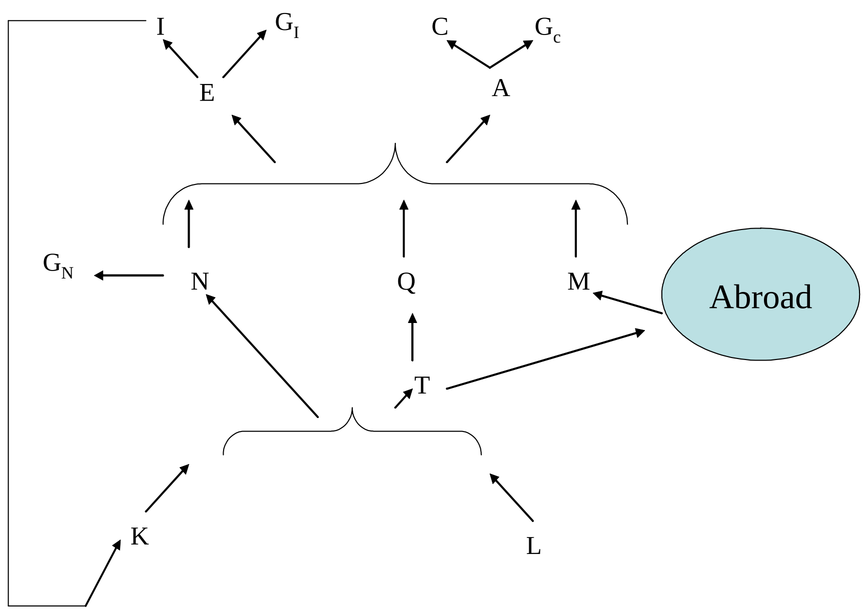

Figure 2: International Trade Linkages (steady-state calibration; percent of world GDP)

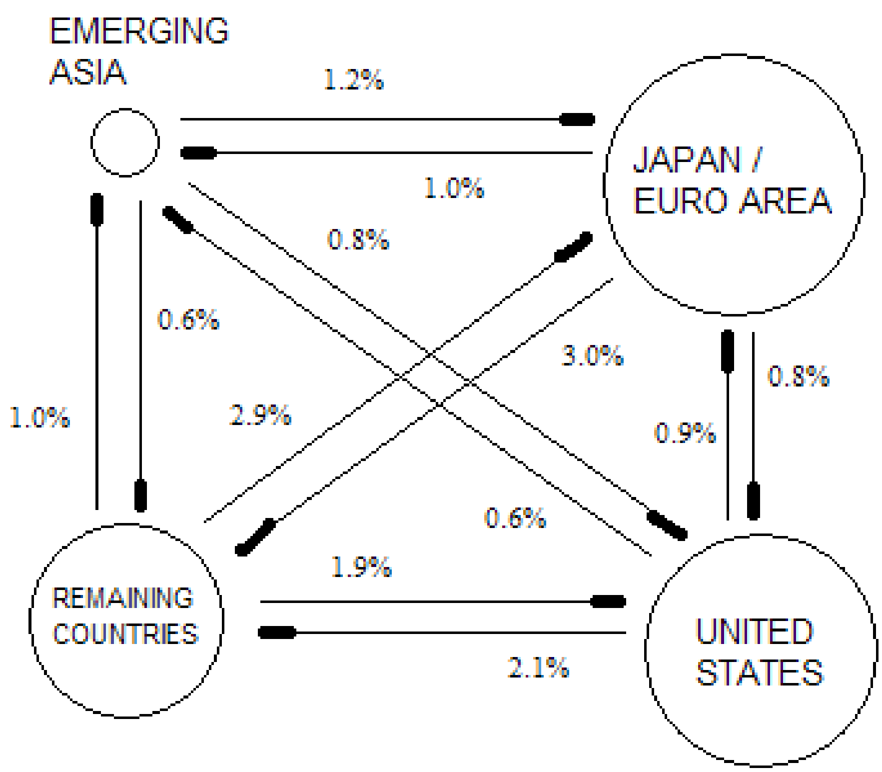

Figure 3: The Baseline Scenario - United States

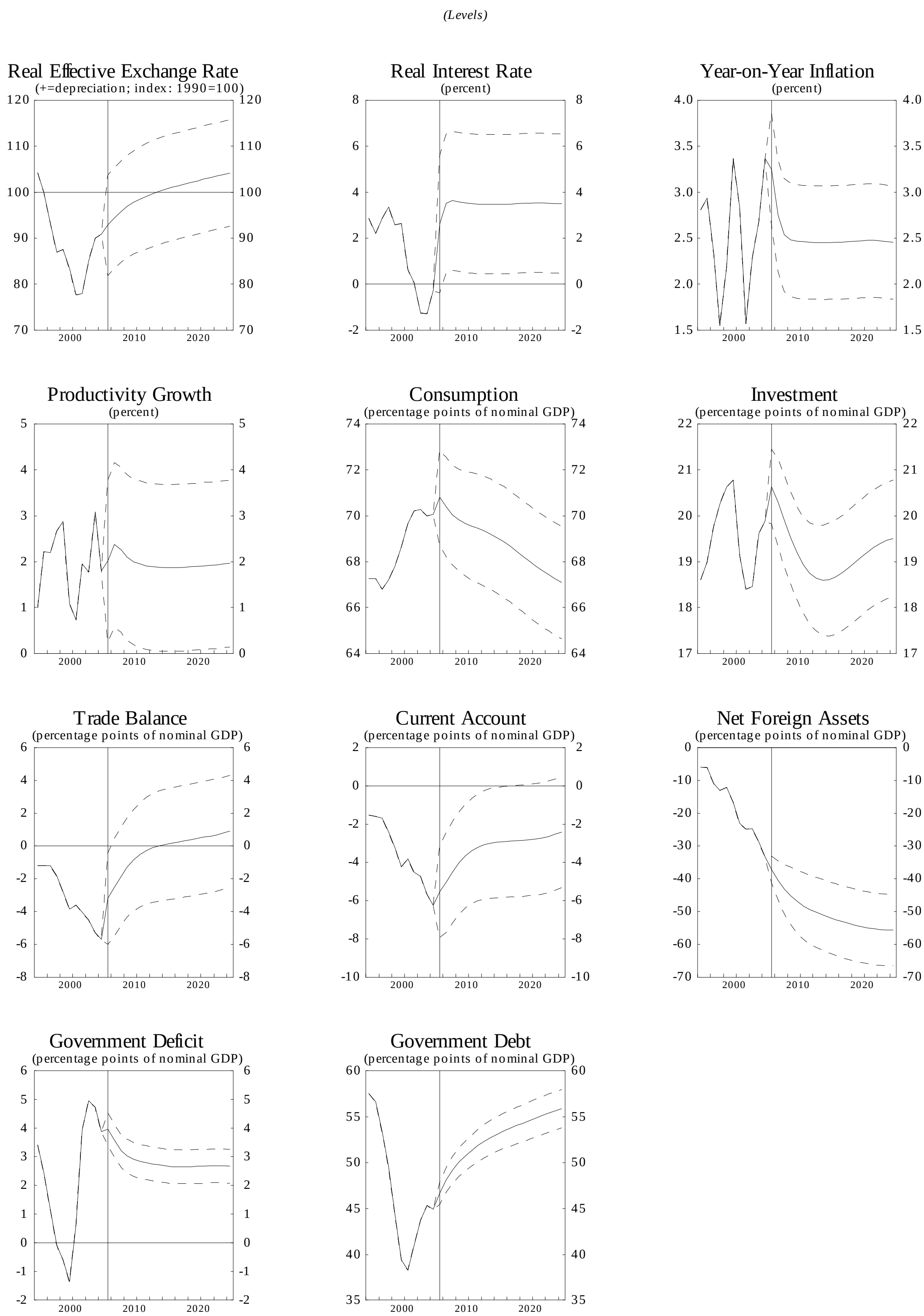

Figure 4: The Baseline Scenario - Emerging Asia

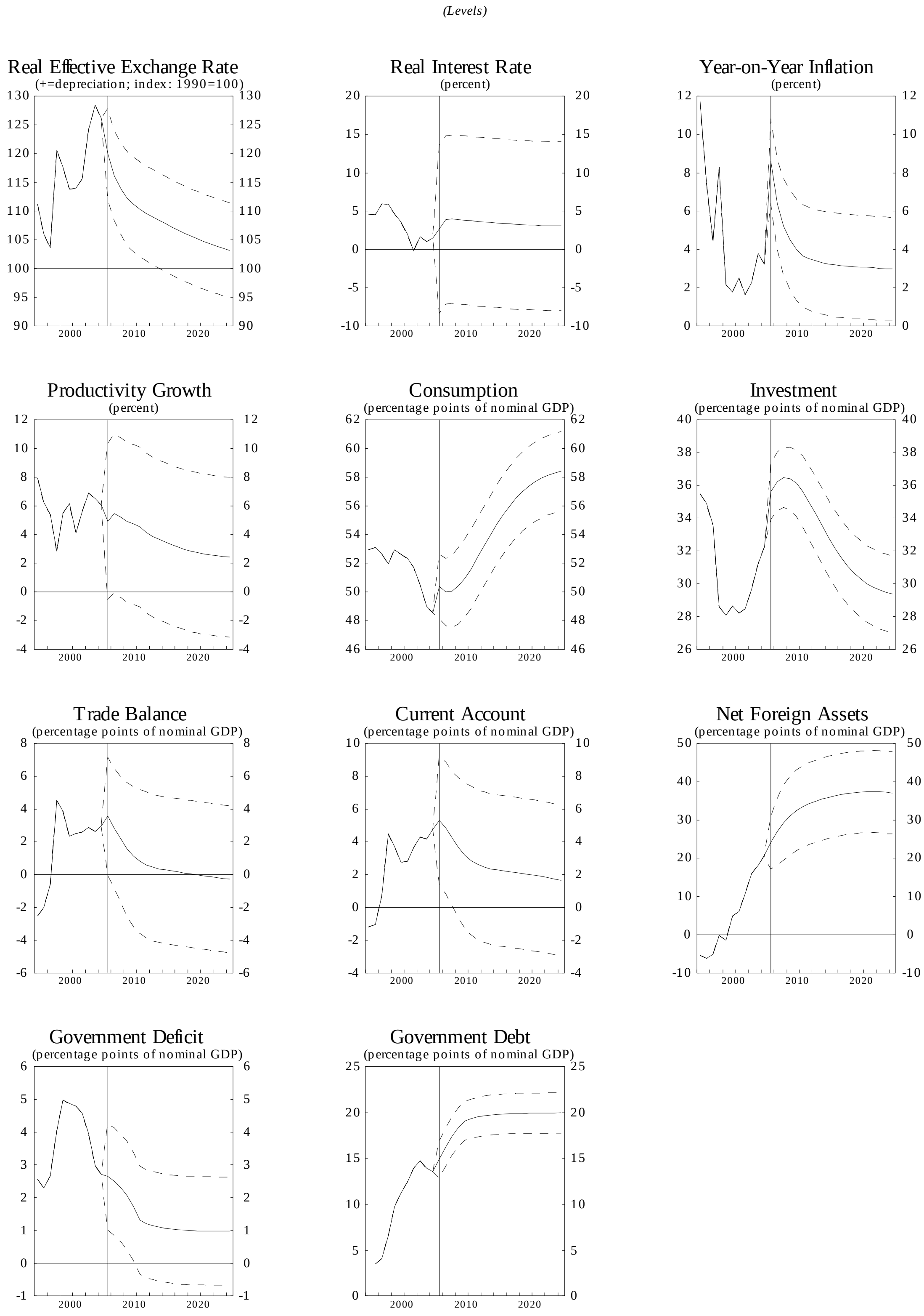

Figure 5: The Baseline Scenario - Japan and the Euro Area

(Levels)

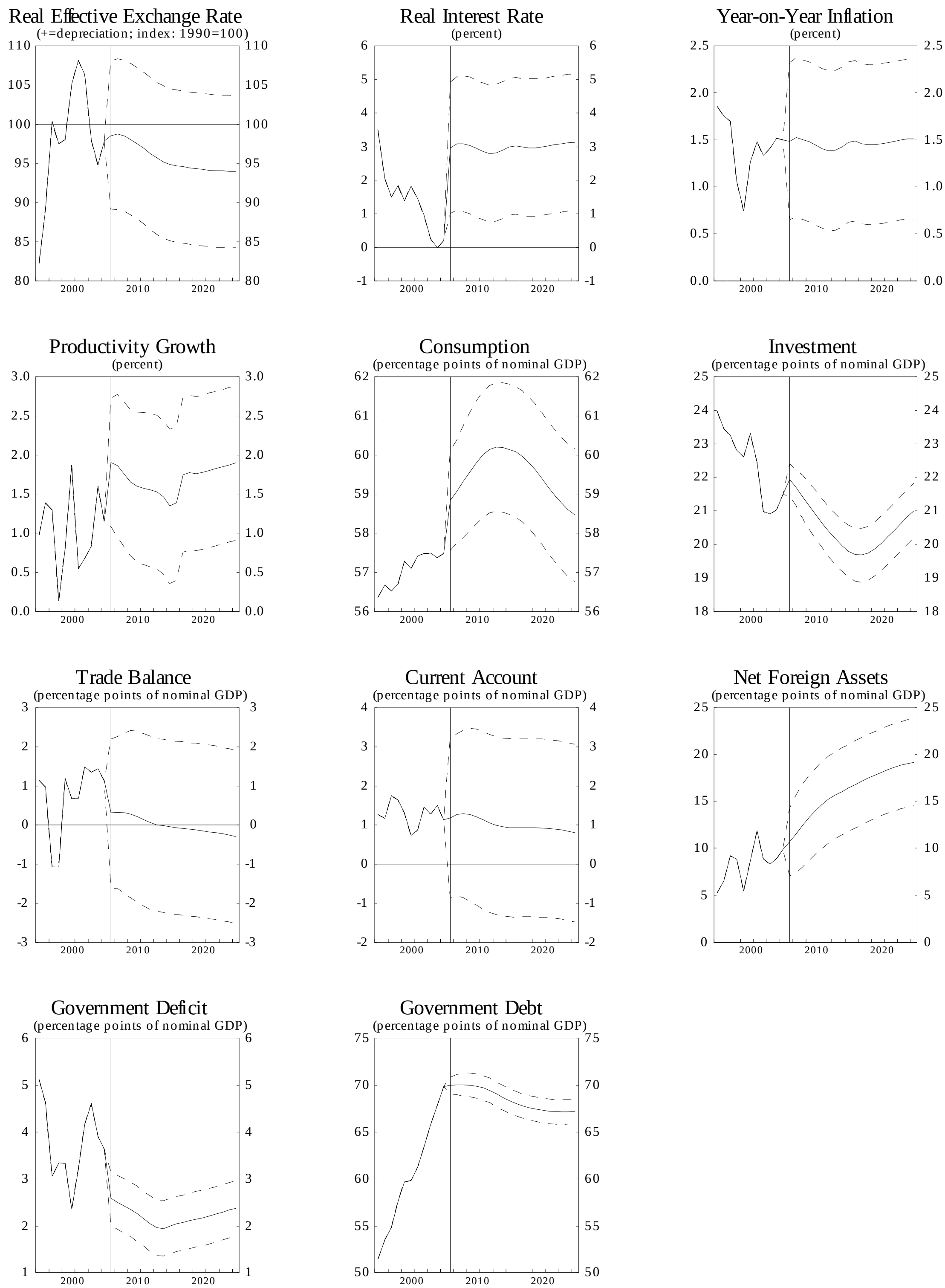

Figure 6: All Regions Impose Tariffs on Emerging Asia

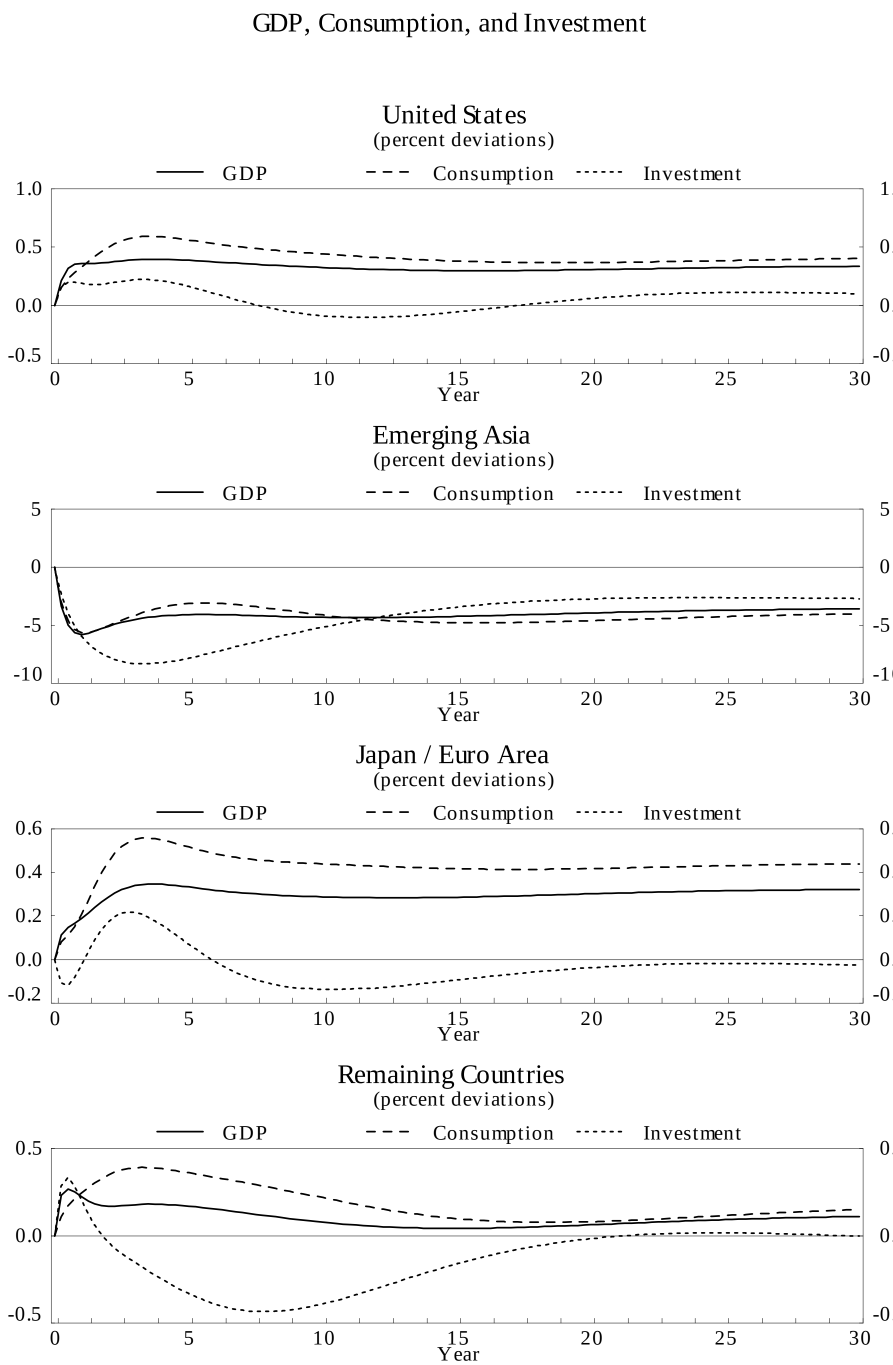

Figure 7: All Regions Impose Tariffs on Emerging Asia

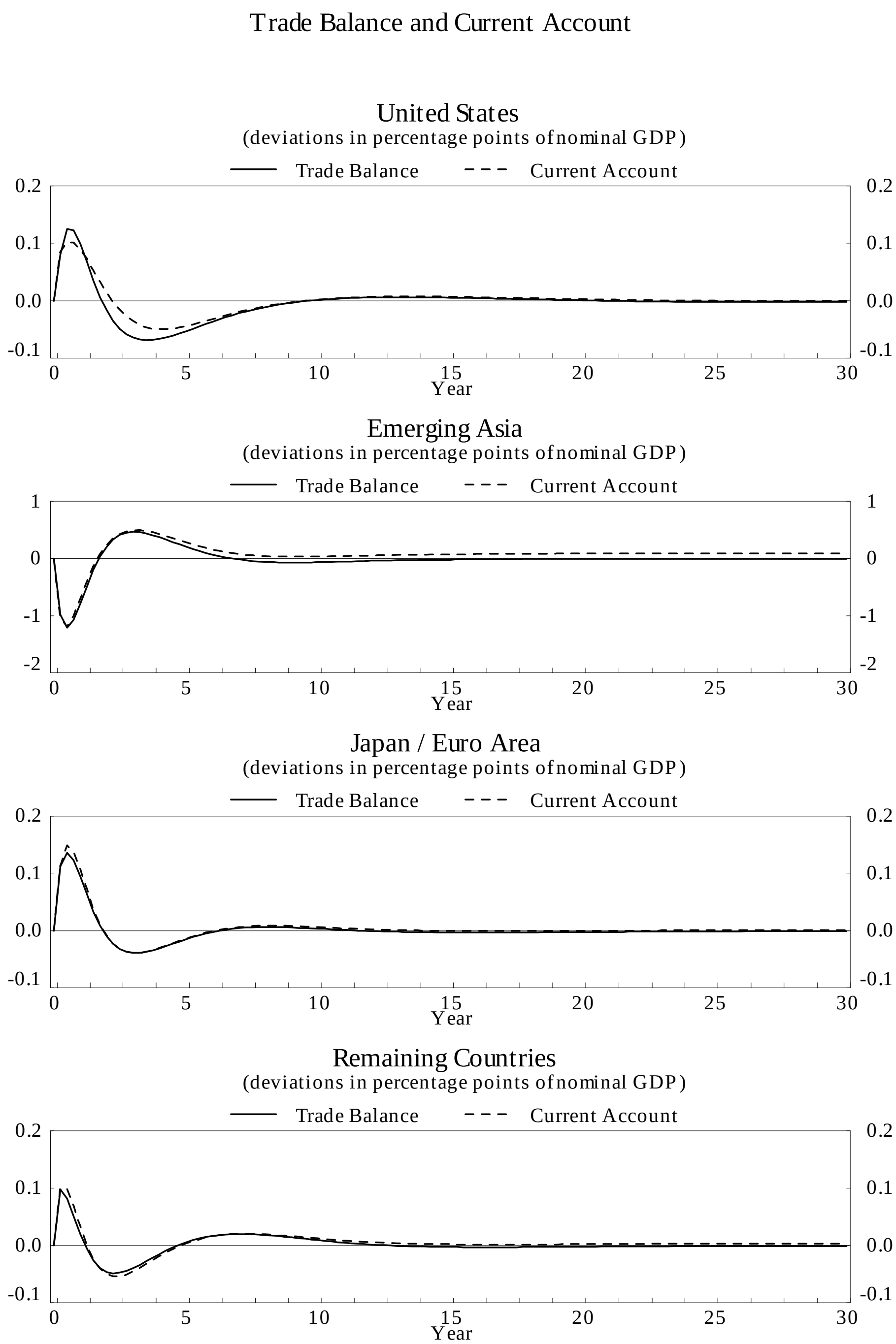

Figure 8: All Regions Impose Tariffs on Emerging Asia

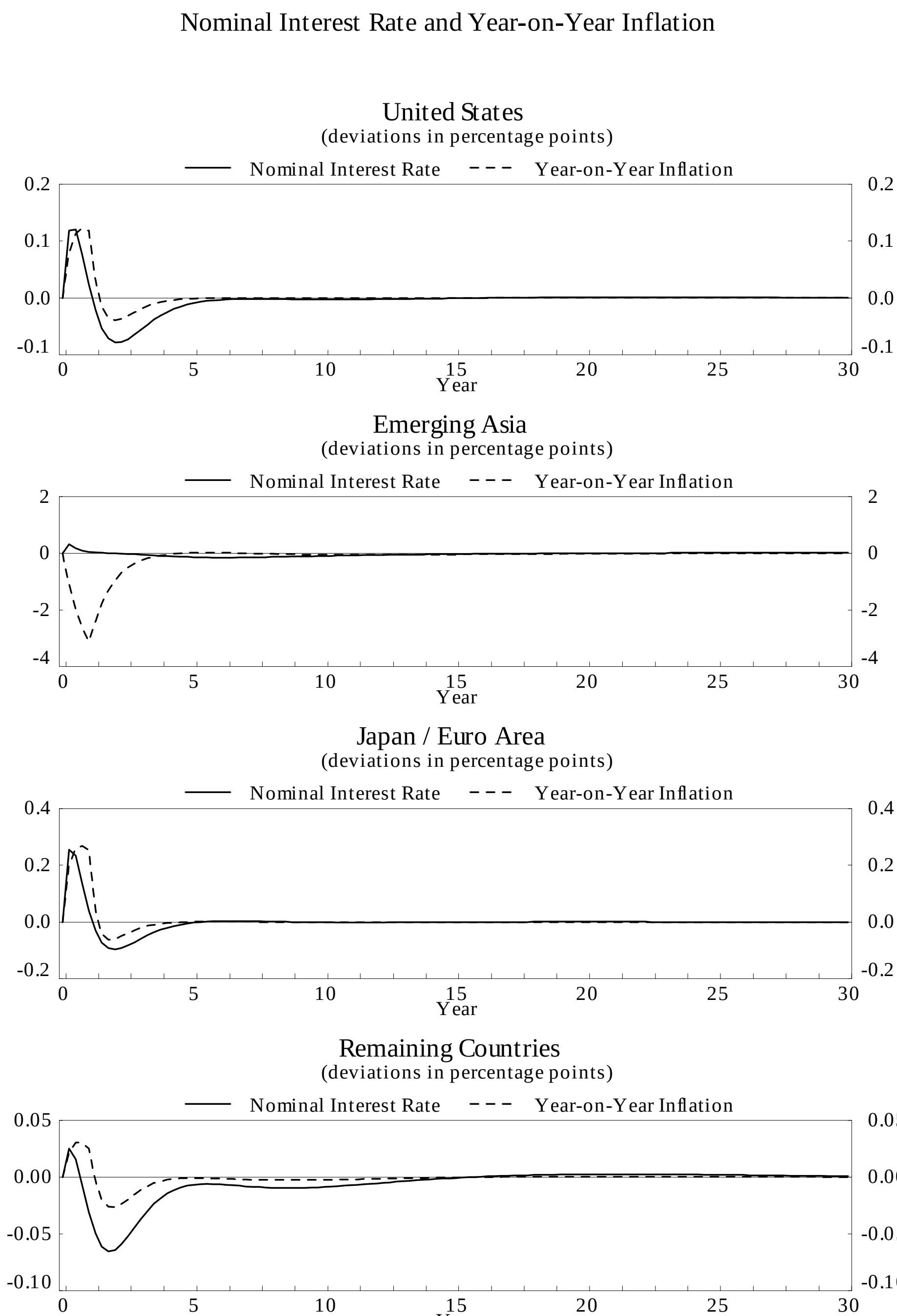

Figure 9: All Regions Impose Tariffs on Emerging Asia

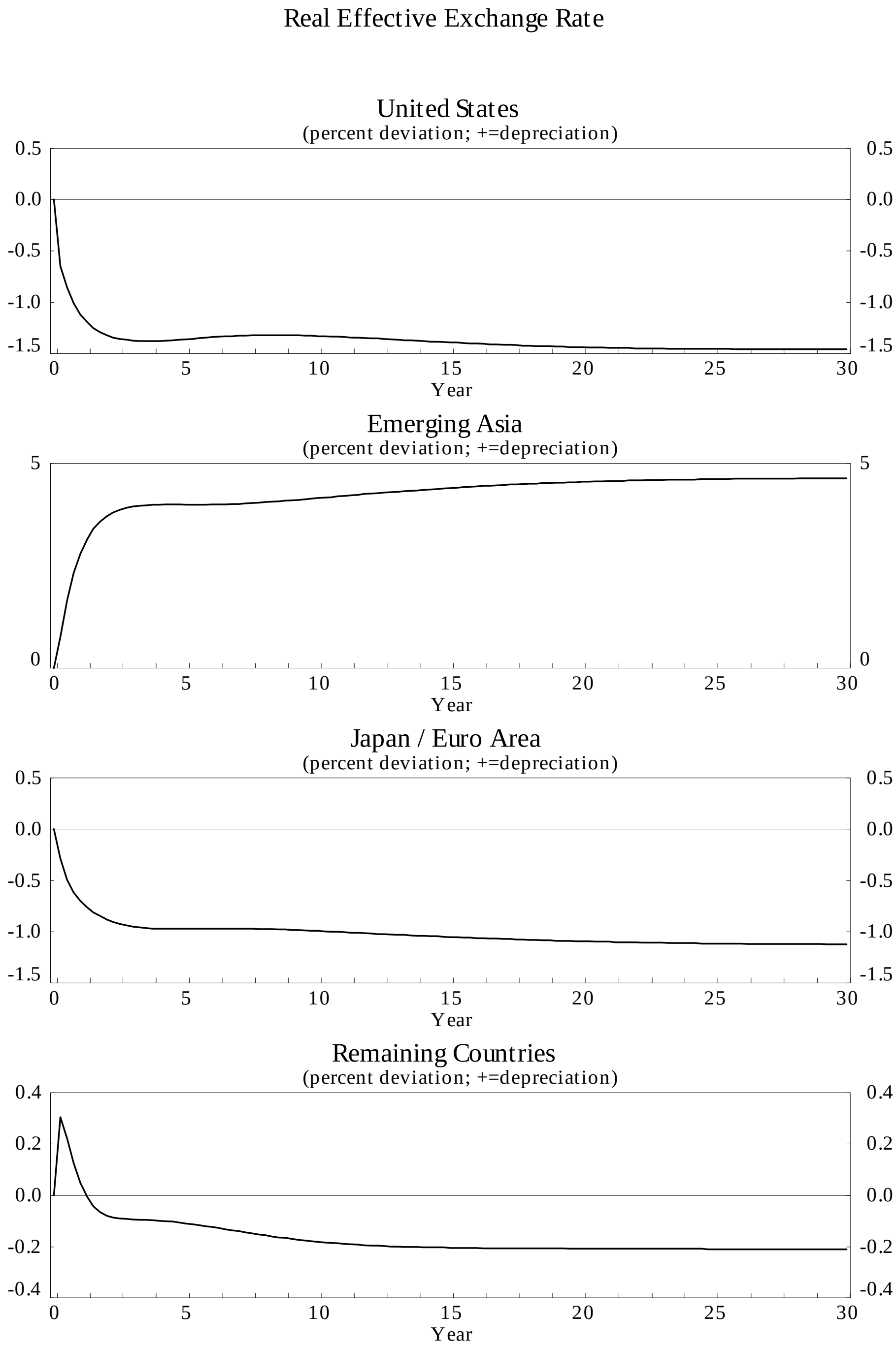

Figure 10: United States Imposes Tariffs on Emerging Asia

GDP, Consumption, and Investment

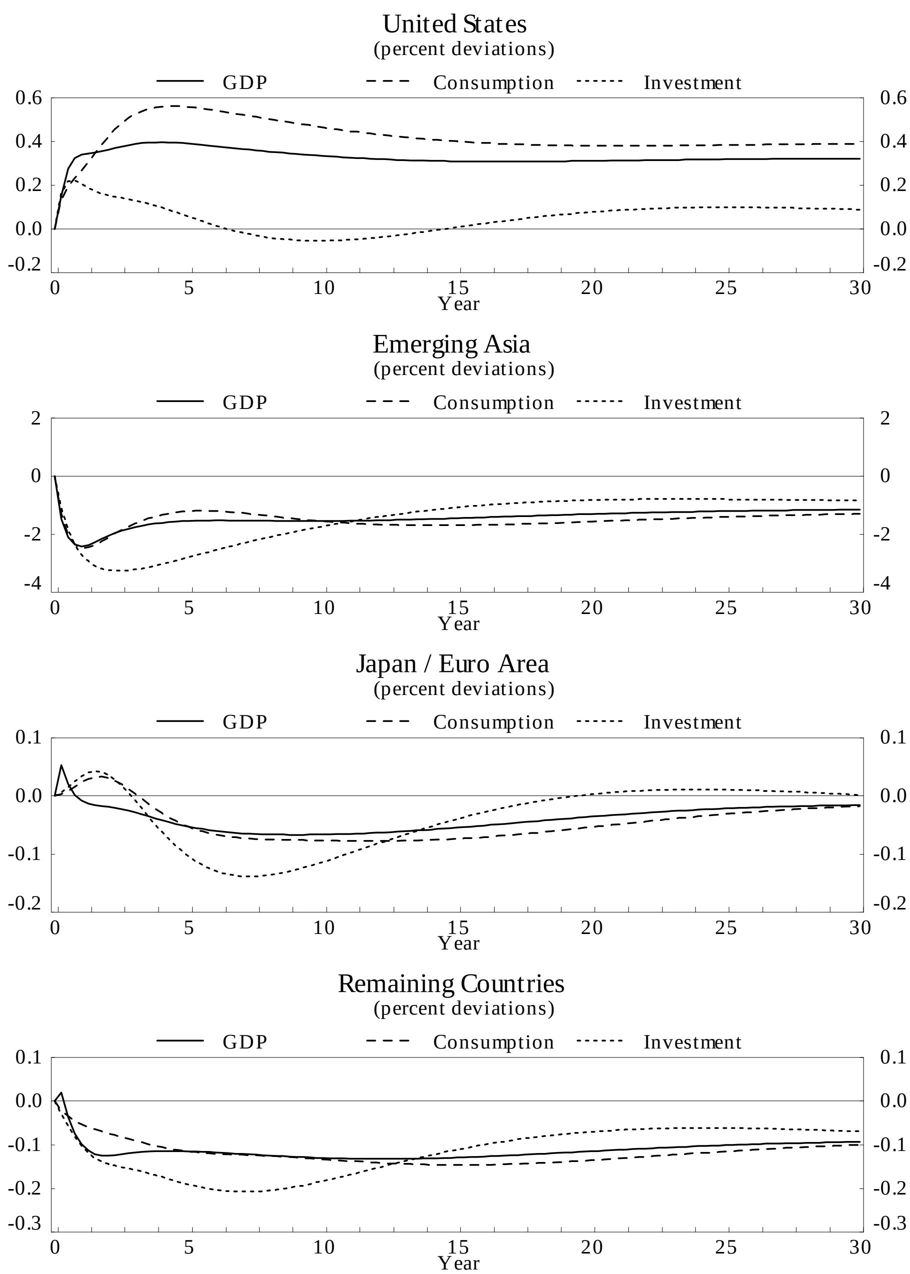

Figure 11: United States Imposes Tariffs on Emerging Asia

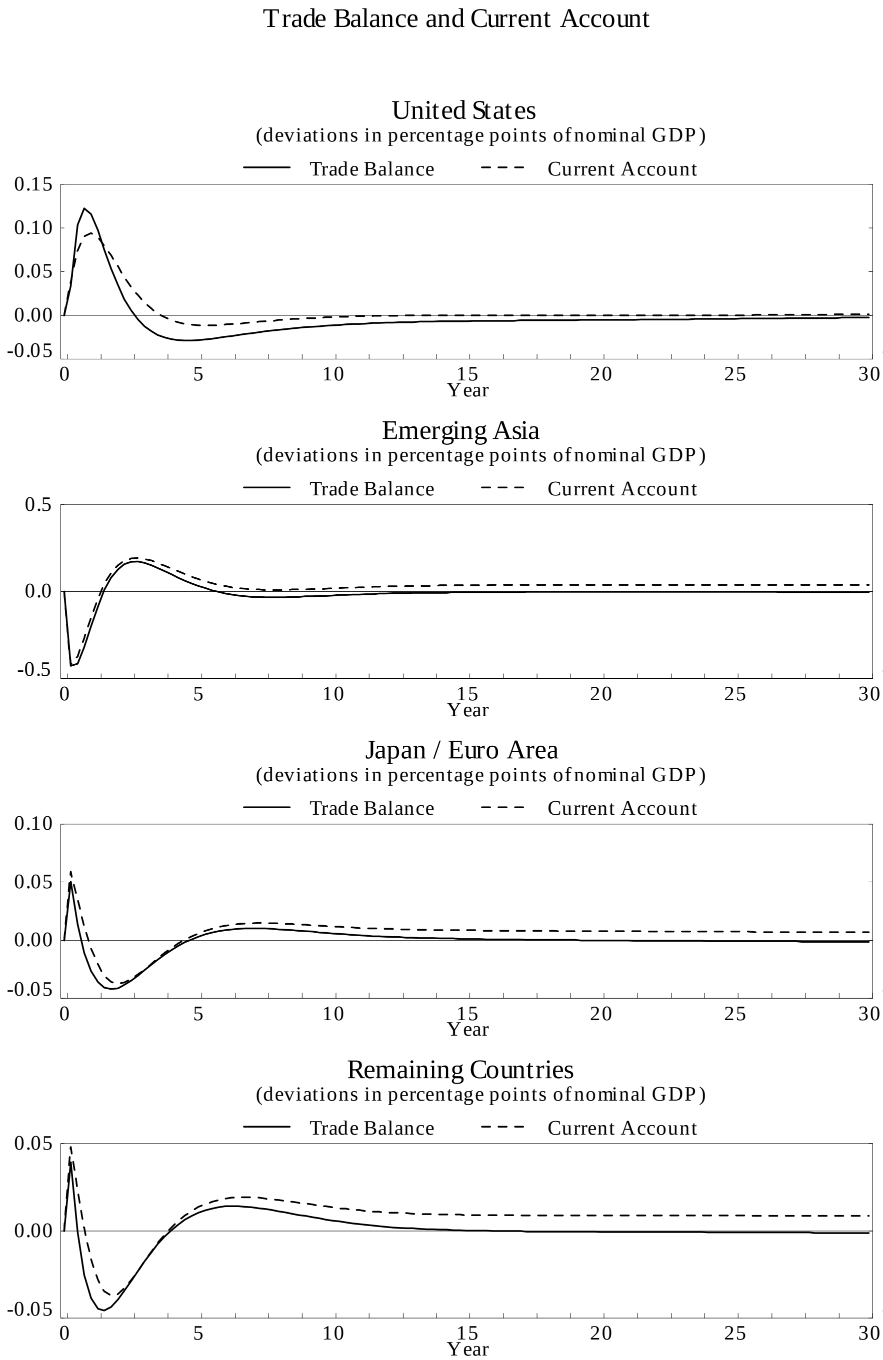

Figure 12: United States Imposes Tariffs on Emerging Asia

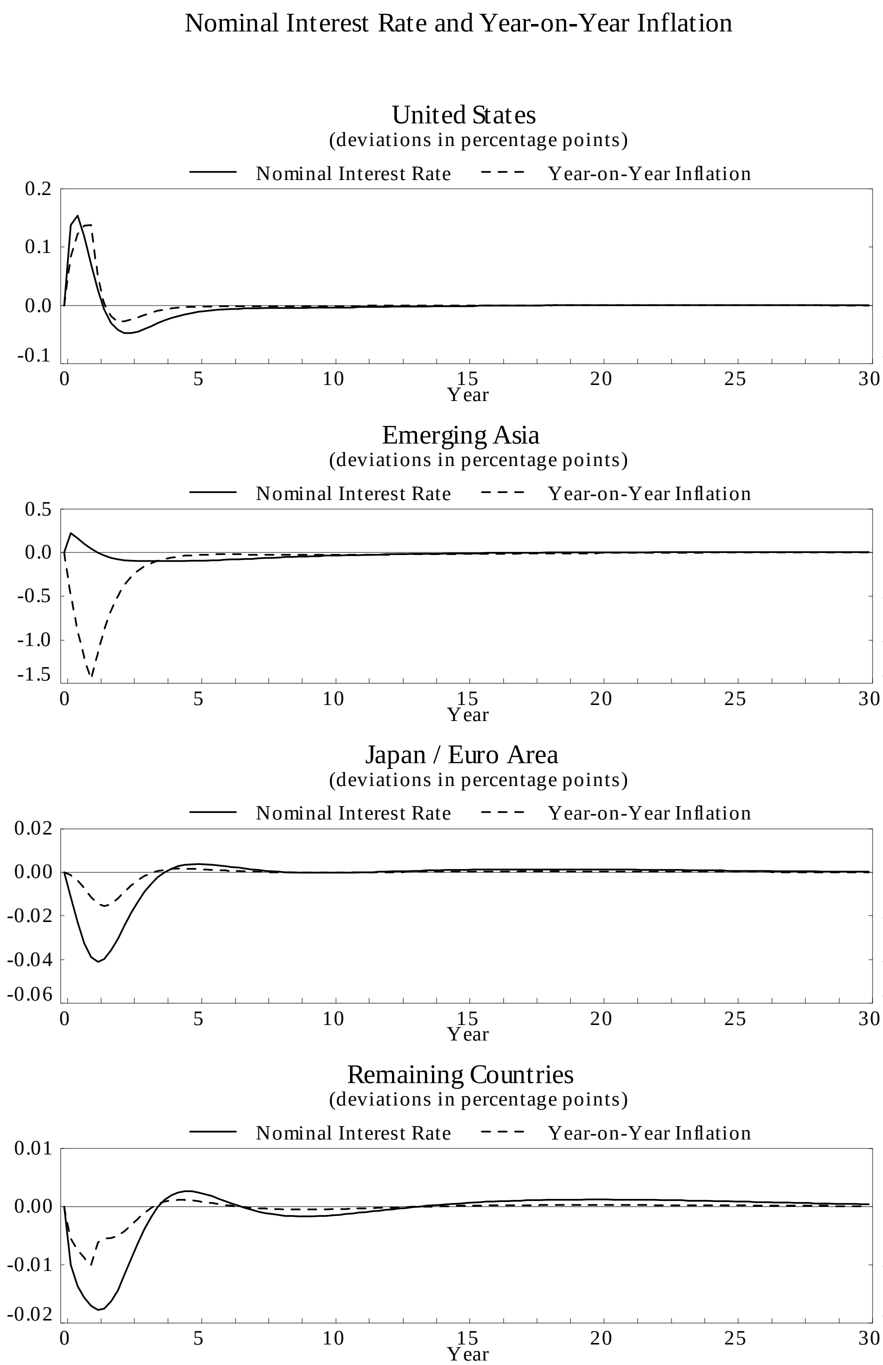

Figure 13: United States Imposes Tariffs on Emerging Asia

Real Effective Exchange Rate

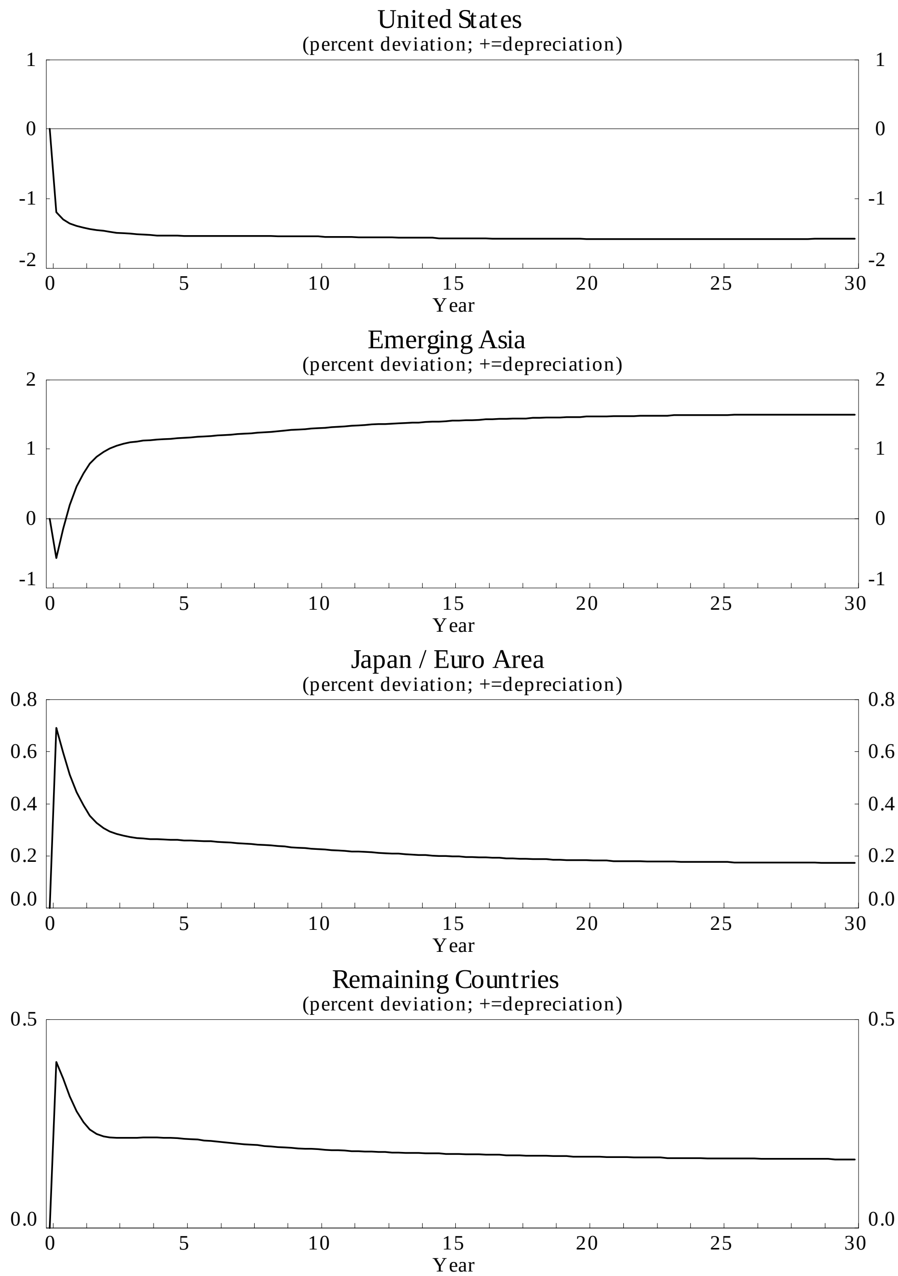

Table 1: Effects of a 10 Percentage Point Hike in Tariff Rates
(Additional Revenue Used to Reduce Labor Tax Rates)

	Effects of Tariff Hikes in:				
	US	AS	JE	RC	ALL
United States (US):					
Real GDP	**1.1**	-0.3	-0.4	-0.6	**-0.2**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	**1.4**	-0.3	-0.4	-0.7	**-0.1**
Liquidity-constrained Consumers	**1.9**	-0.3	-0.4	-0.7	**0.4**
Consumption	**1.4**	-0.3	-0.4	-0.7	**-0.1**
Investment	**0.0**	-0.2	-0.3	-0.5	**-0.9**
Labor Effort	**0.5**	-0.1	-0.1	-0.2	**0.1**
Real Effective Exchange Rate	**-6.3**	1.4	2.0	3.2	**-0.0**
Tariffs/GDP	**1.0**	0.0	0.0	0.0	**1.0**
Current Account/GDP	**0.0**	-0.0	-0.0	-0.0	**0.0**
Emerging Asia (AS):					
Real GDP	-1.0	**2.4**	-1.3	-1.1	**-1.1**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	-1.0	**3.1**	-1.3	-1.2	**-0.6**
Liquidity-constrained Consumers	-1.1	**4.8**	-1.4	-1.3	**0.7**
Consumption	-1.1	**3.4**	-1.4	-1.2	**-0.4**
Investment	-0.7	**0.0**	-1.0	-0.8	**-2.5**
Labor Effort	-0.3	**1.3**	-0.4	-0.4	**0.2**
Real Effective Exchange Rate	1.6	**-6.4**	2.1	2.1	**-0.8**
Tariffs/GDP	0.0	**2.4**	0.0	0.0	**2.3**
Current Account/GDP	0.1	**-0.1**	0.0	0.0	**0.0**
Japan/Euro Area (JE):					
Real GDP	-0.4	-0.5	**1.2**	-1.4	**-1.1**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	-0.5	-0.5	**1.6**	-1.4	**-0.8**
Liquidity-constrained Consumers	-0.5	-0.5	**3.0**	-1.4	**0.5**
Consumption	-0.5	-0.5	**1.7**	-1.4	**-0.8**
Investment	-0.3	-0.4	**-0.3**	-1.3	**-2.3**
Labor Effort	-0.1	-0.1	**0.8**	-0.4	**0.1**
Real Effective Exchange Rate	1.6	1.5	**-5.3**	4.0	**1.4**
Tariffs/GDP	0.0	0.0	**1.3**	0.0	**1.2**
Current Account/GDP	0.0	0.0	**-0.0**	0.0	**0.0**
Remaining Countries (RC):					
Real GDP	-1.1	-0.3	-1.2	**2.2**	**-0.5**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	-1.1	-0.4	-1.3	**2.8**	**-0.1**
Liquidity-constrained Consumers	-1.2	-0.4	-1.3	**4.2**	**1.1**
Consumption	-1.1	-0.4	-1.3	**2.9**	**-0.1**
Investment	-0.8	-0.2	-0.9	**0.2**	**-1.7**
Labor Effort	-0.3	-0.1	-0.4	**1.2**	**0.3**
Real Effective Exchange Rate	2.0	0.8	2.6	**-6.0**	**-0.8**
Tariffs/GDP	0.0	0.0	0.0	**2.0**	**1.9**
Current Account/GDP	0.0	0.0	0.0	**-0.0**	**0.0**
Memo Item:					
Baseline Import Share	12.1	26.2	15.8	24.3	

Table 2: Effects of a 10 Percentage Point Hike in Tariff Rates
(Additional Revenue Used to Increase Government Absorption)

	Effects of Tariff Hikes in:				
	US	AS	JE	RC	ALL
United States (US):					
Real GDP	**0.3**	-0.3	-0.4	-0.7	**-1.2**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	**-0.9**	-0.3	-0.4	-0.8	**-2.4**
Liquidity-constrained Consumers	**-1.2**	-0.4	-0.4	-0.8	**-2.7**
Consumption	**-1.0**	-0.3	-0.4	-0.8	**-2.4**
Investment	**-0.8**	-0.2	-0.3	-0.6	**-1.8**
Labor Effort	**-0.3**	-0.1	-0.1	-0.2	**-0.8**
Real Effective Exchange Rate	**-6.5**	1.5	2.2	3.5	**0.3**
Tariffs/GDP	**1.0**	0.0	0.0	0.0	**1.0**
Current Account/GDP	**0.0**	-0.0	-0.0	-0.0	**0.0**
Emerging Asia (AS):					
Real GDP	-1.0	**0.5**	-1.4	-1.2	**-3.2**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	-1.1	**-2.3**	-1.5	-1.3	**-6.1**
Liquidity-constrained Consumers	-1.2	**-2.9**	-1.6	-1.4	**-6.8**
Consumption	-1.1	**-2.4**	-1.5	-1.4	**-6.2**
Investment	-0.8	**-1.9**	-1.2	-0.9	**-4.6**
Labor Effort	-0.3	**-0.8**	-0.5	-0.4	**-2.0**
Real Effective Exchange Rate	1.7	**-7.1**	2.3	2.3	**-1.0**
Tariffs/GDP	0.0	**2.4**	0.0	0.0	**2.3**
Current Account/GDP	0.1	**-0.1**	0.0	0.0	**0.0**
Japan/Euro Area (JE):					
Real GDP	-0.5	-0.6	**-0.2**	-1.6	**-2.8**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	-0.5	-0.6	**-2.0**	-1.6	**-4.5**
Liquidity-constrained Consumers	-0.5	-0.6	**-2.7**	-1.5	**-5.2**
Consumption	-0.5	-0.6	**-2.0**	-1.6	**-4.5**
Investment	-0.4	-0.5	**-1.7**	-1.4	**-3.9**
Labor Effort	-0.1	-0.2	**-0.8**	-0.4	**-1.5**
Real Effective Exchange Rate	1.6	1.6	**-5.9**	4.4	**1.5**
Tariffs/GDP	0.0	0.0	**1.3**	0.0	**1.2**
Current Account/GDP	0.0	0.0	**-0.0**	0.0	**0.0**
Remaining Countries (RC):					
Real GDP	-1.1	-0.4	-1.4	**0.5**	**-2.4**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	-1.2	-0.4	-1.5	**-2.0**	**-5.0**
Liquidity-constrained Consumers	-1.2	-0.4	-1.6	**-2.7**	**-5.7**
Consumption	-1.2	-0.4	-1.5	**-2.0**	**-5.0**
Investment	-0.8	-0.2	-1.1	**-1.6**	**-3.6**
Labor Effort	-0.4	-0.1	-0.4	**-0.8**	**-1.7**
Real Effective Exchange Rate	2.1	0.9	2.9	**-6.6**	**-1.0**
Tariffs/GDP	0.0	0.0	0.0	**2.0**	**1.9**
Current Account/GDP	0.0	0.0	0.0	**-0.0**	**0.0**
Memo Item:					
Baseline Import Share	12.1	26.2	15.8	24.3	

Table 3: Effects of a 10 Percentage Point Hike in Tariff Rates on Import Goods from Emerging Asia
(Additional Revenue Used to Reduce Labor Tax Rates)

	Effects of Tariff Hikes in:			
	US	JE	RC	ALL
United States (US):				
Real GDP	**0.3**	0.0	0.0	**0.3**
Welfare (Consumption Equiv.)				
Forward-looking Consumers	**0.3**	0.0	0.0	**0.3**
Liquidity-constrained Consumers	**0.4**	0.0	0.0	**0.5**
Consumption	**0.3**	0.0	0.0	**0.4**
Investment	**0.1**	-0.0	0.0	**0.1**
Labor Effort	**0.1**	0.0	0.0	**0.1**
Real Effective Exchange Rate	**-1.5**	0.2	-0.0	**-1.4**
Tariffs/GDP	**0.2**	0.0	0.0	**0.2**
Current Account/GDP	**0.0**	-0.0	-0.0	**0.0**
Emerging Asia (AS):				
Real GDP	-1.1	-1.4	-0.8	-3.3
Welfare (Consumption Equiv.)				
Forward-looking Consumers	-1.1	-1.6	-0.8	-3.5
Liquidity-constrained Consumers	-1.2	-1.6	-0.9	-3.7
Consumption	-1.1	-1.6	-0.8	-3.6
Investment	-0.8	-1.2	-0.6	-2.6
Labor Effort	-0.3	-0.5	-0.2	-1.1
Real Effective Exchange Rate	1.4	2.0	1.0	4.5
Tariffs/GDP	0.0	0.0	0.0	0.0
Current Account/GDP	0.0	0.0	0.0	0.1
Japan/Euro Area (JE):				
Real GDP	-0.0	**0.3**	-0.0	**0.3**
Welfare (Consumption Equiv.)				
Forward-looking Consumers	-0.0	**0.4**	-0.0	**0.4**
Liquidity-constrained Consumers	-0.0	**0.7**	-0.0	**0.7**
Consumption	-0.0	**0.4**	-0.0	**0.4**
Investment	-0.0	**-0.0**	-0.0	**-0.1**
Labor Effort	-0.0	**0.2**	-0.0	**0.2**
Real Effective Exchange Rate	0.2	**-1.2**	0.1	**-1.1**
Tariffs/GDP	0.0	**0.3**	0.0	**0.3**
Current Account/GDP	0.0	**-0.0**	0.0	**0.0**
Remaining Countries (RC):				
Real GDP	-0.1	-0.0	**0.2**	**0.1**
Welfare (Consumption Equiv.)				
Forward-looking Consumers	-0.1	-0.0	**0.2**	**0.1**
Liquidity-constrained Consumers	-0.1	0.0	**0.3**	**0.2**
Consumption	-0.1	0.0	**0.2**	**0.1**
Investment	-0.1	-0.0	**0.1**	**-0.0**
Labor Effort	-0.0	0.0	**0.1**	**0.1**
Real Effective Exchange Rate	0.2	0.1	**-0.5**	**-0.2**
Tariffs/GDP	0.0	0.0	**0.2**	**0.2**
Current Account/GDP	0.0	-0.0	**-0.0**	**0.0**
Memo Item:				
Baseline Import Share from Emerging Asia	2.7	3.3	2.2	

Table 4: Effects of a 10 Percentage Point Hike in Tariff Rates on Import Goods from United States

(Additional Revenue Used to Reduce Labor Tax Rates)

	Effects of Tariff Hikes in:			
	AS	JE	RC	ALL
United States (US):				
Real GDP	-0.2	-0.3	-0.7	-1.3
Welfare (Consumption Equiv.)				
Forward-looking Consumers	-0.2	-0.4	-0.8	-1.4
Liquidity-constrained Consumers	-0.2	-0.4	-0.8	-1.4
Consumption	-0.2	-0.4	-0.8	-1.4
Investment	-0.2	-0.2	-0.5	-1.0
Labor Effort	-0.1	-0.1	-0.2	-0.4
Real Effective Exchange Rate	0.9	1.3	3.0	5.4
Current Account/GDP	-0.0	-0.0	-0.0	-0.0
Emerging Asia (AS):				
Real GDP	**0.5**	-0.1	-0.2	**0.2**
Welfare (Consumption Equiv.)				
Forward-looking Consumers	**0.6**	-0.1	-0.2	**0.3**
Liquidity-constrained Consumers	**1.0**	-0.1	-0.2	**0.6**
Consumption	**0.7**	-0.1	-0.2	**0.3**
Investment	**0.0**	-0.1	-0.2	**-0.3**
Labor Effort	**0.3**	-0.0	-0.1	**0.2**
Real Effective Exchange Rate	**-1.3**	0.2	0.5	**-0.8**
Current Account/GDP	**-0.0**	-0.0	-0.0	**-0.1**
Japan/Euro Area (JE):				
Real GDP	-0.0	**0.3**	-0.0	**0.3**
Welfare (Consumption Equiv.)				
Forward-looking Consumers	-0.0	**0.3**	-0.0	**0.3**
Liquidity-constrained Consumers	-0.0	**0.5**	0.0	**0.6**
Consumption	-0.0	**0.3**	-0.0	**0.3**
Investment	-0.0	**0.1**	-0.0	**0.0**
Labor Effort	-0.0	**0.2**	0.0	**0.2**
Real Effective Exchange Rate	0.0	**-1.1**	0.2	**-0.9**
Current Account/GDP	-0.0	**-0.0**	-0.0	**-0.0**
Remaining Countries (RC):				
Real GDP	0.0	-0.0	**0.7**	**0.7**
Welfare (Consumption Equiv.)				
Forward-looking Consumers	0.0	-0.0	**0.9**	**1.0**
Liquidity-constrained Consumers	0.0	-0.0	**1.4**	**1.5**
Consumption	0.0	-0.0	**0.9**	**1.0**
Investment	0.0	-0.0	**-0.0**	**0.0**
Labor Effort	0.0	-0.0	**0.4**	**0.4**
Real Effective Exchange Rate	0.0	0.1	**-2.2**	**-2.2**
Current Account/GDP	-0.0	-0.0	**-0.0**	**-0.0**
Memo Item:				
Baseline Import Share from United States	6.1	2.5	8.4	

Table 5: Effects of Higher Markups in the Tradables Sector

	Effects of Higher Markups in:				
	US	AS	JE	RC	ALL
United States (US):					
Real GDP	**-1.3**	-0.1	-0.1	-0.2	**-1.7**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	**-0.9**	-0.1	-0.1	-0.2	**-1.3**
Liquidity-constrained Consumers	**-3.5**	-0.1	-0.1	-0.2	**-3.9**
Consumption	**-1.0**	-0.1	-0.1	-0.2	**-1.5**
Investment	**-2.2**	-0.1	-0.1	-0.2	**-2.5**
Labor Effort	**-1.0**	-0.0	-0.0	-0.1	**-1.1**
Real Effective Exchange Rate	**2.0**	-0.2	-0.3	-0.8	**0.8**
Current Account/GDP	**-0.0**	0.0	0.0	0.0	**0.0**
Emerging Asia (AS):					
Real GDP	-0.2	**-2.2**	-0.4	-0.4	**-3.2**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	-0.3	**-0.5**	-0.5	-0.4	**-1.6**
Liquidity-constrained Consumers	-0.3	**-5.8**	-0.5	-0.4	**-6.9**
Consumption	-0.3	**-1.4**	-0.5	-0.4	**-2.5**
Investment	-0.2	**-4.0**	-0.4	-0.3	**-4.8**
Labor Effort	-0.1	**-1.7**	-0.1	-0.1	**-2.0**
Real Effective Exchange Rate	-0.4	**0.7**	-0.8	-0.6	**-1.0**
Current Account/GDP	-0.0	**0.0**	0.0	0.0	**0.0**
Japan/Euro Area (JE):					
Real GDP	-0.1	-0.2	**-1.5**	-0.4	**-2.2**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	-0.1	-0.2	**-1.1**	-0.4	**-1.9**
Liquidity-constrained Consumers	-0.1	-0.2	**-4.5**	-0.4	**-5.1**
Consumption	-0.1	-0.2	**-1.3**	-0.4	**-2.0**
Investment	-0.1	-0.1	**-2.3**	-0.4	**-2.9**
Labor Effort	-0.0	-0.0	**-1.3**	-0.1	**-1.5**
Real Effective Exchange Rate	-0.3	-0.2	**1.9**	-0.7	**0.6**
Current Account/GDP	-0.0	0.0	**0.0**	0.0	**0.0**
Remaining Countries (RC):					
Real GDP	-0.2	-0.1	-0.5	**-1.5**	**-2.3**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	-0.3	-0.1	-0.5	**-0.9**	**-1.8**
Liquidity-constrained Consumers	-0.3	-0.1	-0.5	**-4.5**	**-5.4**
Consumption	-0.3	-0.1	-0.5	**-1.1**	**-2.0**
Investment	-0.2	-0.1	-0.4	**-2.9**	**-3.5**
Labor Effort	-0.1	-0.0	-0.1	**-1.3**	**-1.6**
Real Effective Exchange Rate	-0.8	0.0	-1.1	**1.4**	**-0.6**
Current Account/GDP	-0.0	0.0	0.0	**0.0**	**-0.0**

Table 6: Effects of Higher Markups in the Non-Tradables Sector

	Effects of Higher Markups in:				
	US	AS	JE	RC	ALL
United States (US):					
Real GDP	**-2.1**	-0.0	-0.0	-0.0	**-2.2**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	**-1.3**	-0.0	-0.0	-0.0	**-1.4**
Liquidity-constrained Consumers	**-5.5**	-0.0	-0.0	-0.0	**-5.6**
Consumption	**-1.5**	-0.0	-0.0	-0.0	**-1.6**
Investment	**-4.2**	-0.0	-0.0	-0.0	**-4.3**
Labor Effort	**-1.6**	-0.0	-0.0	-0.0	**-1.6**
Real Effective Exchange Rate	**-3.0**	0.5	0.7	1.3	**-0.4**
Current Account/GDP	**0.0**	-0.0	-0.0	-0.0	**0.0**
Emerging Asia (AS):					
Real GDP	-0.1	**-1.5**	-0.1	-0.1	**-1.7**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	-0.1	**-0.2**	-0.1	-0.1	**-0.5**
Liquidity-constrained Consumers	-0.1	**-3.7**	-0.1	-0.1	**-4.0**
Consumption	-0.1	**-0.8**	-0.1	-0.1	**-1.1**
Investment	-0.0	**-3.0**	-0.1	-0.1	**-3.2**
Labor Effort	-0.0	**-1.1**	-0.0	-0.0	**-1.2**
Real Effective Exchange Rate	0.7	**-2.2**	1.1	1.0	**0.6**
Current Account/GDP	0.0	**-0.0**	0.0	0.0	**0.0**
Japan/Euro Area (JE):					
Real GDP	-0.0	-0.0	**-2.3**	-0.1	**-2.5**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	-0.0	-0.0	**-1.5**	-0.1	**-1.6**
Liquidity-constrained Consumers	-0.0	-0.0	**-6.5**	-0.1	**-6.6**
Consumption	-0.0	-0.0	**-1.7**	-0.1	**-1.8**
Investment	-0.0	-0.0	**-4.3**	-0.1	**-4.4**
Labor Effort	-0.0	-0.0	**-1.9**	-0.0	**-1.9**
Real Effective Exchange Rate	0.5	0.5	**-2.8**	1.5	**-0.3**
Current Account/GDP	0.0	-0.0	**-0.0**	0.0	**0.0**
Remaining Countries (RC):					
Real GDP	-0.0	-0.0	-0.1	**-1.8**	**-1.9**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	-0.0	-0.0	-0.1	**-0.9**	**-1.1**
Liquidity-constrained Consumers	-0.1	-0.0	-0.1	**-4.8**	**-4.9**
Consumption	-0.0	-0.0	-0.1	**-1.1**	**-1.3**
Investment	-0.0	-0.0	-0.1	**-3.6**	**-3.7**
Labor Effort	-0.0	-0.0	-0.0	**-1.4**	**-1.4**
Real Effective Exchange Rate	1.1	0.2	1.5	**-2.5**	**0.2**
Current Account/GDP	0.0	0.0	-0.0	**-0.0**	**0.0**

Table 7: Effects of Higher Markups in the Labor Market

	Effects of Higher Markups in:				
	US	AS	JE	RC	ALL
United States (US):					
Real GDP	**-1.5**	-0.0	-0.0	-0.1	**-1.7**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	**-1.5**	-0.0	-0.0	-0.1	**-1.7**
Liquidity-constrained Consumers	**-1.5**	-0.0	-0.0	-0.1	**-1.7**
Consumption	**-1.5**	-0.0	-0.0	-0.1	**-1.7**
Investment	**-1.6**	-0.0	-0.0	-0.1	**-1.7**
Labor Effort	**-1.6**	-0.0	-0.0	-0.0	**-1.7**
Real Effective Exchange Rate	**-0.6**	0.1	0.2	0.2	**-0.0**
Current Account/GDP	**-0.0**	0.0	0.0	0.0	**-0.0**
Emerging Asia (AS):					
Real GDP	-0.1	**-1.3**	-0.2	-0.1	**-1.7**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	-0.1	**-1.2**	-0.2	-0.1	**-1.6**
Liquidity-constrained Consumers	-0.1	**-1.2**	-0.2	-0.1	**-1.6**
Consumption	-0.1	**-1.2**	-0.2	-0.1	**-1.6**
Investment	-0.1	**-1.4**	-0.1	-0.1	**-1.7**
Labor Effort	-0.0	**-1.5**	-0.1	-0.0	**-1.7**
Real Effective Exchange Rate	0.1	**-0.5**	0.2	0.2	**-0.0**
Current Account/GDP	-0.0	**0.0**	0.0	0.0	**-0.0**
Japan/Euro Area (JE):					
Real GDP	-0.0	-0.1	**-1.3**	-0.2	**-1.5**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	-0.1	-0.1	**-1.3**	-0.2	**-1.5**
Liquidity-constrained Consumers	-0.1	-0.1	**-1.3**	-0.2	**-1.5**
Consumption	-0.1	-0.1	**-1.3**	-0.2	**-1.5**
Investment	-0.0	-0.0	**-1.3**	-0.1	**-1.5**
Labor Effort	-0.0	-0.0	**-1.4**	-0.0	**-1.5**
Real Effective Exchange Rate	0.1	0.1	**-0.5**	0.3	**0.1**
Current Account/GDP	-0.0	0.0	**0.0**	0.0	**-0.0**
Remaining Countries (RC):					
Real GDP	-0.1	-0.0	-0.2	**-1.3**	**-1.6**
Welfare (Consumption Equiv.)					
Forward-looking Consumers	-0.1	-0.0	-0.2	**-1.2**	**-1.6**
Liquidity-constrained Consumers	-0.1	-0.0	-0.2	**-1.2**	**-1.6**
Consumption	-0.1	-0.0	-0.2	**-1.2**	**-1.6**
Investment	-0.1	-0.0	-0.1	**-1.4**	**-1.6**
Labor Effort	-0.0	-0.0	-0.1	**-1.5**	**-1.6**
Real Effective Exchange Rate	0.2	0.1	0.3	**-0.5**	**-0.0**
Current Account/GDP	-0.0	0.0	0.0	**0.0**	**-0.0**

Appendix: Theoretical framework

In this Appendix we provide a brief but comprehensive overview of the model used in our scenario analysis. 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 countries are analogously characterized. In the sections involving international transactions, instead, we adopt a more general notation that includes country indexes.

The world economy consists of four regional blocs ('countries'): US (United States), JE (Japan and euro area), AS (Emerging Asia), and RC (Remaining Countries). The size of the world economy is normalized to one. The size of each country H is denoted s^H, with $0 < s^H < 1$ and $\sum_H s^H = 1$ for $H \in \{US, JE, AS, RC\}$.

There is a common trend for the world economy (the variable $TREND$), whose gross rate of growth between time t and time τ is denoted $g_{t,\tau}$. All quantity variables in the model are expressed in detrended terms, that is as ratios relative to $TREND$.

Final goods

In each country there is a continuum of symmetric firms producing two final goods, A (the consumption good) and E (the investment good) under perfect competition. As a convention throughout the model, in each country 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).[1] For instance, p_E denotes the price of one unit of E in terms of A. Also we denote the CPI inflation rate between time t and time τ with $\pi_{t,\tau}$. The inflation rate in sector E is therefore equal to:

$$\pi_{Et,\tau} \equiv \frac{p_{E,\tau}}{p_{E,t}} \pi_{t,\tau} \tag{A.1}$$

Consider first the consumption sector. Each firm is indexed by $x \in [0, s]$, where s 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:

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

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 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 (A.2). Cost minimization implies that firm x's demands for

[1] By transforming all prices in relative terms and all quantities in detrended terms we avoid dealing with unit roots, either nominal or real, in quantitative simulations of the model over very long time horizons.

intermediate inputs are:

$$
\begin{aligned}
N_{A,t}(x) &= \left(1-\gamma_{A,t}\right) p_{N,t}^{-\varepsilon_A} A_t(x) && \text{(A.3)}\\
Q_{A,t}(x) &= \gamma_{A,t}\nu_A p_{Q,t}^{-\mu_A} p_{XA,t}^{\mu_A-\varepsilon_A} A_t(x) && \text{(A.4)}\\
M_{A,t}(x) &= \gamma_{A,t}\left(1-\nu_A\right) p_{MA,t}^{-\mu_A} p_{XA,t}^{\mu_A-\varepsilon_A} A_t(x) && \text{(A.5)}
\end{aligned}
$$

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:

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

The production technologies in the consumption and investment sectors 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:

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

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.

Demand for domestic 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:

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

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 $p(n)$ and minimizes its costs. Cost minimization implies:

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

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

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

The basket N_E is similarly characterized. Aggregating across firms,[2] and accounting for public demand of nontradables — here assumed to have the same composition as private

[2] 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, $A_t \equiv (1/s)\int_0^s A_t(x)dx$.

demand — we obtain the total demand for good n as:

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

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

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

Demand for imports

The derivation of the foreign demand schedule for good h is analytically more complex but, as we show in (A.21) at the end of this section, it shares the same functional form as (A.11) and (A.12) above and can be written as a function of the relative price of good h (with elasticity $\theta_{T,t}$) and total foreign demand for imports.

We 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, in this section H will refer to a specific country, and J will refer to each of the other countries different from H.

Denote 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:

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

where:

$$0\leq b^{H,J}\leq 1,\quad \sum_{J\neq H}b^{H,J}=1 \quad (A.14)$$

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

The response of imports to changes in fundamentals and their price elasticities are typically estimated 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 $\Gamma_{MA}^{H,J}$. These costs are specified in terms of import shares relative to firm x^H's output and can be different across exporters J. They are zero in steady state. Specifically, we adopt the parameterization:

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

with $\phi_{MA}^{H,J}\geq 0$. The specification is such that $\Gamma_{MA}^{H,J}[1]=0$, $\Gamma_{MA}^{H,J}[\infty]=\phi_{MA}^{H,J}/2$, and $\Gamma_{MA}^{H,J}[0]=\Gamma_{MA}^{H,J}[2]=\phi_{MA}^{H,J}/4$.[3]

[3] 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.

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

$$\frac{M_{A,t}^{H,J}(x^H)\left(1-\Gamma_{MA,t}^{H,J}(x^H)\right)}{\left(1-\Gamma_{MA,t}^{H,J}(x^H)-M_{A,t}^{H,J}(x^H)\Gamma'^{H,J}_{MA,t}(x^H)\right)^{\rho_A^H}}=b_A^{H,J}\left(\frac{p_{M,t}^{H,J}}{p_{MA,t}^{H}(x^H)}\right)^{-\rho_A^H}M_{A,t}^{H}(x^H)\quad\text{(A.16)}$$

where $\Gamma'^{H,J}_{MA}(x^H)$ is the first derivative of $\Gamma_{MA}^{H,J}(x^H)$ with respect to $M_A^{H,J}(x^H)$. The import price deflator in the consumption sector, p_{MA}^H, is defined as:[4]

$$p_{MA,t}^{H}(x^H)=\left[\sum_{J\neq H}b^{H,J}\left(\frac{p_{M,t}^{H,J}}{1-\Gamma_{MA,t}^{H,J}(x^H)-M_{A,t}^{H,J}(x^H)\Gamma'^{H,J}_{MA,t}(x^H)}\right)^{1-\rho_A^H}\right]^{\frac{1}{1-\rho_A^H}}\quad\text{(A.17)}$$

In principle, the cost-minimizing import price $p_{MA}^H(x^H)$ is firm-specific, as it depends on firm x^H's import shares. 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.[5]

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

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

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

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

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

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

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

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 J's demand schedule for country H's intermediate good h^H, that is, the analog of (A.12). Aggregating across

[4] The deflator $p_{MA}^H(x^H)$ is the Lagrangean multiplier associated with minimizing costs $\sum_J p_M^{H,J}M_A^{H,J}(x^H)$ subject to (A.13).

[5] It follows that $p_{MA}^H M_A^H=\sum_{J\neq H}p_M^{H,J}M_A^{H,J}(1-\Gamma_{MA}^{H,J})/(1-\Gamma_{MA}^{H,J}-M_A^{H,J}\Gamma'^{H,J}_{MA})$

firms (and paying attention to the order of the country indexes) we obtain:

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

Supply of intermediate goods

The nontradable n is produced with the following CES technology:

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

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.[6]

Defining as w_t and r_t the prices of labor and capital, the marginal cost in nontradables production is:[7]

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

and the capital-labor ratio is:

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

Labor inputs are differentiated and come in different varieties (skills). Each input is associated to one household, defined over a continuum of mass equal to the country size and indexed by $j \in [0, s]$. As discussed below, there are two types of households, LC-type households and FL-type households. FL-type households represents a share $(1 - s_{LC})$ of domestic households and are indexed by $j \in [0, s(1 - s_{LC})]$. LC-type households represent a share s_{LC} of domestic households and are indexed by $j \in (s(1 - s_{LC}), s]$.

Each firm n uses a CES combination of labor inputs:

$$\ell_t(n) = \left[s_{LC}^{\frac{1}{\psi_{L,t}}}\ell_{LC,t}(n)^{1-\frac{1}{\psi_{L,t}}} + (1-s_{LC})^{\frac{1}{\psi_{L,t}}}\ell_{FL,t}(n)^{1-\frac{1}{\psi_{L,t}}}\right]^{\frac{\psi_{L,t}}{\psi_{L,t}-1}} \tag{A.25}$$

where $\ell_{LC}(n)$ is a basket of LC-type labor inputs, $\ell_{FL}(n)$ a basket of FL-type inputs, and ψ_L the elasticity of substitution between the two types. The two baskets are defined as:

$$\ell_{FL,t}(n) = \left[\left(\frac{1}{s(1-s_{LC})}\right)^{\frac{1}{\psi_{FL,t}}}\int_0^{s(1-s_{LC})}\ell(n,j)^{1-\frac{1}{\psi_{FL,t}}}dj\right]^{\frac{\psi_{FL,t}}{\psi_{FL,t}-1}} \tag{A.26}$$

[6] 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.

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

$$\ell_{LC,t}(n)=\left[\left(\frac{1}{s*s_{LC}}\right)^{\frac{1}{\psi_{LC,t}}}\int_{s(1-s_{LC})}^{s}\ell(n,j)^{1-\frac{1}{\psi_{LC,t}}}dj\right]^{\frac{\psi_{LC,t}}{\psi_{LC,t}-1}} \tag{A.27}$$

where $\ell(n,j)$ is the demand of labor input of type j by the producer of good n and $\psi_{FL},\psi_{LC}>1$ are the elasticities of substitution among varieties of labor inputs.

Cost minimization implies that $\ell(n,j)$ is a function of the relative wages:

$$\ell_t(n,j)=\begin{cases}\frac{1}{s}\left(\frac{w_t(j)}{w_{FL,t}}\right)^{-\psi_{FL,t}}\left(\frac{w_{FL,t}}{w_t}\right)^{-\psi_{L,t}}\ell_t(n) & \text{for } FL \text{ inputs}\\ \frac{1}{s}\left(\frac{w_t(j)}{w_{LC,t}}\right)^{-\psi_{LC,t}}\left(\frac{w_{LC,t}}{w_t}\right)^{-\psi_{L,t}}\ell_t(n) & \text{for } LC \text{ inputs}\end{cases} \tag{A.28}$$

where $w(j)$ is the wage paid to labor input j and the wage indexes w_{LC}, w_{FL} and w are defined as:

$$w_{FL,t}=\left[\left(\frac{1}{s\,(1-s_{LC})}\right)\int_{0}^{s(1-s_{LC})}w_t(j)^{1-\psi_{FL,t}}dj\right]^{\frac{1}{1-\psi_{FL,t}}} \tag{A.29}$$

$$w_{LC,t}=\left[\left(\frac{1}{s*s_{LC}}\right)\int_{s(1-s_{LC})}^{s}w_t(j)^{1-\psi_{LC,t}}dj\right]^{\frac{1}{1-\psi_{LC,t}}} \tag{A.30}$$

$$w_t=\left[s_{LC}\;w_{LC,t}^{1-\psi_{L,t}}+(1-s_{LC})\,w_{FL,t}^{1-\psi_{L,t}}\right]^{\frac{1}{1-\psi_{L,t}}} \tag{A.31}$$

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:

$$T_t\,(h)=Z_{T,t}\left[(1-\alpha_T)^{\frac{1}{\xi_T}}\;\ell_t(h)^{1-\frac{1}{\xi_T}}+\alpha_T^{\frac{1}{\xi_T}}\,K_t(h)^{1-\frac{1}{\xi_T}}\right]^{\frac{\xi_T}{\xi_T-1}} \tag{A.32}$$

where Z_T is total factor productivity. Aggregating across firms, we obtain the total demand for FL-type labor input j as:

$$\begin{aligned}&\int_0^{s(1-s_{LC})}\ell_t(n,j)dn+\int_0^{s(1-s_{LC})}\ell_t(h,j)dh\\ &=\frac{1}{s}\left(\frac{w_t(j)}{w_{FL,t}}\right)^{-\psi_{FL,t}}\left(\frac{w_{FL,t}}{w_t}\right)^{-\psi_{L,t}}\left(\int_0^{s(1-s_{LC})}\ell_t\,(n)\,dn+\int_0^{s(1-s_{LC})}\ell_t\,(h)\,dh\right)\\ &\equiv\left(\frac{w_t(j)}{w_{FL,t}}\right)^{-\psi_{FL,t}}\left(\frac{w_{FL,t}}{w_t}\right)^{-\psi_{L,t}}(1-s_{LC})\,\ell_t\end{aligned} \tag{A.33}$$

where ℓ is per-capita total labor in the economy. Similarly, total demand for LC-type labor input j is:

$$\begin{aligned}&\int_{s(1-s_{LC})}^{s}\ell_t(n,j)dn+\int_{s(1-s_{LC})}^{s}\ell_t(h,j)dh\\ &=\frac{1}{s}\left(\frac{w_t(j)}{w_{LC,t}}\right)^{-\psi_{LC,t}}\left(\frac{w_{LC,t}}{w_t}\right)^{-\psi_{L,t}}\left(\int_{s(1-s_{LC})}^{s}\ell_t\,(n)\,dn+\int_{s(1-s_{LC})}^{s}\ell_t\,(h)\,dh\right)\\ &\equiv\left(\frac{w_t(j)}{w_{LC,t}}\right)^{-\psi_{LC,t}}\left(\frac{w_{LC,t}}{w_t}\right)^{-\psi_{L,t}}s_{LC}\;\ell_t\end{aligned} \tag{A.34}$$

Price setting in the nontradables sector

Consider now profit maximization in the intermediate nontradables sector. Each firm n takes into account the demand (A.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 $\Gamma_{PN,t}$ $[p_t(n), p_{t-1}(n)]$.[8]

The price-setting problem is then characterized as:

$$\max_{p_t(n)} \mathsf{E}_t \sum_{\tau=t}^{\infty} D_{t,\tau}\pi_{t,\tau}g_{t,\tau}\left[p_\tau(n) - mc_\tau(n)\right]\left(\frac{p_\tau(n)}{p_{N,\tau}}\right)^{-\theta_{N,\tau}}\left(N_{A,\tau} + N_{E,\tau} + G_{N,\tau}\right)\left(1 - \Gamma_{PN,\tau}(n)\right) \tag{A.35}$$

where $D_{t,\tau}$ (with $D_{t,t} = 1$) is the appropriate discount rate, to be defined below in eq. (A.55). As real variables are detrended and prices are deflated by the CPI, eq. (A.35) 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.

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

$$\begin{aligned} 0 = &\left(1 - \Gamma_{PN,t}(n)\right)\left[p_t(n)\left(1 - \theta_{N,t}\right) + \theta_{N,t}mc_t(n)\right] - \left[p_t(n) - mc_t(n)\right]\frac{\partial \Gamma_{PN,t}}{\partial p_t(n)}p_t(n) \\ &- \mathsf{E}_t D_{t,t+1}\pi_{t,t+1}g_{t,t+1}\left[p_{t+1}(n) - mc_{t+1}(n)\right]\frac{N_{A,t+1} + N_{E,t+1} + G_{N,t+1}}{N_{A,t} + N_{E,t} + G_{N,t}}\frac{\partial \Gamma_{PN,t+1}}{\partial p_t(n)}p_t(n) \end{aligned} \tag{A.36}$$

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

$$p_t(n) = \frac{\theta_{N,t}}{\theta_{N,t} - 1}mc_t(n) \tag{A.37}$$

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:

$$\Gamma_{PN,t}(n) \equiv \frac{\phi_{PN}}{2}\left(\pi_{t-1,t}\frac{p_t(n)/p_{t-1}(n)}{\Pi_{t-4,t}^{0.25}} - 1\right)^2 \tag{A.38}$$

The adjustment cost is related to changes of the nominal price of nontradable n relative to the contemporaneous inflation target for the CPI, indexed by $\Pi_{t-4,t}$. Underlying this specification is the notion that firms should not be penalized when their price hikes are indexed to some (publicly observable) measures of aggregate or sectoral inflation.[9] The

[8] 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 (A.36) since $P_t(n)\partial G_{PN,t}/\partial P_t(n) = p_t(n)\partial \Gamma_{PN,t}/\partial p_t(n)$ and $P_t(n)\partial G_{PN,t+1}/\partial P_t(n) = p_t(n)\partial \Gamma_{PN,t+1}/\partial p_t(n)$.

[9] More generally, the adjustment cost could be specified relative to any variable that converges asymptotically to the steady-state inflation rate.

inflation target is specified in annualized terms (hence indexed by $t-4,t$), while changes in $p(n)$ occur at a quarterly frequency.[10]

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

Consider now the price-setting problem in the tradables sector. As we re-introduce export markets, once again our notation needs to make explicit the country indexes. In what follows we use the index J for a generic country, and denote as H the country where the exporting firm h^H is located. We also introduce the distinction between import prices at the national level and at the border level. National import prices such as $p^J(h^H)$ are paid by firms in country J for one unit of a good produced and exported by firm h^H located in country H. These are the prices that enter equations such as (A.16) above. Border import prices are indexed with a bar (e.g. $\overline{p}^J(h^H)$). These are the prices set by the exporting firm h^H. The difference between the two prices stems from trade barriers such as tariffs.[11] In terms of our notation, we have:

$$p_t^J(h^H) = \left(1 + tar_t^{J,H}\right)\overline{p}_t^J(h^H) \tag{A.39}$$

where $tar_t^{J,H}$ is a proportional tariff duty imposed by country J over its imports from country H.[12]

To the extent that the four country blocs represent segmented markets in the global economy, each firm h^H in country 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.

Accounting for (A.21), the four price-setting problems of firm h in country H at time t can then be characterized as follows:

$$\begin{aligned}&\max_{\overline{p}_t^J(h^H)} \sum_J \mathsf{E}_t \sum_{\tau=t}^{\infty} D_{t,\tau}^H \pi_{t,\tau}^H g_{t,\tau} [\varepsilon_\tau^{H,J} \overline{p}_\tau^J(h^H) - mc_\tau^H(h^H)] \\ &* \frac{s^J}{s^H} \left(\frac{\left(1 + tar_t^{J,H}\right)\overline{p}_\tau^J(h^H)}{p_{M,\tau}^{J,H}} \right)^{-\theta_{T,\tau}^H} \left(M_{A,\tau}^{J,H} + M_{E,\tau}^{J,H}\right)\left(1 - \Gamma_{PM,\tau}^{J,H}(h)\right)\end{aligned} \tag{A.40}$$

When $H \neq J$, recall that $\overline{p}^J(h^H)$ is the border price of good h^H in country J, $\overline{p}_M^{J,H}$ is the border price of the basket of country J's imports from country H, and $M_A^{J,H} + M_E^{J,H}$ is country J's aggregate imports from country H. The term $\varepsilon^{H,J}$ is the bilateral real exchange rate between country H and country J (an increase in $\varepsilon^{H,J}$ represents a real depreciation of country H's currency against country J)[13]

To determine the domestic prices of tradables $\overline{p}^H(h^H)$ we still use (A.40) with $J = H$, adopting the notational conventions $\overline{p}_M^{H,H} = p_Q^H$, $M_A^{H,H} = Q_A^H$ and $M_E^{H,H} = Q_E^H$ as described in (A.12), $\Gamma_{PM}^{H,H} = \Gamma_{PQ}^H$, as well as $tar^{H,H} = 0$.

[10] This specification implies that the inflation target is known at any point in time.

[11] In a more general specification of the model the gap between the two prices reflects distribution costs and retail margins. See for instance Corsetti and Dedola (2005) and Laxton and Pesenti (2003).

[12] Our notation encompasses domestic sales of tradables, provided $tar^{H,H} = 0$ so that $p^H(x^H) = \overline{p}^H(x^H)$.

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

The term $\Gamma^{H,J}_{PM}(h^H)$ denotes adjustment costs related to changes of the price of good h^H in country J. These costs are the analogs of (A.38):

$$\Gamma^{J,H}_{PM,t}(h^H) \equiv \frac{\phi^{J,H}_{PM}}{2}\left(\pi^J_{t-1,t}\frac{\overline{p}^J_t(h^H)/\overline{p}^J_{t-1}(h^H)}{\left(\Pi^J_{t-4,t}\right)^{0.25}} - 1\right)^2 \tag{A.41}$$

Despite its fastidiousness, the notation above is straightforward and the equations are self-explanatory. Accounting for firms' symmetry ($\overline{p}^J(h^H) = \overline{p}^{J,H}_M$ and $\left(1 + tar^{J,H}_t\right)\overline{p}^J(h^H) = p^{J,H}_M$ in equilibrium), profit maximization yields:

$$\begin{aligned}
0 = & \left(1 - \Gamma^{J,H}_{PM,t}(h^H)\right)\left[\varepsilon^{H,J}_t \overline{p}^J_t(h^H)\left(1 - \theta^H_{T,t}\right) + \theta^H_{T,t} mc^H_t(h^H)\right] \\
& - \left[\varepsilon^{H,J}_t \overline{p}^J_t(h^H) - mc^H_t(h^H)\right]\frac{\partial \Gamma^{J,H}_{PM,t}}{\partial \overline{p}^J_t(h^H)}\overline{p}^J_t(h^H) - \mathsf{E}_t\{D^H_{t,t+1}\pi^H_{t,t+1}g_{t,t+1} \\
& * \left[\varepsilon^{H,J}_{t+1}\overline{p}^J_{t+1}(h^H) - mc^H_{t+1}(h^H)\right]\left(\frac{M^{J,H}_{A,t+1} + M^{J,H}_{E,t+1}}{M^{J,H}_{A,t} + M^{J,H}_{E,t}}\right)\frac{\partial \Gamma^{J,H}_{PM,t+1}}{\partial \overline{p}^J_t(h^H)}\overline{p}^J_t(h^H)\}
\end{aligned} \tag{A.42}$$

If adjustment costs in the export market 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 movements (and other shocks to marginal costs in country H) affect import prices in country J is rather small in the short run. If instead the $\phi^{J,H}_{PM}$ coefficients are zero worldwide, expression (A.42) collapses to a markup rule under the law of one price, and exchange rate pass-through is full:

$$p^{H,H}_t(h^H) = p^H_{Q,t} = \varepsilon^{H,J}_t \overline{p}^J_t(h^H) = \varepsilon^{H,J}_t \overline{p}^{J,H}_{M,t} = \frac{\theta^H_{T,t}}{\theta^H_{T,t} - 1} mc^H_t \tag{A.43}$$

Consumer preferences

As considered above, 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' (FL). We refer to the second type as 'non-Ricardian' or 'liquidity-constrained' (LC). The two types of households are also heterogeneous in the labor market, as discussed above.

Denoting with $\mathcal{W}_t(j)$ the lifetime expected utility of household j, household preferences are specified as:

$$\mathcal{W}_t(j) \equiv \mathsf{E}_t \sum_{\tau=t}^{\infty} \beta_{t,\tau} g^{1-\sigma}_{t,\tau} u_\tau(\ C_\tau(j), \ell_\tau(j)\ ) \tag{A.44}$$

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

$$u_t\ (\ C_t(j), \ell_t(j)\ ) = \frac{Z_U}{1-\sigma}[C_t(j) - \frac{b_c C_{j,t-1}}{g_{t-1,t}} - \frac{Z_V}{1+\zeta}\frac{(\ell_t(j) - b_\ell \ell_{j,t-1})^{1+\zeta}}{(1-b_\ell)^\zeta}]^{1-\sigma} \tag{A.45}$$

In the expressions above $\beta_{t,\tau}$ is the discount rate between time t and time τ, possibly different across countries. The term $g^{1-\sigma}_{t,\tau}$ in (A.44) implies that the disutility of labor effort increases with the common trend.[14] The parameter σ in (A.45), which affects the curvature

[14] The implicit assumption is that technological progress associated with home production activities is related to the global trend. The restriction $\beta_{t,\tau} g^{1-\sigma}_{t,\tau} < 1$ is imposed to ensure that utility is bounded.

of consumption utility, 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 (A.45) 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 $0 < b_\ell < 1$. The terms Z_U and Z_V are positive parameters. Households' preferences are therefore symmetric within their respective categories but, because of different reference groups in habit formation, they are not symmetric across categories.

Budget constraint (Ricardian households)

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

$$\begin{aligned} B_t(j) + \varepsilon_t B_t^*(j) &\leq (1 + i_{t-1}) \frac{B_{t-1}(j)}{\pi_{t-1,t} g_{t-1,t}} + (1 + i_{t-1}^*) \left[1 - \Gamma_{B,t-1}\right] \frac{\varepsilon_t B_{t-1}^*(j)}{\pi_{t-1,t}^{US} g_{t-1,t}} \\ &+ (1 - \tau_{K,t})\, r_t K_t(j) + (1 - \tau_{L,t})\, w_t(j) \ell_t(j) \left(1 - \Gamma_{W,t}(j) \right) \\ &- C_t(j) - p_{E,t} I_t(j) + \Phi_t(j) - TT_t(j) \end{aligned} \tag{A.46}$$

Households hold two nominal bonds, denominated in domestic and US currency, respectively.[15] In terms of our notation, $B_t(j)$ is holdings of the domestic bond by household j, expressed in terms of domestic consumption units, $B_t^*(j)$ is 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.[16]

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 governments, so that $i^* = i^{US}$. 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. It follows that the net financial wealth of each FL-type household j at time t is:

$$F_t(j) \equiv (1 + i_{t-1}^*) \left[1 - \Gamma_{B,t-1}\right] \frac{\varepsilon_t B_{t-1}^*(j)}{\pi_{t-1,t}^{US} g_{t-1,t}} \tag{A.47}$$

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.[17] 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.[18] This transaction cost is a function of the average net asset position of

---

[15] 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.

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

[17] See Ghironi, İşcan, and Rebucci (2005) for an analysis of the steady-state distribution of net foreign assets with heterogeneous discounting.

[18] 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.

the whole economy. Specifically, we adopt the following functional form:

$$1-\Gamma_{B,t}=(1-\phi_{B1}\frac{\exp\left(\phi_{B2}\left[\varepsilon_t B_t^*/GDP_t-b^*_{FDES,t}\right]\right)-1}{\exp\left(\phi_{B2}\left[\varepsilon_t B_t^*/GDP_t-b^*_{FDES,t}\right]\right)+1}-Z_{B,t})\frac{\beta_t^{US}}{\beta_t} \tag{A.48}$$

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.[19] This variable measures the degree of international exposure that financial intermediaries consider appropriate for the economy, based on their assessment of the economic outlook. Both desired (b^*_{FDES}) and actual ($\varepsilon B^*/GDP$) net asset positions converge over the long term to their steady-state value $b^*_{F,SS}$.

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.

Consider now the other components of (A.48). 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 variable $Z_{B,t}$ can be a stochastic process with zero mean in steady state:[20] in our framework, uncertainty in international financial intermediation plays the same role that 'uncovered interest parity shocks' or risk-premium fluctuations play in 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. An appropriate parameterization allows the model to generate realistic dynamics for net asset positions and current account.

The desired net asset position in country H is characterized as follows:

$$b^{*H}_{FDES,t}=b^{*H}_{FNEUT}-\phi^H_{F1}\frac{B_t^H}{GDP_t^H}+\sum_{J\neq H}\phi^{J,H}_{F2}\frac{B_t^J}{GDP_t^J} \tag{A.49}$$

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^J/GDP^J).

This specification provides a plausible link between debt imbalances and net asset positions. When the national debt-to-GDP ratio increases, domestic agents reduce the share of

[19] The concept of GDP in our model is discussed below with reference to (A.90).

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

foreign securities in their portfolios by selling the international bond to foreigners. By the same token, if the 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. 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.

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:

$$K_{t+1}(j)g_{t,t+1} = (1-\delta)\,K_t(j) + \Gamma_{I,t}K_t(j) \qquad 0<\delta\leq 1 \tag{A.50}$$

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:

$$\Gamma_{I,t}(j) \equiv \frac{I_t(j)}{K_t(j)} - \frac{\phi_{I1}}{2}\left(\frac{I_t(j)}{K_t(j)} - (\delta+g-1)\right)^2 - \frac{\phi_{I2}}{2}\left(\frac{I_t(j)}{K_t(j)} - \frac{I_{t-1}}{K_{t-1}}\right)^2 \tag{A.51}$$

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

Each forward-looking household is the monopolistic supplier of a specific labor input and sets the nominal wage for its labor variety j accounting for (A.33). 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 (A.38) above:

$$\Gamma_{WFL,t}(j) \equiv \frac{\phi_{WFL}}{2}\left(\pi_{t-1,t}\frac{w_t(j)/w_{t-1}(j)}{\Pi^{0.25}_{t-4,t}} - 1\right)^2 \tag{A.52}$$

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.

Consumer optimization (Ricardian households)

The representative Ricardian household chooses bond holdings, capital and consumption paths, and sets wages to maximize its expected lifetime utility (A.44) subject to (A.46) and (A.50), taking into account (A.33).

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:

$$
\begin{aligned}
&\max_{C_t(j), I_t(j), B_t(j), B_t^*(j), K_{t+1}(j), w_t(j)} \mathsf{E}_t \sum_{\tau=t}^{\infty} \beta_{t,\tau} g_{t,\tau}^{1-\sigma} \{\ u \left(C_\tau(j), w_\tau(j)^{-\psi_{FL,\tau}} w_{FL,\tau}^{\psi_{FL,\tau}} \left(\frac{w_{FL,\tau}}{w_\tau} \right)^{-\psi_{L,\tau}} \ell_{FL,\tau} \right) \\
&+ \mu_\tau(j)\ (\ -B_\tau(j) - \varepsilon_\tau B_\tau^*(j) + \frac{(1+i_{\tau-1}) B_{\tau-1}(j)}{\pi_{\tau-1,\tau} g_{\tau-1,\tau}} + \frac{(1+i_{\tau-1}^*)(1-\Gamma_{B,\tau-1}) \varepsilon_\tau B_{\tau-1}^*(j)}{\pi_{\tau-1,\tau}^{US} g_{\tau-1,\tau}} \\
&+ (1-\tau_{L,\tau})\, w_\tau(j)^{1-\psi_{FL,\tau}} w_{FL,\tau}^{\psi_{FL,\tau}} \left(w_{FL,\tau}/w_\tau \right)^{-\psi_{L,\tau}} \ell_{FL,\tau} (1 - \Gamma_{W,\tau}[w_\tau(j), w_{\tau-1}(j)]) \\
&+ (1-\tau_{K,\tau})\, r_\tau K_\tau(j) - C_\tau(j) - p_{E,\tau} I_\tau(j) + \Phi_\tau(j) - TT_\tau(j)\ \ ) \\
&+ \lambda_\tau(j)\ (\ -K_{\tau+1}(j) g_{\tau,\tau+1} + (1-\delta)\, K_\tau(j) + \Gamma_{I,\tau} \left[I_\tau(j)/K_\tau(j) \right] K_\tau(j)\ )\ \}
\end{aligned}
\tag{A.53}
$$

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

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

$$
\mu_t(j) = \partial u_t(j)/\partial C_t(j) = \lambda_t(j) \Gamma'_{I,t}(j)/p_{E,t} \tag{A.54}
$$

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:

$$
D_{t,\tau} \equiv \beta_{t,\tau} g_{t,\tau}^{1-\sigma} \frac{\mu_\tau}{\mu_t} \frac{1}{\pi_{t,\tau}} \frac{1}{g_{t,\tau}} \tag{A.55}
$$

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

$$
1 = (1+i_t)\, \mathsf{E}_t D_{t,t+1} \tag{A.56}
$$

$$
1 = (1+i_t^*)\, (1-\Gamma_{B,t})\, \mathsf{E}_t \left(D_{t,t+1} \Delta_{t,t+1} \right) \tag{A.57}
$$

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

$$
\Delta_{t,\tau} = \frac{\varepsilon_\tau}{\varepsilon_t} \frac{\pi_{t,\tau}}{\pi_{t,t}^*} \tag{A.58}
$$

In a non-stochastic steady state (A.56) implies $(1+i_{SS})/\pi_{SS} = g_{SS}^\sigma/\beta_{SS}$, where π_{SS} is the (gross steady-state quarterly) inflation rate, $(1+i_{SS})/\pi_{SS}$ is the real interest rate, g_{SS} is the (gross steady-state quarterly) rate of growth of the world economy, $1/\beta_{SS}$ is the rate of time preference, and g_{SS}^σ/β_{SS} is the 'natural' rate of the economy.[21] Expressions (A.56) and (A.57) 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 $(1+i_{SS})/[(1+i_{SS}^*)(1-\Gamma_{B,SS})]$ 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:

$$
\begin{aligned}
\frac{p_{E,t}}{\Gamma'_{I,t}(j)} \mathsf{E}_t g_{t,t+1} = \mathsf{E}_t \{\ & D_{t,t+1} \pi_{t,t+1} g_{t,t+1} (\ (1-\tau_{K,t+1})\, r_{t+1} \\
&+ \frac{p_{E,t+1}}{\Gamma'_{I,t+1}(j)} \left[1 - \delta + \Gamma_{I,t+1}(j) - \Gamma'_{I,t+1}(j) \frac{I_{t+1}(j)}{K_{t+1}(j)} \right]\ )\ \}
\end{aligned}
\tag{A.59}
$$

[21] International differences in natural rates can arise from asymmetric rates of time preference. They are accounted for in the definition of Γ_B in (A.48)

Expression (A.59) links capital accumulation to the behavior of the after-tax price of capital $(1-\tau_K)\,r$. In a non-stochastic steady state $1+(1-\tau_{K,SS})\,r_{SS}/p_{E,SS}$ is equal to the sum of the natural real rate $g_{SS}^{\sigma}/\beta_{SS}$ and the rate of capital depreciation δ.[22]

Finally, taking the first order condition with respect to $w(j)$ and noting that $w(j)=w_{FL}$ in equilibrium, the Ricardian household' wage rate is set according to:

$$
\begin{aligned}
&-\psi_{FL,t}\frac{u_{\ell,t}(j)}{u_{C,t}(j)}\frac{1}{w_t(j)}=\left(\psi_{FL,t}-1\right)\left[1-\Gamma_{WFL,t}(j)\right](1-\tau_{L,t})+\frac{\partial\Gamma_{WFL,t}(j)}{\partial w_t(j)}w_t(j)\,(1-\tau_{L,t})\\
&+\mathsf{E}_t D_{t,t+1}\pi_{t,t+1}g_{t,t+1}\frac{\left(w_{FL,t+1}/w_{t+1}\right)^{-\psi_{L,t+1}}}{\left(w_{FL,t}/w_t\right)^{-\psi_{L,t}}}\frac{w_{t+1}(j)}{w_t(j)}\frac{\ell_{FL,t+1}}{\ell_{FL,t}}\frac{\partial\Gamma_{WFL,t+1}(j)}{\partial w_t(j)}w_t(j)\,(1-\tau_{L,t+1})
\end{aligned}
\tag{A.60}
$$

The interpretation of (A.60) is similar to (A.42) above. In a non-stochastic steady state the real wage w_{FL} 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.

Consumer optimization (liquidity-constrained households)

As 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:

$$
\begin{aligned}
&\max_{C_t(j),w_t(j)} u\ \left(\ C_t(j),w_t^{-\psi_{LC,t}}(j)w_{LC,t}^{\psi_{LC,t}}\left(w_{LC,t}/w_t\right)^{-\psi_{L,t}}\ell_{LC,t}\ \right)+\mu_t(j)\ \left(\ -C_t(j)-TT_t(j)\right.\\
&\left.+(1-\tau_{L,t})\,w_t(j)^{1-\psi_{LC,t}}w_{LC,t}^{\psi_{LC,t}}\left(w_{LC,t}/w_t\right)^{-\psi_{L,t}}\ell_{LC,t}(1-\Gamma_{WLC,t}[w_t(j),w_{t-1}(j)])\ \right)
\end{aligned}
\tag{A.61}
$$

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

$$
C_t(j)=(1-\tau_{L,t})\,w_t(j)\ell_t(j) \tag{A.62}
$$

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

$$
-\psi_{LC,t}\frac{u_{\ell,t}(j)}{u_{C,t}(j)}\frac{1}{w_t(j)}=(1-\tau_{L,t})\ \left[\left(\psi_{LC,t}-1\right)\left(\ 1-\Gamma_{WLC,t}(j)\ \right)+\frac{\partial\Gamma_{WLC,t}(j)}{\partial w_t(j)}w_t(j)\ \right] \tag{A.63}
$$

Denoting w_{FL} the wage rate $w(j)$ that solves (A.60), and w_{LC} the wage rate $w(j)$ that solves (A.63), equation (A.31) determines the wage rate for the whole economy as:

$$
w_t^{1-\psi_{L,t}}=s_{LC}w_{LC,t}^{1-\psi_{L,t}}+(1-s_{LC})\,w_{FL,t}^{1-\psi_{L,t}} \tag{A.64}
$$

[22] The expectation operator on the left hand side of (A.59) 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.

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 four sources of (net) tax revenue: taxes on capital income τ_K, taxes on labor income τ_L, import tariffs tar, and lump-sum taxes net of transfers to households TT. 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:

$$B_t \geq (1+i_{t-1})\frac{B_{t-1}}{\pi_{t-1,t}g_{t-1,t}} + G_t - G_{REV,t} \tag{A.65}$$

where:

$$G_t \equiv G_{C,t} + p_{E,t}G_{I,t} + p_{N,t}G_{N,t} \tag{A.66}$$

and (using familiar country indexes):

$$\begin{aligned} G^H_{REV,t} \equiv{}& \frac{1}{s^H}\left(\int_0^{s^H} TT^H_t(j)dj + \tau^H_{K,t}r^H_t \int_0^{s^H(1-s^H_{LC})} K^H_t(j)dj + \tau^H_{L,t}\int_0^{s^H} w^H_t(j)\ell^H_t(j)dj\right) \\ &+\frac{1}{s^H}\sum_{J\neq H} tar^{H,J}_t \int_0^{s^J} \overline{p}^H_t(h^J)\left(M^{H,J}_{A,t}(h^J) + M^{H,J}_{E,t}(h^J)\right)dh^J \end{aligned} \tag{A.67}$$

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

$$\tau_t \equiv G_{REV,t}/GDP_t \tag{A.68}$$

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

$$\frac{DEF_t}{GDP_t} = \left(B_t - \frac{B_{t-1}}{\pi_{t-1,t}g_{t-1,t}}\right)/GDP_t \tag{A.69}$$

From (A.65), in steady state we have:

$$\frac{B_{SS}}{GDP_{SS}} = \frac{\pi_{SS}g_{SS}}{\pi_{SS}g_{SS}-(1+i_{SS})}\left(\frac{G_{SS}}{GDP_{SS}} - \tau_{SS}\right) = \frac{\pi_{SS}g_{SS}}{\pi_{SS}g_{SS}-1}\frac{DEF_{SS}}{GDP_{SS}} \tag{A.70}$$

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_{SS} and DEF_{SS}/GDP_{SS} be determined by (A.70).

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

$$\begin{aligned} \tau_t ={}& (\tau_{t-1} + \tau_t + \mathsf{E}_t\tau_{t+1})/3 + \phi_{\tau 1}(\frac{B_t}{GDP_t} - \phi_{\tau 2}b_{TAR,t} - (1-\phi_{\tau 2})\frac{B_{t-1}}{GDP_{t-1}}) \\ &+\phi_{\tau 3}\left(\frac{DEF_t}{GDP_t} - \frac{DEF_{SS}}{GDP_{SS}}\right) + \phi_{\tau 4}\left(\frac{G_t}{GDP_t} - \frac{G_{SS}}{GDP_{SS}}\right) \end{aligned} \tag{A.71}$$

where b_{TAR} is the targeted debt-to-GDP ratio, converging to B_{SS}/GDP_{SS}. 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:

$$(1+i_t)^4 = \omega_i (1+i_{t-1})^4 + (1-\omega_i)\left(1+i_t^{neut}\right)^4 + \omega_1 \mathsf{E}_t\left(\pi_{t-1,t+3} - \Pi_{t-1,t+3}\right) \tag{A.72}$$

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:[23]

$$1+i_t^{neut} \equiv \frac{\Pi_{t-4,t}^{0.25}\left(g_{t-1,t}\right)^{\sigma}}{\beta_{t-1,t}} \tag{A.73}$$

This average is adjusted to account for the expected inflation gap three quarters in the future.[24] The rule (A.72) 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:

$$1+i_{SS} = 1+i_{SS}^{neut} = \frac{\Pi_{SS}^{0.25} g_{SS}^{\sigma}}{\beta_{SS}} = \frac{\pi_{SS} g_{SS}^{\sigma}}{\beta_{SS}}. \tag{A.74}$$

Market clearing

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

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

$$\int_0^{s^H\left(1-s_{LC}^H\right)} K_t^H(j^H)dj^H \geq \int_0^{s^H} K_t^H(n^H)dn^H + \int_0^{s^H} K_t^H(h^H)dh^H \tag{A.75}$$

and:

$$\ell_t^H(j^H) \geq \int_0^{s^H} \ell_t^H(n^H, j^H)dn^H + \int_0^{s^H} \ell_t^H(h^H, j^H)dh^H \tag{A.76}$$

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

$$N_t^H(n^H) \geq \int_0^{s^H} N_{A,t}^H(n^H, x^H)dx^H + \int_0^{s^H} N_{E,t}^H(n^H, e^H)de^H + G_{N,t}^H(n^H) \tag{A.77}$$

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

$$\begin{aligned} T_t\left(h^H\right) \geq & \int_0^{s^H} Q_{A,t}(h^H, x^H)dx^H + \int_0^{s^H} Q_{E,t}(h^H, e^H)de^H \\ & + \sum_{J\neq H}\left(\int_0^{s^J} M_{A,t}^{J,H}(h^H, x^J)dx^J + \int_0^{s^J} M_{E,t}^{J,H}(h^H, e^J)de^J\right) \end{aligned} \tag{A.78}$$

---

[23] 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 $t-\tau+4$.

[24] In the case of AS, we model an exchange rate targeting regime by introducing the component $\omega_2^{AS}\Delta_t^{AS}$ in (A.72), where Δ^{AS} is defined in (A.58) and we choose a very high value of ω_2^{AS} to peg the nominal bilateral exchange rate against the US.

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

$$\int_0^{s^H} A_t^H(x^H)dx^H \geq \int_0^{s^H} C_t^H(j^H)dj^H + s^H G_{C,t}^H \tag{A.79}$$

and similarly for the investment good E:

$$\int_0^{s^H} E_t^H(e^H)de^H \geq \int_0^{\left(1-s_{LC}^H\right)s^H} I_t^H(j^H)dj^H + s^H G_{I,t}^H \tag{A.80}$$

All profits and intermediation revenue accrue to Ricardian households:

$$\begin{aligned}
&\int_0^{s^H(1-s_{LC}^H)} \Phi_t^H(j^H)dj^H = \int_0^{s^H(1-s_{LC}^H)} (1+i_{t-1}^*)\Gamma_{B,t-1}^H \frac{\varepsilon_t^{H,US} B_{t-1}^{*H}(j^H)}{\pi_{t-1,t}^{US} g_{t-1,t}} dj^H \\
&+ \int_0^{s^H(1-s_{LC}^H)} \Gamma_{WFL,t}^H(j^H)\left(1-\tau_{L,t}^H\right) w_t^H(j^H)dj^H + \int_{s^H(1-s_{LC}^H)}^{s^H} \Gamma_{WLC,t}^H(j^H)\left(1-\tau_{L,t}^H\right) w_t^H(j^H)dj^H \\
&+ \int_0^{s^H} \left[p_t^H(n^H) - mc_t^H(n^H)\right] \left(\int_0^{s^H} N_{A,t}^H(n^H,x^H)dx^H + \int_0^{s^H} N_{E,t}^H(n^H,e^H)de^H + G_{N,t}^H(n^H)\right)dn^H \\
&+ \int_0^{s^H} \left[p_t^H(h^H) - mc_t^H(h^H)\right] \left(\int_0^{s^H} Q_{A,t}^H(h^H,x^H)dx^H + \int_0^{s^H} Q_{E,t}^H(h^H,e^H)de^H\right)dh^H \\
&+ \sum_{J\neq H} \int_0^{s^H} [\varepsilon_t^{H,J}\overline{p}_t^J(h^H) - mc_t^H(h^H)]\left(\int_0^{s^J} M_{A,t}^{J,H}(h^H,x^J)dx^J + \int_0^{s^J} M_{E,t}^{J,H}(h^H,e^J)de^J\right)dh^H \\
&+ \sum_{J\neq H} \int_0^{s^H} \frac{p_M^{H,J} M_A^{H,J}(x^H)\Gamma_{MA,t}'^{H,J}(x^H)}{1-\Gamma_{MA,t}^{H,J}(x^H) - M_A^{H,J}\Gamma_{MA,t}'^{H,J}(x^H)} M_A^{H,J}(x^H))dx^H \\
&+ \sum_{J\neq H} \int_0^{s^H} \frac{p_M^{H,J} M_E^{H,J}\Gamma_{ME,t}'^{H,J}(e^H)}{1-\Gamma_{ME,t}^{H,J}(e^H) - M_E^{H,J}\Gamma_{ME,t}'^{H,J}(e^H)} M_E^{H,J}(e^H))de^H
\end{aligned} \tag{A.81}$$

Market clearing in the asset market requires:

$$\int_0^{s^H(1-s_{LC}^H)} B_t^H(j^H)dj^H = s^H B_t^H \tag{A.82}$$

for the four government bond markets, and:

$$\sum_J \int_0^{s^J(1-s_{LC}^J)} B_t^{*J}(j^J)dj^J = 0. \tag{A.83}$$

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:

$$\begin{aligned}
&\mathsf{E}_t D_{t,t+1}^H \pi_{t,t+1}^H g_{t,t+1} F_{t+1}^H = F_t^H + \Gamma_{B,t-1}^H \frac{\left(1+i_{t-1}^*\right)\varepsilon_t^{H,US} B_{t-1}^{*H}}{\pi_{t-1,t}^{US} g_{t-1,t}} \\
&+ p_{N,t}^H N_t^H + p_{T,t}^H T_t^H + \sum_{J\neq H}\left(p_{M,t}^H - \overline{p}_{M,t}^{H,J}\right)\left(M_{A,t}^{H,J} + M_{E,t}^{H,J}\right) + IMPADJ_t^H - C_t^H - p_{E,t}^H I_t^H - G_t^H
\end{aligned} \tag{A.84}$$

where the total value of tradables is defined as:

$$p_{T,t}^{H}T_t^{H} \equiv p_{Q,t}^{H}\left(Q_{A,t}^{H}+Q_{E,t}^{H}\right)+\sum_{J\neq H}\frac{s^J}{s^H}\varepsilon_t^{H,J}\overline{p}_{M,t}^{J,H}\left(M_{A,t}^{J,H}+M_{E,t}^{J,H}\right) \tag{A.85}$$

and the variable $IMPADJ$ is the sum of the last two terms in (A.81).

Measuring output and trade balance

Expression (A.85) can be written as:

$$CURBAL_t^H = \varepsilon_t^{H,US}\left(B_t^{*H}-\frac{B_{t-1}^{*H}}{\pi_{t-1,t}^{US}g_{t-1,t}}\right)=\frac{i_{t-1}^{*}\varepsilon_t^{H,US}B_{t-1}^{*H}}{\pi_{t-1,t}^{US}g_{t-1,t}}+TBAL_t^H \tag{A.86}$$

The left hand side of (A.86) 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:

$$TBAL_t^H = EX_t^H - IM_t^H \tag{A.87}$$

where total exports EX are evaluated at border prices:

$$EX_t^H = p_{T,t}^{H}T_t^{H} - p_{Q,t}^{H}\left(Q_{A,t}^{H}+Q_{E,t}^{H}\right) \tag{A.88}$$

and, similarly, total imports IM are:

$$IM_t^H = \sum_{J\neq H}\overline{p}_{M,t}^{H,J}\left(M_{A,t}^{H,J}+M_{E,t}^{H,J}\right) \tag{A.89}$$

Using the definition above, the model-based Gross Domestic Product (in consumption units) is:

$$\begin{aligned}GDP_t^H &= A_t^H + p_{E,t}^{H}E_t^H + p_{N,t}^{H}G_{N,t}^{H} + EX_t^H - IM_t^H \\ &= p_{N,t}^{H}N_t^H + p_{T,t}^{H}T_t^H + \sum_{J\neq H}\left(p_{M,t}^{H}-\overline{p}_{M,t}^{H,J}\right)\left(M_{A,t}^{H,J}+M_{E,t}^{H,J}\right)+IMPADJ_t^H\end{aligned} \tag{A.90}$$

Note that there is a discrepancy between GDP measured according to national accounting standards (goods output), and GDP measured as manufacturing output. This discrepancy reflects the portion of the revenue from sales of goods that is not earned by producers, such as costs incurred with imports adjustment and wedges between border and market prices of imported goods.[25]

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 our simulations, 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.

[25] For a statistical assessment of the relationship between the two concepts, see Steindel (2004).