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Asia's Post-Global Financial Crisis Adjustment:

A Model-Based Dynamic Scenario Analysis

Masahiro Kawai and

Fan Zhai

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Masahiro Kawai is dean of the Asian Development Bank Institute. Fan Zhai is a managing director at China Investment Corporation.

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Please contact the author(s) for information about this paper.

Asian Development Bank Institute
Kasumigaseki Building 8F
3-2-5 Kasumigaseki, Chiyoda-ku
Tokyo 100-6008, Japan

Tel: +81-3-3593-5500
Fax: +81-3-3593-5571
URL: www.adbi.org
E-mail: info@adbi.org

Abstract

Using a dynamic global general equilibrium model, the paper assesses the short- and medium-term impacts of the global financial crisis on Asian economies and the implications of post-crisis adjustment in emerging East Asia (EEA) for the world economy. The analysis suggests that EEA is unlikely to be severely damaged permanently by the global financial crisis, and a worldwide fiscal stimulus could play an important role in stabilizing the global economy in crisis. EEA's efforts at strengthening regional demand, in conjunction with adopting a more flexible exchange rate regime, will promote more balanced regional growth and facilitate an orderly global rebalancing. However, despite the growing size of EEA in the global economy, the region's growth rebalancing has only modest spillover effects on the rest of the world. EEA can contribute to global growth, but it alone cannot become the sole engine driving post-crisis growth in the world economy.

JEL Classification: C68, E62, F32, F47, G01

Contents

1. INTRODUCTION

Since the outbreak of the global financial crisis in the United States (US) in the fall of 2008, Asian economies have experienced substantial growth swings. In the initial stages of the crisis, as global aggregate demand dropped due to the falling consumer and investor confidence, exports from all major East Asian economies declined sharply. Imports from these economies also plummeted at almost similar rates to those of export declines, reflecting the tightly knit regional production networks and supply chains in Asia. Given the high trade dependence in most Asian economies, the slump in trade significantly dragged down their economic growth in the fourth quarter of 2008 and the first quarter of 2009.

But the Asian economies rebounded strongly beginning in the second quarter of 2009. The extraordinarily massive economic stimulus provided by governments and central banks in major advanced and emerging economies—including those in Asia—in response to the crisis helped stabilize financial markets, improve the confidence of investors and consumers, and foster the recovery of economic activity.[1] As a result, the inventory cycle turned from depleting to rebuilding in most parts of the world and global trade rebounded. The improved external environment, together with stronger domestic demand spurred by these policy stimulus measures, led to a dramatic V-shaped recovery in Asian economies. By the end of 2009, most Asian economies resumed their pre-crisis growth levels. Some of them have begun to moderate their macroeconomic stimulus policies in the face of the increasing risks of overheating, inflation, and asset price bubbles.

The global recovery now remains on track but faces considerable downside risks. The recent unfolding of the European sovereign debt crisis has highlighted the risks arising from the rapid accumulation of public debt, suggesting that the positive effects of fiscal stimulus could be more than offset by the markets' concerns over long-term debt sustainability. With most advanced economies embracing fiscal consolidation in the coming years and inventory restocking gradually running its course, the future pace of global recovery will be largely contingent on the degree to which the sources of demand can shift from the public to the private sector. However, given that the reconstruction of the financial sector and the deleveraging of private balance sheets could take a long time to resolve and that the unemployment rate remains high in major advanced economies, one would expect to observe a slower global economic growth and consequently an extended shortfall in global aggregate demand in the years to come.

The slower growth of aggregate demand in the US and European economies will pose significant challenges for Asian economies. With an export-oriented development strategy, emerging Asian economies have maintained not only high growth, but also large current account surpluses in the past decade, contributing to the global current account imbalance. As economic growth in advanced economies remains slow, Asian economies need to change the source of their growth from exports to extraregional markets to regional demand in order to sustain growth. The reorientation of growth toward Asia's internal demand can contribute to the orderly correction of the global imbalance. In fact, the ongoing crisis has indeed induced a partial and disorderly correction of the global imbalance, with a large contraction of demand in the US, a sharp increase in US household savings and an improvement in its current account. This adjustment has not been accompanied by the collapse of the US dollar, however, as was feared by many experts and policymakers before

[1] Immediately after the eruption of the global financial crisis, governments and central banks around the world responded swiftly to deal with liquidity and solvency problems of affected financial institutions through easing monetary policy and recapitalizing or restructuring troubled financial institutions. In addition to such measures, fiscal stimulus packages have been implemented around the world to boost demand. The IMF estimated that the total amount of fiscal stimulus in the G-20 countries amounted to US$692 billion in 2009, about 1.4% of their combined GDP. The US, the People's Republic of China, Japan, and Germany are the key contributors of global fiscal stimulus, with stimulus packages worth approximately 2% of their respective GDP.

the outbreak of the financial crisis; it has been accompanied by a global collapse of trade and output, and a rise in unemployment. The ongoing ultra-expansionary monetary policy—including quantitative easing—could lead to a sharp US dollar depreciation, which may exert significant adjustment pressures on Asian economies.

The aim of this paper is to provide a model-based analysis of the adjustment of Asian economies in the wake of the global financial crisis. Specifically, it attempts to answer the following questions: What are the macroeconomic impacts of the global financial crisis on Asian economies? What are the effects of global fiscal stimulus, and how would it contribute to mitigate the impacts of the ongoing crisis? What are the roles of emerging East Asia (EEA) in the rebalancing of global demand following the crisis? How much will EEA's efforts at currency appreciation and structural reforms for its own growth rebalancing contribute to sustained global economic growth? We use a multi-region, intertemporal dynamic general equilibrium model of the world economy to simulate different scenarios for the global financial crisis. Our quantitative simulations suggest that East Asia is unlikely to be severely damaged permanently by the global financial crisis, and a worldwide fiscal stimulus could play an important role in stabilizing the global economy in crisis. East Asia's efforts at strengthening regional demand, in conjunction with adopting a more flexible exchange rate regime in the region, will promote more balanced regional growth and facilitate an orderly global rebalancing. However, despite the growing size of EEA in the global economy, Asia-led growth rebalancing has only modest spillover effects on the rest of the world. Even though EEA can contribute to global growth, it alone cannot become the sole engine driving post-crisis growth in the world economy.

The paper is organized as follows. Section 2 describes the model used in the analysis. Section 3 discusses the design of the simulation scenarios, reports their results, and provides our interpretation. Finally section 4 offers conclusions.

2. THE MODEL

The model used in this study is a version of a multi-country dynamic general equilibrium model for the world economy inspired by the new open economy macroeconomics literature (Obstfeld and Rogoff 1995 and 1996). It combines the long-run properties of neoclassical models with short-run dynamics arising from nominal rigidities *a la* new Keynesian macroeconomics. The structure of the model closely follows the global integrated monetary and fiscal model (GIMF) developed by the International Monetary Fund (IMF) Research Department (Kumhof and Laxton 2007; Laxton 2008).[2] Agents in the model are forward looking, endowed with perfect foresight and subject to the dynamic budget constraints. The model features overlapping generations agents with finite economic lifetime. This leads to the non-Ricardian feature of the model and makes it suitable for fiscal policy analysis. Countries and regions in the model are linked through trade and financial markets. Nominal price and wage stickiness, as well as real frictions in investment, are incorporated to generate more realistic adjustment dynamics. The presence of nominal price and wage rigidity allows monetary policy to play a key role. Different from the GIMF, our model is deterministic, excluding stochastic shocks or other uncertainties. The model is in annual frequency and calibrated to the Global Trade Analysis Project (GTAP, version 7) global database with 2004 as the base year. This section outlines the basic structure of the model and discusses its parameterization. The detailed specifications of the model are described in the Appendix.

[2] See Zhang, Zhang, and Han (2010) for a recent application of the GIMF model to evaluating the impacts of the US credit crisis on Asia.

(1) Model structure

The world economy in the model consists of four economic blocs: the US, Japan, EEA, and the rest of the world (ROW). There are four types of agents in each region, namely, households, labor unions, firms, and government. Households have finite lives, facing a constant probability of survival, as in the perpetual youth model in line with Blanchard (1985) and Yaari (1965). Households consume a basket of goods and services and exhibit habit persistence in their consumption. The model distinguishes two types of households: forward-looking ones and liquidity-constrained ones. The former own the portfolio of domestic firms. They also hold two types of nominal bonds: domestic bonds issued by the domestic government denominated in domestic currency, and international bonds issued by the US and denominated in US dollars. International bonds are traded only bilaterally with the US and issued in zero net supply worldwide. The liquidity-constrained households do not have access to domestic or international capital markets. They finance their consumption exclusively with current disposable labor and transfer incomes. Firms' investment is subject to adjustment costs, which allow for the variation in Tobin's *q* and generate plausible investment dynamics.

The model assumes a continuum of labor unions in each economic bloc which purchase labor services from households and sell labor to firms.[3] Unions are monopolistic suppliers of differentiated labor inputs to domestic firms and face nominal rigidities in wage setting. They set nominal wages according to constant-elasticity downward-sloping demand schedules and quadratic costs of wage adjustment as in Rotemberg (1982).

The production activity is characterized by monopolistic competition. There is a continuum of firms in the production sector which produce differentiated varieties of products. They set the nominal prices of their products in domestic and exporting markets to maximize the present discounted value of profits. Similar to wage setting, price changes are subject to adjustment costs, which give rise to nominal price rigidities. When exporting, firms set prices in terms of the export-market currency, i.e., traded goods are invoiced in the currencies of the importing economic bloc.

Production technology in each sector is modeled using nested constant elasticity of substitution (CES) and Cobb-Douglas functions. At the top level, the output is produced as a combination of public capital and an aggregate private input using Cobb-Douglas technology. At the second level, the aggregate private input is split into an intermediate input and aggregate primary factor. At the third level, the aggregate primary factor is further disaggregated into private capital and aggregate labor. Finally, at the bottom level, aggregate labor is decomposed into the differentiated labor input by each union. At each level of production, there is a unit cost function that is dual to the CES aggregator function and demand functions for corresponding inputs. The top-level unit cost function defines the marginal cost of sectoral output. The stock of public capital is identical for all firms and provided free of charge to them. As the production function exhibits decreasing returns to scale for private inputs, the return to public capital is distributed to firms as profits.

International trade is modeled using a nested Armington structure, in which domestic absorption is allocated between domestic goods and aggregate imports, and then aggregate imports are allocated across sourcing countries, which determine bilateral trade flows. Demand for domestic and imported goods is expressed as a composite good defined by the Dixit-Stiglitz aggregator over domestic and imported varieties, respectively.

The government collects tax and issues debt to finance its budget deficit. There are five types of tax in the model: labor income tax, capital income tax, sales tax, import tariff, and lump-sum tax on households. Government consumption and investment are exogenous and the lump-sum tax on households is endogenously adjusted to achieve a target path for the

[3] The introduction of labor unions is for model simplification, as aggregation across generations would be difficult if nominal rigidities were faced by households rather than unions.

desired government debt-to-gross domestic product (GDP) ratio. The monetary policy rule in the model follows a Henderson-McKibbin-Taylor rule in which the nominal interest rate depends on the lagged nominal interest rate, the inflation gap and the output growth gap. For EEA, the monetary policy rule is augmented with the gap between actual and desired values of the bilateral nominal exchange rate against the US dollar, reflecting the dollar stabilization regimes in some EEA economies.

(2) Model calibration

The calibration of a dynamic model with the assumption of perfect foresight involves finding a set of data that covers all periods of the model and is consistent with the intra-period and intertemporal equilibria. This set of data needs to replicate the data of the base year and could serve as the dynamic benchmark equilibrium of the model. There could be two alternative calibration strategies here. The first one, the so-called steady state calibration, would consider the base year as a steady state equilibrium and the dynamic benchmark equilibrium of the model as a steady state growth path. The second one would assume that the economy in the base year is a temporal equilibrium along a dynamic adjustment path, that is, the dynamic benchmark equilibrium of the model is a transitional dynamic path to a final steady state (Knudsen et al. 1998; Wendner 1999). Here we follow the second approach and calibrate the model for a non-steady state situation.

The model is calibrated to GTAP database with 2004 as the base year. The GTAP database contains a set of consistent input-output tables and bilateral trade data with detailed country and sector disaggregation. For most elasticity parameters and dynamic adjustment parameters, we draw on the GIMF and other dynamic general equilibrium models in determining their values.

In calibrating the household sector, we assume that in the US, Japan, and ROW the share of liquidity-constrained consumers is 25%. In EEA the share is higher at 40%, reflecting the underdeveloped nature of financial markets in this region. The households are assumed to have a finite planning horizon of 20 years, implying a constant yearly death rate of 5%. In addition, the labor productivity of each generation is assumed to decline throughout his lifetime at an annual rate of 5%. The value of the intertemporal elasticity of substitution is 0.33, slightly higher than those chosen in the GIMF model. The habit persistence parameter for consumption is set to 0.4 as in Kumhof and Laxton (2007). We set the weight parameters of leisure and consumption in the household's utility function in such a way that on aggregate 33% of available time endowment during work years is spent at work in the base year. The rate of time preference in each economic bloc is set to obtain a reasonable net foreign asset position in the steady state.

In the supply side, elasticity of substitution between capital and labor is set at 0.8. The elasticity of substitution between labor varieties, which determines the markup in the labor market, is assumed to be 7.3 in the US, Japan, and EEA and 6.0 in ROW. This assumption implies relatively competitive labor markets in the US, Japan, and EEA. The depreciation rate of capital is assumed to be 8% per year. The data for capital stock in each economic bloc is taken from the GTAP database. The ratio of public capital to GDP is assumed to be 30% in the base year and the elasticity of GDP with respect to public capital is assumed to be 0.1.

Following the literature of business cycle models, the elasticity of substitution between imports and domestic goods, i.e. the Armington elasticity, is set equal to 2.0.[4] The elasticity of substitution between imports across economic blocs is 2.5. Elasticity of substitution

[4] The trade literature on empirical estimation of the Armington elasticity usually found a high value ranging from about 6 to 15, and these estimates are typically used in applied general equilibrium models for trade policy analysis (see, e.g. Hertel et al., 2004). See Ruhl (2003) for a reconciliation of the low elasticity value found in aggregate high frequency time series data with the high elasticity found in cross-section data.

between varieties of goods ranges from 4.3 to 6.0, implying a markup of 20% to 30%. Japan and ROW have relatively high markups while the markups in the US and EEA are lower.

The parameters for nominal rigidity and real adjustment costs that govern the dynamics of the model are drawn from the GIMF and the Global Economic Model (GEM) of the IMF. In the monetary policy rule, the weights for the inflation gap and the output growth gap are both set at 0.5. For EEA, the weight on the changes in the exchange rate is set to 1. In the simulations for fiscal stimulus below in Section 3, an alternative accommodative monetary policy rule is used with a zero weight for the output growth gap and the weight(s) on other gap(s) unchanged.

In the baseline scenario for model calibration, EEA is assumed to have a higher growth rate of productivity in initial periods. Its labor-augmented productivity grows at 10% in the base year and gradually declines to the global average growth trend of 3% after 25 years. In contrast, productivity growth in Japan is assumed to rise from 1.6% in the base year to 3% in the period after 25 years. The consumer price index (CPI) inflation target is set to 2% per annum for all regions. Time preference rates in the base year are endogenously determined in the baseline scenario to match the base year consumption in each economic bloc. These base year time preference rates are assumed to gradually converge to their long-run values within 40 years. Similarly, a constant adjustment parameter for Tobin's *q* is added to the arbitrage equation for each sector's *q* to reproduce the baseline-scenario investment level in the base year.[5]

3. SIMULATION SCENARIOS

To explore the implications of the global financial crisis for East Asia, we simulate five scenarios. All these scenarios are simulated in a cumulative fashion, so that the second scenario includes the first as well as the second shocks; the third includes the first, second, and third shocks; and so on.

The first scenario examines the effects of an economic crisis confined to the US alone. It assumes a US recession induced by a collapse of domestic investment and consumption. In this scenario, US households are assumed to be more concerned about their future—their desire to save increases and their consumption declines. In the model this is represented by lowering forward-looking households' time preference by two percentage points per annum permanently. In addition, we assume the risk premium of investors in the US to rise by five percentage points for the next three years and gradually decline after that until it vanishes in another three years. This scenario simulates a temporary drop in domestic demand in the US triggered by the financial crisis.

The second scenario looks at a world-wide financial crisis which goes beyond the US recession. It assumes, in addition to the US, all other regions also experience a fall in consumption and investment due to the contagion through financial and confidence channels. The shocks in non-US regions are assumed to be half of that in the US, i.e., a one percentage point reduction in households' time preference rate and a two and a half percentage points rise of the risk premium of investors.

The third scenario considers the impacts of globally concerted expansionary fiscal policies to deal with the global financial crisis. We assume a global fiscal stimulus package under which all countries increase government spending by 2% of GDP over a two-year period. Such government spending is assumed to be distributed evenly between government consumption and investment. The fiscal stimulus is assumed to be temporary, as in the period following the expenditure expansion, lump-sum taxes adjust to return the government debt-to-GDP ratio back to its baseline value over time. As monetary policy can play an

[5] This constant adjustment parameter can be interpreted as risk premium. See McKibbin and Wilcoxen (1998) for a similar treatment in their multi-sectoral, intertemporal G-Cubed model.

important role in determining the effects of fiscal expansion, the simulations here explore two types of a monetary policy rule for the two years of fiscal stimulus, that is, the standard interest rate rule in our benchmark model and an accommodative interest rate rule. The standard interest rate rule has equal weights on the inflation gap and the output growth gap, while the accommodative interest rate rule has a zero weight on the output growth gap. Given that fiscal expansion tends to raise both output and inflation, the interest rate hikes are smaller in the latter policy rule, suggesting a more accommodative monetary policy in the face of fiscal stimulus.

The final two scenarios look at the impact of other types of policy measures designed to rebalance growth in EEA. The fourth scenario examines the role of exchange rate policy. It assumes that EEA allows large currency movements against the US dollar by putting a zero weight on the exchange rate gap in its monetary policy reaction function. The fifth scenario postulates that, in addition to greater exchange rate flexibility, EEA boosts its domestic consumption and investment through structural reforms. Instead of specifying the exact nature for these structural reforms, we capture their effects using a permanent one percentage point increase in the time preference rate of EEA's forward-looking households and a one percentage point reduction of its investors' risk premium. These two scenarios simulate a partial global rebalancing initiative led by the adjustment in EEA.

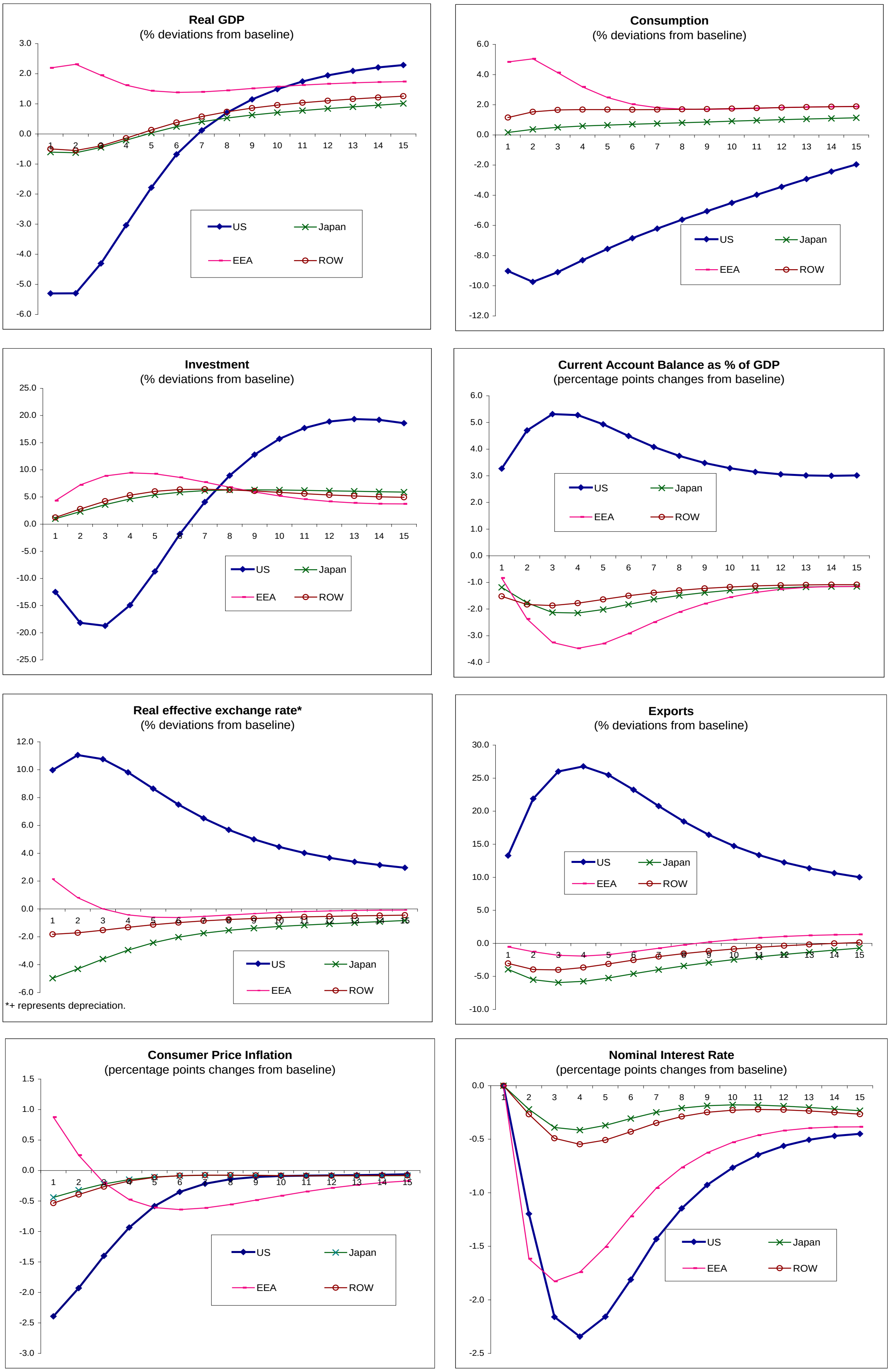
(1) US recession

The macroeconomic effects of a US recession—the combined negative investment and consumption shocks—are reported in Figure 1. The US recession leads to a sharp output loss in the US, with real GDP falling by around 5% in the first two years compared with the baseline. The GDP reduction is tempered after that and output begins to expand after seven years, driven by stronger net external demand and the recovery in investment. As to the components of domestic demand, investment exhibits greater volatility than consumption. It contracts by around 15% in the initial years and then, along with the diminished investment risk premium, expands by nearly 20% after 12-15 years. In comparison with investment, the change in private consumption is more modest, but still significant. The consumption of US households declines by 9% in the first three years, but begins to increase after fifteen years because of the expanded output and income.

As the shrinking domestic absorption significantly drags down imports, the US current account as a ratio to GDP improves by around five percentage points in the first five years. This improvement in the current account gradually diminishes to 3% of GDP in the medium-term. The falling US demand depresses US domestic prices relative to foreign prices, leading to a real depreciation of the US dollar. The real effective exchange rate of the US dollar weakens by 10-12% initially relative to the baseline. The US dollar depreciation moderates to 3% in fifteen years. The more rapid recovery of domestic demand relative to supply implies an excess demand in the medium term, thereby moderating the pace of US dollar depreciation.

The dynamics of prices are driven by supply and demand conditions, the degree of nominal rigidities, and monetary policy reactions. In tandem with the initial demand collapse, inflation falls by two percentage points initially. After five years, the drop in the inflation rate narrows to less than half of a percentage point. Lower inflation leads to a lower interest rate—through the Taylor rule-based monetary policy—causing larger interest differentials between the US and other economic blocs, which reinforces the initial US dollar depreciation. Nominal exchange rate changes are the major channel to achieve real exchange rate adjustment, reflecting the sluggish price responses, and the effects of inflation targeting and flexible exchange rates.

Figure 1: Impacts of US Recession



Source: Authors' model simulations.

Reduced US import demand leads to trade spillover effects, with all other economic blocs experiencing falling external demand in comparison with the baseline. The extent of these spillovers in different economic blocs depends on their respective trade dependence on the US. Generally, economies with larger export exposure to the US are more severely impacted than those less dependent on the US market. However, exchange rate policy also plays a significant role in determining the impact of trade spillovers of the US recession. This is evident from the divergent movements in real exchange rates in initial years between Japan (and ROW) and EEA. As shown Figure 1, while both Japan and ROW experience large real appreciation initially, the real exchange rate of EEA depreciates in the first three years because of the non-zero weight on the gap of the nominal exchange rate against the US dollar in its monetary policy rule. Consequently, the export and current account balance of EEA only decline slightly in the initial two years, in contrast to those in Japan and ROW.

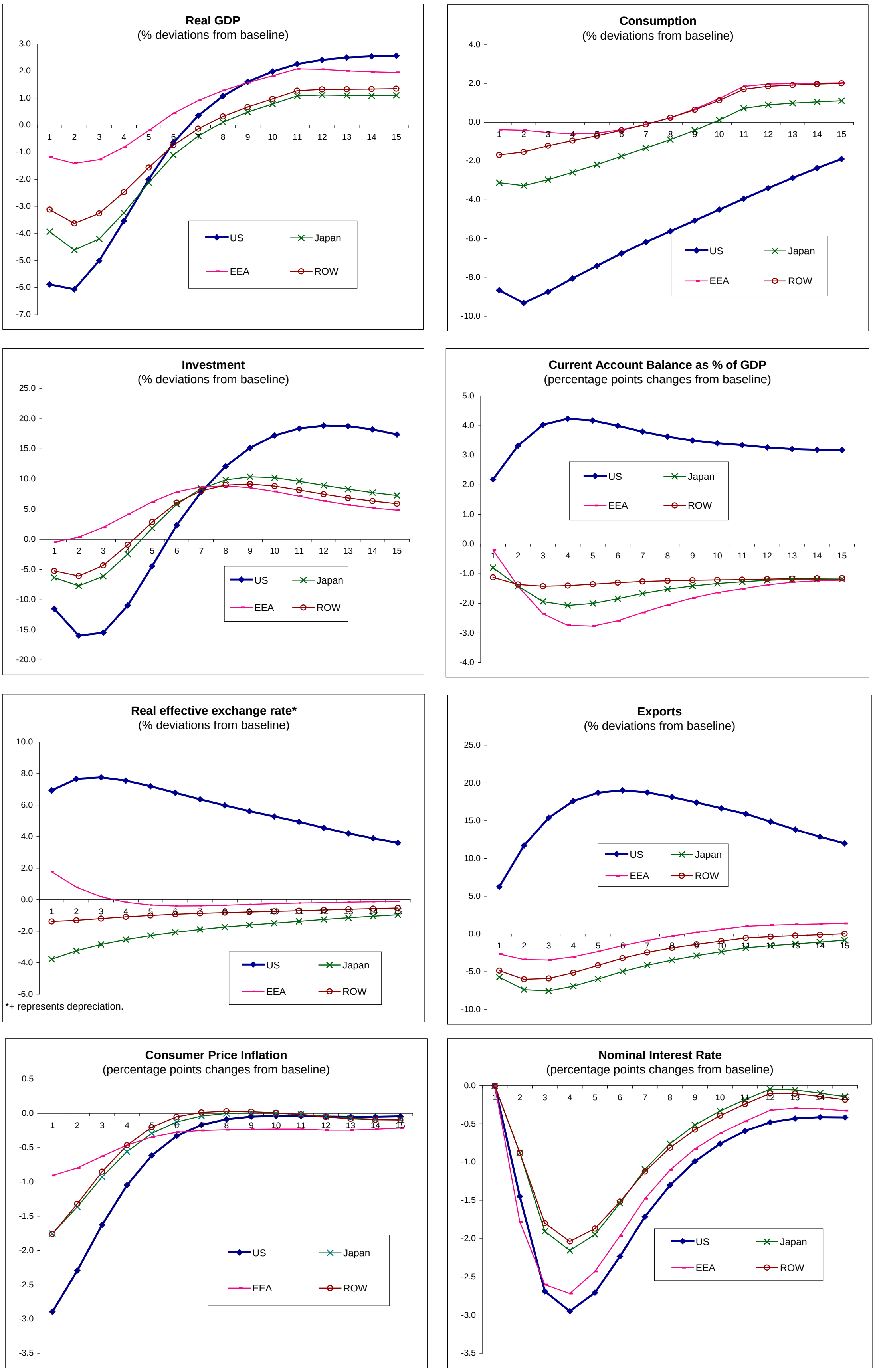
Beside the trade channel, international capital markets offer another channel though which the US recession impacts the world economy. The declining US import demand lowers the profitability of investment in the short run, leading to a tendency to reduce investment everywhere. However, investment may be boosted by the declines in real interest rates, made possible by monetary policy reactions in the short run and higher US savings in the longer term. The combined net effect is an investment rise in all the three non-US regions. In Japan and ROW, investment rises by 0.5-0.8% in the first year and 5-6% in the seventh year. In EEA where the exchange rate target in its monetary policy rule leads to a sharp drop in the nominal interest rate, investment expands by 5-10% in the initial six years in comparison with the baseline. Lower interest rates also stimulate consumption in EEA and ROW. In Japan, private consumption falls in the first year and rises only slightly from then on, mainly due to its relatively larger drops in employment and labor income. Given that Japan is a net holder of US-dollar bonds, the negative revaluation effect arising from US dollar depreciation also contributes to its consumption weakness.

As the trade and capital flow effects partly offset each other, the net effect of the US recession on output in other regions are relatively modest, standing around a 1% decline in the first four years in Japan and ROW. EEA's real GDP expands by 2-3% in the initial years, at the expense of higher inflation, due to its policy of partially stabilizing the exchange rate against the US dollar. Consistent with other studies such as McKibbin and Stoeckel (2009), our results suggest that a recession in the US alone would have small negative impacts on the world economy. A US recession can even raise economic growth in the short run in economies whose exchange rates are relatively stable against the US dollar through real effective currency depreciation. Of course given the pivotal role of the US in the global financial market, the contagion effect leads to a world-wide demand slowdown.

(2) A global financial crisis

The results of the scenario of the global financial crisis are reported in Figure 2. Given that the US has small external trade exposure relative to its GDP, the world-wide demand slowdown brings only modest additional impacts on the US economy in comparison with the scenario of US only recession. However, for other regions, the contagion-induced demand drops cause significant impacts on their domestic economy. Both consumption and investment fall in initial years in comparison with the baseline in Japan and ROW, leading to a sharp contraction in their real GDP. CPI inflation drops by as much as two percentage points initially in these two regions. In EEA, despite a larger drop in the nominal interest rate in response to lower inflation, consumption hardly expands in the first six years and investment increases only by 2% or so initially. As a result, EEA's real GDP shrinks by 1% in the first three years in comparison with the baseline.

Figure 2: Impacts of the Global Financial Crisis



Source: Authors' model simulations.

Global trade is also negatively impacted by the declining demand in the wake of a global financial crisis. With a relatively sharper drop in domestic demand, the US dollar depreciates against other currencies and, consequently, the US's exports increase by around 10-15% relative to the baseline. However, all other regions experience declines in exports in initial eight years, ranging from around 3% for EEA and around 7% for Japan. The relatively smaller export decline in EEA is mainly a result of its monetary policy, which partially stabilizes its currency to the US dollar. As shown in the figure, the real effective exchange rate of EEA actually depreciates in the first two years in the wake of the global financial crisis. Despite a relatively modest drop in exports, EEA's current account surplus shrinks by nearly 3% of its GDP, a larger relative decline than that in Japan and other regions of the world, due to the region's large volume of exports relative to GDP.

(3) Global fiscal expansion with alternative monetary policy rules

The third scenario assumes that all economic blocs in the world increase government spending—by 2% of GDP—for two years, while following their respective monetary policy rules. Figure 3A presents the dynamic impacts of globally concerted fiscal stimulus packages under the benchmark monetary policy rule, which are plotted as changes from the second scenario—i.e., the scenario of a global financial crisis. The benchmark monetary policy rule follows the standard Taylor rule, except in EEA where the interest rate responds positively to the exchange rate gap as well as the inflation and output growth gaps. With the temporary fiscal expansion all over the world, real GDP, consumption and investment all rise during the period of fiscal stimulus and beyond. The increase in real GDP during the two years of fiscal expansion is around 1.5%, suggesting fiscal multipliers of 0.75. Real GDP drops by around 0.2% after the completion of fiscal stimulus, but begins to expand by around 0.5% after six years, largely due to the larger stock of public capital. Increased fiscal expenditures lead to more employment and higher wages, boosting private consumption. EEA experiences the largest rise in private consumption during the period of fiscal expansion, reflecting its higher share of liquidity-constrained households. During the years of fiscal stimulus, private investment drops by around 4% in the US, Japan, and ROW, and more than 2% in EEA reflecting the crowding-out effects through rises in interest rates. However, private investment enjoys larger gains in the medium and long run, thanks to the long-term crowding-in effect of public investment.

Current account balances and real exchange rates are generally little impacted by the world-wide fiscal expansion. Fiscal deficits in the two expansion years widen by 1.7-1.8% of GDP, as government spending of 2% of GDP is offset by additional tax revenues due to faster economic growth. Consequently, the ratio of government debt to GDP rises only by two to three percentage points in the fourth year, then gradually fall to the baseline level with increases in household lump-sum tax.

Figure 3B presents the effects of global fiscal stimulus under the accommodative monetary policy rule, where the interest rate responds only to the inflation gap (and the exchange rate gap in EEA). With monetary accommodation, inflation is generally higher and the real interest rate is lower, which facilitates the expansion of consumption and investment. As a result, there is almost no crowding out of fiscal spending. This is in sharp contrast with the simulation results under the benchmark monetary policy rule—as shown in Figure 3A—where private investment during the years of fiscal expansion is negatively affected, showing evidence of strong crowding-out effects of public expenditure.

To deepen our analysis of the impact of globally concerted fiscal stimulus, we have run separate simulations under which each economic bloc alone engages in fiscal stimulus. Table 1 summarizes the fiscal multipliers of individual regions' fiscal actions and of worldwide fiscal actions. Several interesting observations can be made. First, the fiscal multipliers rise significantly by moving from the benchmark to the accommodative monetary policy rule in every region of the world. Under the benchmark rule, the fiscal multipliers are in the range of 0.55 (Japan) to 0.80 (EEA), while under the accommodative rule they rise to the range of 1.01 (EEA) to 1.42 (US). This can be explained by the change in the interest rate rule from the one that responds to the output growth gap (benchmark rule) to the one that does not (accommodative rule). Under the benchmark rule, the interest rate rises in response to both the inflationary pressure and output expansion (and declines in response to exchange rate appreciation in EEA) arising from fiscal stimulus, while under the accommodative rule the interest rate rises less responding only to the inflationary pressure (and declines in response to exchange rate appreciation in EEA). In other words, the smaller interest rate increase makes the fiscal multipliers larger under the accommodative rule than under the benchmark monetary policy rule.

Table 1: Comparison of Fiscal Multipliers by Economic Bloc

	Stimulus in				
	US	Japan	EEA	ROW	World
Benchmark monetary policy rule					
US	**0.61**	0.02	0.03	0.15	0.81
Japan	0.08	**0.55**	0.06	0.12	0.81
EEA	-0.30	0.06	**0.80**	0.24	0.80
ROW	0.10	0.02	0.04	**0.62**	0.78
World	0.20	0.08	0.11	0.40	**0.79**
Accommodative monetary policy rule					
US	**1.42**	0.13	0.15	0.28	1.65
Japan	0.18	**1.37**	0.21	0.23	1.64
EEA	0.23	0.14	**1.01**	0.33	1.48
ROW	0.15	0.09	0.12	**1.30**	1.45
World	0.52	0.25	0.23	0.80	**1.53**

Note: Fiscal multiplier is defined as a percentage change in GDP induced by fiscal expansion of 1% of GDP.

Source: Authors' model simulations.

Second, the extent of the rise in fiscal multipliers, associated with a move from the benchmark to the accommodative policy rule, varies across regions in the world; fiscal multipliers rise the least in EEA (from 0.80 to 1.01) while those in other regions rise much more substantially (e.g., from 0.61 to 1.42 in the US). This can be explained by the specific interest rate rule chosen for EEA, i.e., the inclusion of the exchange rate gap, as well as this region's large trade leakage from its imports. Under either monetary policy rule, EEA's interest rate would rise the least among the four regions in the world because the interest rate rise resulting from the positive inflationary gap (and the output growth gap under the benchmark rule) associated with fiscal expansion would be partly offset by the interest rate decline resulting from the real currency appreciation pressure. Under the benchmark monetary policy rule, EEA's own fiscal multiplier is 0.80, the largest among the four regions in the world. In this rule, even though the impact of fiscal expansion would leak out most substantially in EEA to other regions due to its having the highest ratio of imports to GDP, the favorable effect of the interest rate change dominates the unfavorable trade leakage effect, thereby making EEA's fiscal multiplier the largest in the world. Under the accommodative monetary policy rule, however, EEA's own fiscal multiplier is 1.01, the smallest among the four economic blocs. This is explained by the fact that the favorable interest rate effect is more than offset by the unfavorable trade leakage effect. That is, although EEA's interest rate rises the least, in response to its own fiscal expansion, among the four regions in the world, the large trade leakage effect dominates the interest rate effect, thereby making EEA's fiscal multiplier the smallest in the world.

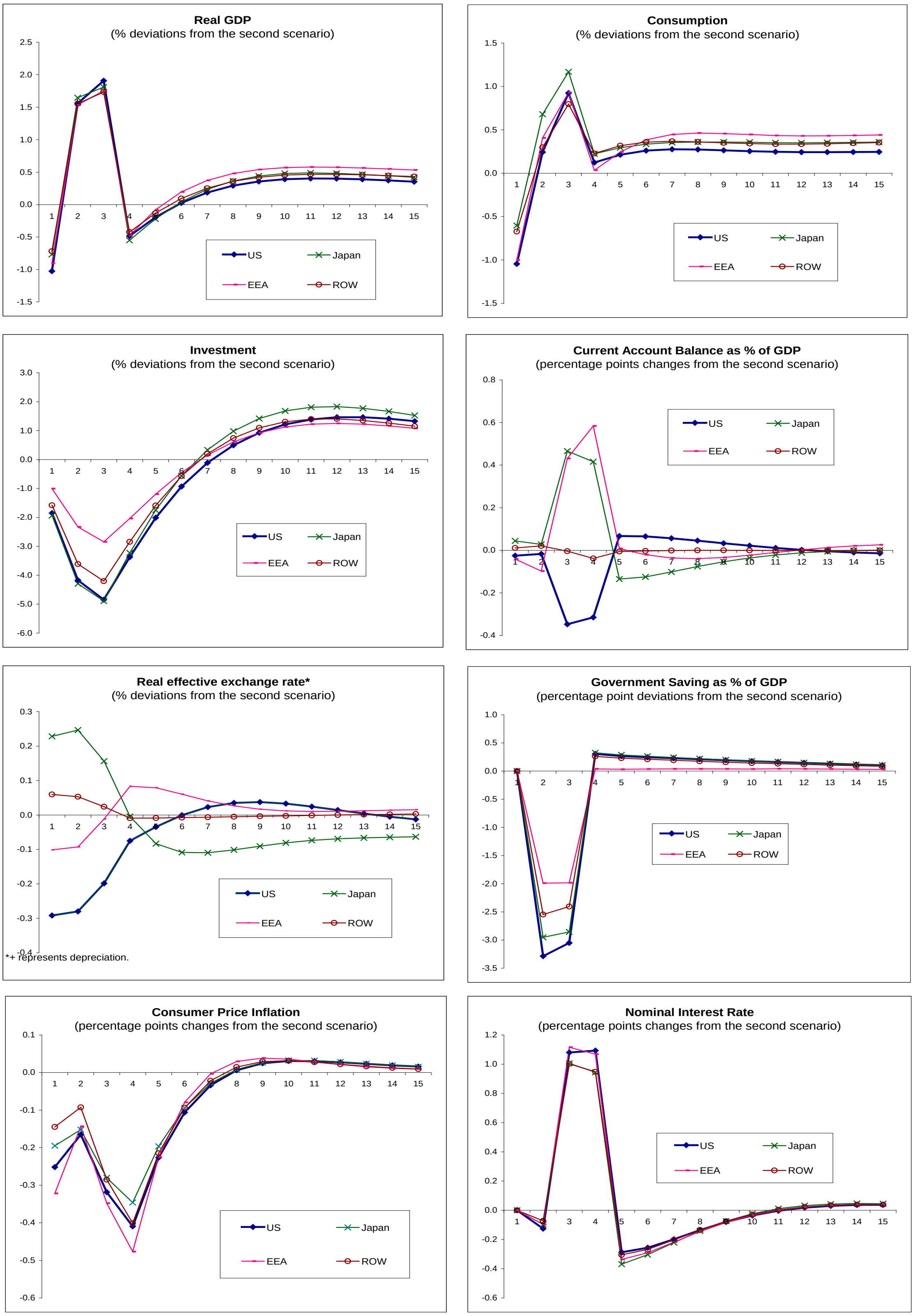
Finally, under the accommodative monetary policy rule, nearly 30% of the impact of the global financial expansion on EEA's fiscal multiplier effect comes from the stimulus in other regions. This suggests that, under an accommodative global monetary policy environment, a globally coordinated fiscal stimulus action will be desirable for EEA (as well as for other economic blocs in the world).

(4) Exchange rate flexibility in emerging East Asia

The results of the fourth scenario—impacts of increasing exchange rate flexibility of the EEA currency vis-à-vis the US dollar—are presented in Figure 4A. As a result of dropping the exchange rate target in its monetary policy rule, EEA's nominal exchange rate appreciates against the US dollar by 7.3% and 4.8% respectively in the first and second years. An appreciating exchange rate leads to falling exports and, consequently, shrinking aggregate demand. With excess supply over demand, CPI inflation falls by around three percentage points in the initial two years. Because of differential inflation rates between EEA and other regions in the world, EEA's real effective exchange rate appreciates 2.5% and 1.2% in the first and second years.

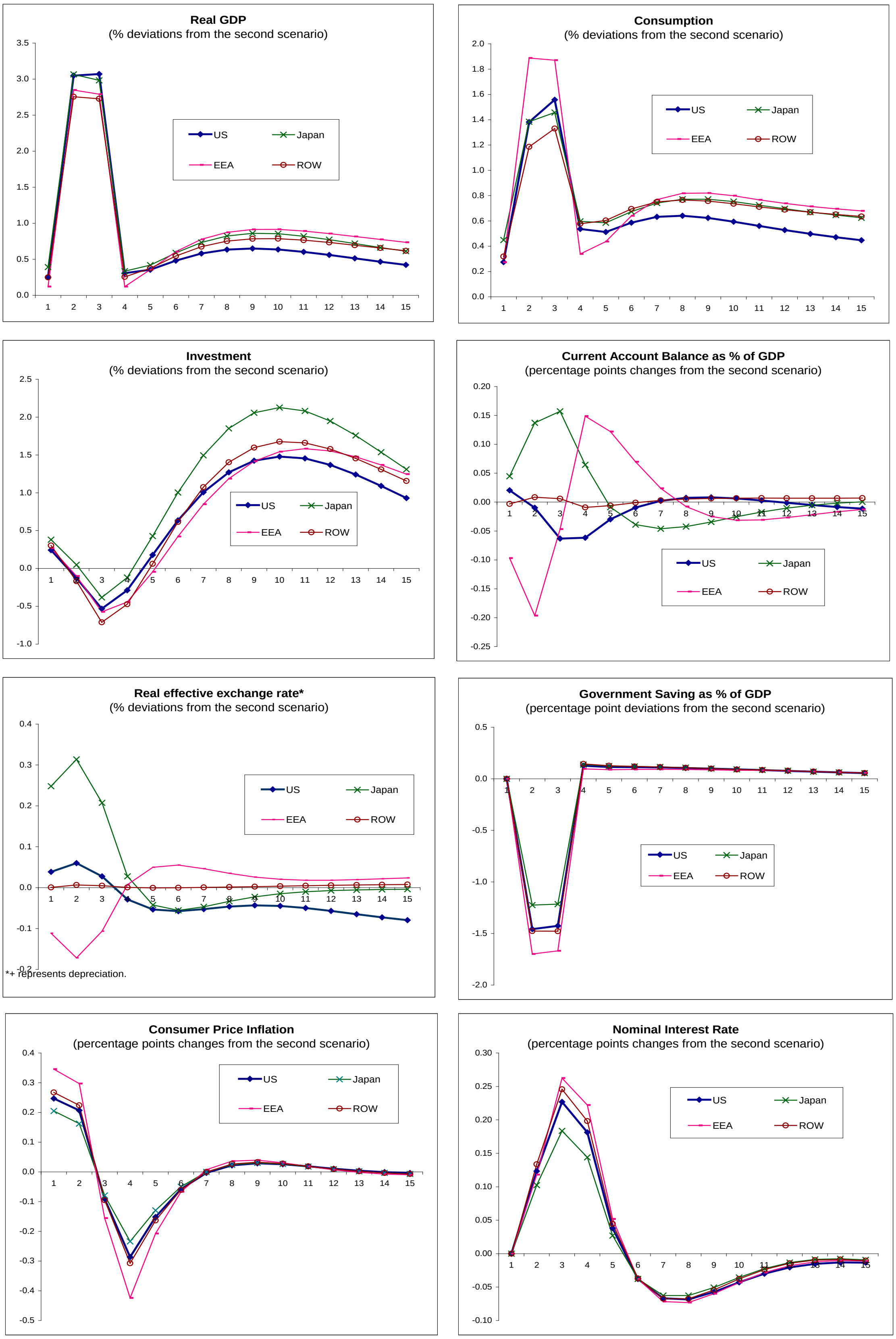
EEA's exports fall by 2% in the first two years after introducing full exchange rate flexibility, then gradually recover and begin to expand in the fifteenth year. It might be surprising that EEA's imports also decline at around the same pace as exports, despite currency appreciation inducing a substitution toward cheaper imports. The falling income associated with output contraction, as well as the rising real interest rate due to lower inflation, lead to weaker domestic demand. As shown in Figure 4A, EEA's investment and consumption fall by 3-4% in the initial two years, dampening demand for imports. As a result, EEA's current account surplus declines only by 0.8% of GDP in the first year. Reflecting the importance of export demand in EEA economies, this economic bloc experiences a large and sustained GDP contraction in the wake of its currency appreciation.

Figure 3A: Impacts of Global Fiscal Expansion under the Benchmark Monetary Policy Rule



Source: Authors' model simulations.

Figure 3B: Impacts of Global Fiscal Expansion under the Accommodative Monetary Policy Rule



Source: Authors' model simulations.

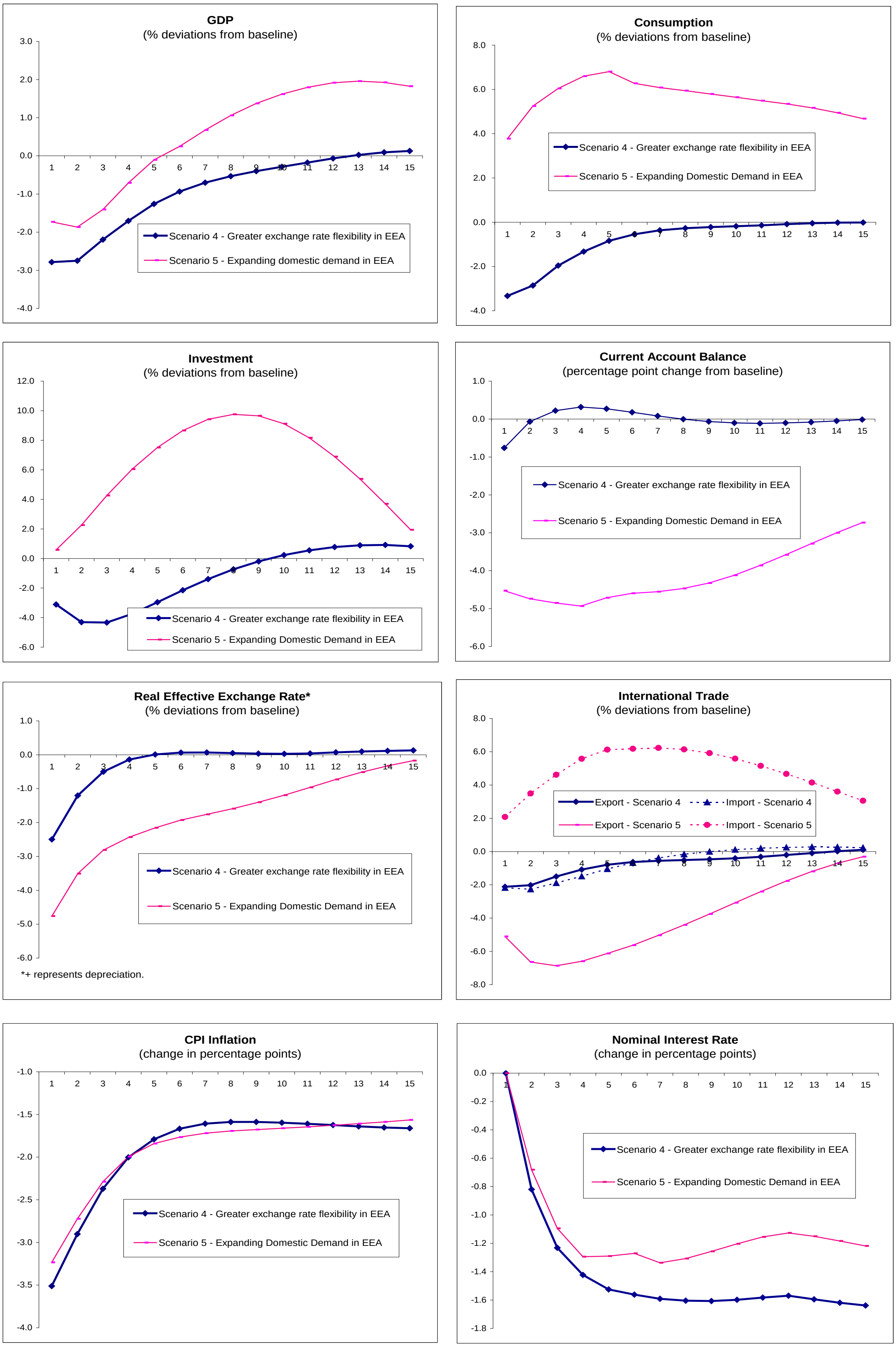
Despite the relatively large effect on its own economy, EEA's currency appreciation has only modest impacts on other regions, as indicated in the left panel of Figure 4B. Given its strong economic linkage with EEA, Japan experiences the largest contraction in trade, with a 0.8% decline in exports and a 0.5% decline in imports in the initial two years. The US is less impacted and ROW is the least impacted, consistent with their limited respective export dependence on EEA. As both exports and imports shrink, the current account balances of the US, Japan, and ROW change little following EEA's introduction of full exchange rate flexibility and currency appreciation. Consequently, the impacts on their real GDP range from 0.20% to 0.35% in the initial years and are less than 0.1% annually afterwards.

(5) Expanding regional demand in emerging East Asia

The results of our fifth scenario—EEA's domestic demand expansion in addition to its full exchange rate flexibility—are plotted in Figure 4A and the right panel of Figure 4B. As shown in Figure 4A, the rise in domestic consumption and investment partly offsets the negative impacts from currency appreciation on EEA's output, resulting in a smaller initial loss in GDP compared with the fourth scenario. As stronger domestic demand sucks more imports and discourages exports, the imports of EEA rise by 2-6% and its exports fall by around 6% initially. As a result, the current account surplus of EEA declines by 5% of GDP over a period of decade. Reflecting the changes in relative prices induced by the demand expansion in EEA, the real effective exchange rate of the EEA currency appreciates much more—by around 4% initially—than in the fourth scenario.

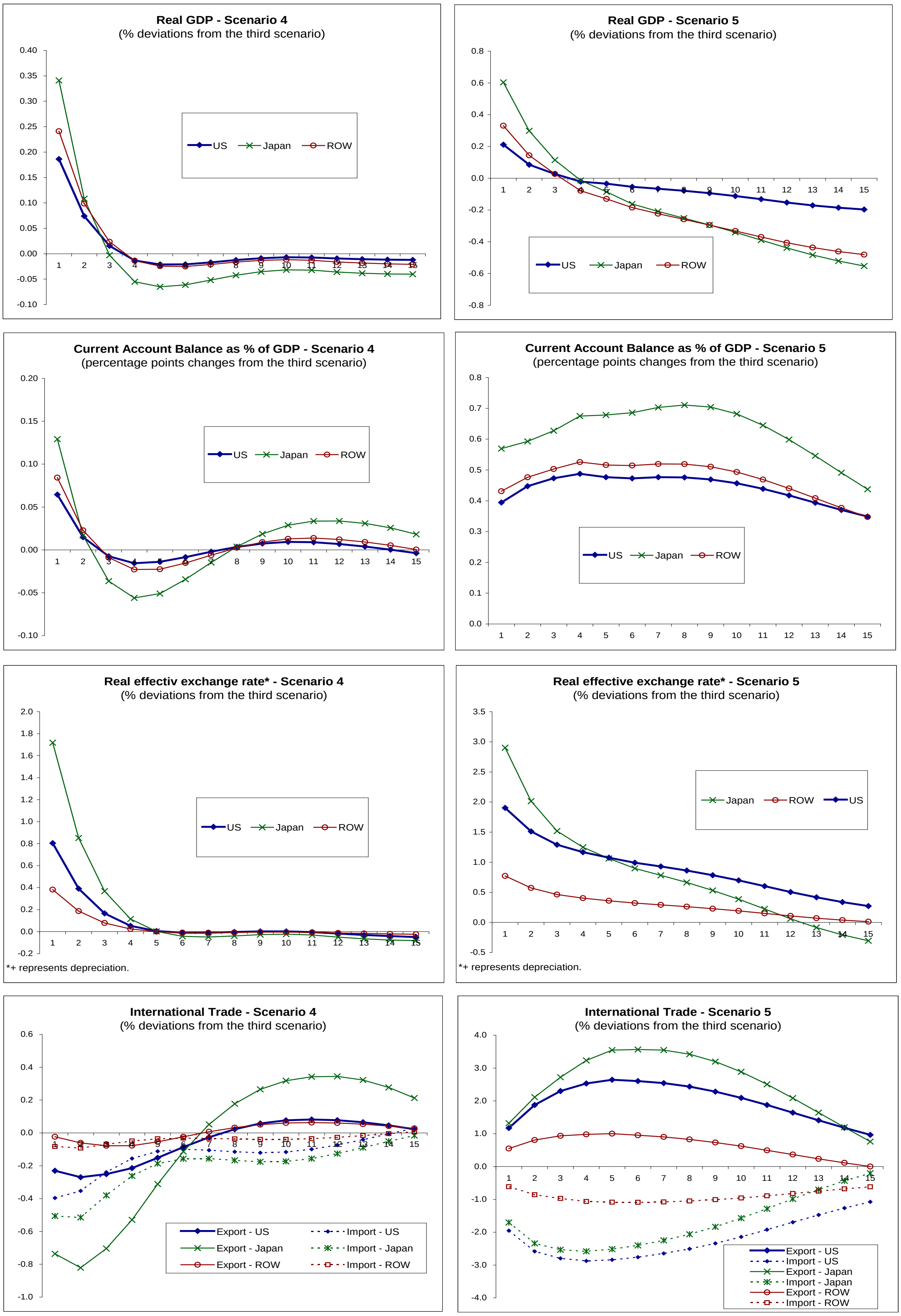
The deterioration in EEA's current account balance is mirrored in the improvement in the current account balances in other regions of the world. As shown in the right panel of Figure 4B, the current account balances of the US, Japan, and ROW improve by 0.4-0.6% of their respective GDP. Although US experiences larger export expansion in comparison to ROW, its gain in the current account balance is smaller due to its lower trade dependence. Rising net exports in non-EEA regions stimulate their GDP growth in the short run, but declining domestic demand soon dominates the improvement in net exports, resulting in GDP contraction from the fourth year onwards. The reason is that rising domestic demand in EEA reduces its trade surplus and, hence, net capital outflows, pushing up real interest rates globally. With the negative effect of higher real interest rates on investment and consumption dominating the improvement in net exports, real GDP contracts in the US, Japan, and ROW over the medium term. This result highlights the importance of the general equilibrium impacts on international capital flows in analyzing the long-term implications of adjustment in global current account imbalances.

Figure 4A: Impacts of EEA's Growth Rebalancing Policies on EEA



Source: Authors' model simulations.

Figure 4B: Impacts of EEA's Growth Rebalancing Policies on Other Regions



Source: Authors' model simulations.

4. CONCLUSIONS

This paper has examined the implications of the global financial crisis, emanating from the US, and of a global fiscal stimulus package as well as EEA's dynamic adjustment toward global rebalancing. Especially, using a calibrated global dynamic general equilibrium model, we have simulated the scenarios of a US recession, a global recession, worldwide expansion in fiscal spending, and EEA's rebalancing policies—such as introducing full exchange rate flexibility and expansion in regional demand. Simulation results of the first two scenarios suggest that a financial crisis, if confined to the US alone, would have only small negative impacts on the world economy. A global financial crisis, which spreads demand contraction from the US to other regions in the world, would cause a slowdown in economic growth and trade all over the world. But the negative impacts are not evenly distributed across regions. Because of its exchange rate regime that stabilizes the currency against the US dollar, EEA is least impacted by a financial crisis, whether in the US alone or world-wide, in terms of output.

We have also investigated the effects of global fiscal stimulus in response to the crisis. With a global fiscal stimulus package of 2% of GDP for two years, world GDP is likely to be lifted by 2.0% and 3.0% during the period of fiscal expansion under the benchmark and accommodative monetary policy rules, respectively. This result suggests that fiscal stimulus combined with an appropriate monetary policy rule can serve as an important stabilizer for the world economy during the crisis. For EEA economies, given their high level of trade dependence, globally coordinated fiscal stimulus would be much more desirable than acting just on its own.

With its large current account surplus and increasing importance in the world economy, EEA's growth rebalancing policy is an important component of the global effort to unwind the global imbalance. The exchange rate inflexibility in EEA is widely regarded as a major impediment to global rebalancing. Our simulation results show that exchange rate flexibility alone in EEA would not contribute much to the correction of its current account imbalance. Given EEA's highly export-dependent growth pattern, its currency appreciation would lead to large output and income losses, depressing its appetite for imports and reducing its current account surplus by only 2% of GDP. Other types of policies—particularly of a structural reform nature—to boost regional demand, supported by greater flexibility in the regional currency, would be needed to have a much larger and persistent impact on EEA's current account.

Indeed, an appreciation of 5% in EEA's real effective exchange rate, driven by its domestic demand expansion and nominal currency appreciation, is likely to reduce its own current account balance by 5% of GDP. However, without any adjustment in any other country, this change in EEA's current account will be largely evenly distributed among other regions of the world. The simulation results show that the US current account deficit narrows only by 0.5% of GDP under this scenario, hardly correcting the US and, hence, global imbalances. Although the global economic impact of EEA is growing, its rebalancing policy has limited impact globally, suggesting the need for policy actions on the part of the US in reducing its own current account deficit. Essentially, both the current-account surplus and deficit economies should implement their respective policies in order to reduce the global imbalance and achieve sustained global economic growth.

Several important limitations of our modeling exercises should be mentioned. First, our model does not explicitly incorporate the linkages through global financial markets and the mechanisms of co-movements in asset prices. As they are important transmission channels through which the US recession may drag down the EEA and world economies, our results likely underestimate the impacts of the US and global financial crises on the Asian economies. Second, the global financial crisis and the need for global rebalancing would require EEA economies to shift demand from external to internal sources. Using a static multi-sectoral general equilibrium model, our previous work has shown that, given the different product composition in domestic and external demand, this would involve substantial structural shifts in their production activities (Kawai and Zhai, 2009). Without sectoral disaggregation, our model does not fully capture the role of structural adjustment and the associated adjustment costs required for growth rebalancing. A dynamic general equilibrium model incorporating detailed sectoral disaggregation—including tradables and non-tradables sectors—and inter-sectoral labor adjustment frictions would better serve the detailed analysis of dynamic impacts of the global financial crisis. Finally, recent advances in trade theory have emphasized the importance of the extensive margin in trade adjustment. Incorporating firm heterogeneity and dynamics of firm entry and exit into the traditional framework of new open economy macroeconomics model may somewhat alter the analytical results, and provide new insights about the implications of global financial crisis and rebalancing.[6]

[6] See Bilbiie, Ghironi, and Melitz (2007) and Kumhof, Laxton, and Naknoi (2009) for the incorporation of firm dynamics into dynamic stochastic general equilibrium models. Corsetti, Martin, and Pesenti (2008) analyzed the exchange rate adjustment to correct the global imbalance in consideration of endogenous firm entry and new varieties of exports of goods and services, suggesting milder exchange rate adjustments for reducing US current account deficits.

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APPENDIX: MODEL SPECIFICATION

Basic Setup

The model economy consists of four regional blocs, which are indexed by *r* or *s*. Each region is populated by overlapping generations households with finite planning horizons as in Blanchard (1985). Households are indexed by age *a.* In each region there are a continuum of firms and a continuum of labor unions, which are indexed by $n \in [0,1]$ and $\mu \in [0,1]$, respectively. The time index in the model is *t*.

The model assumes the presence of an exogenous trend in labor productivity growth (at rate *g-1*). For a clear separation of an endogenous dynamic from an exogenous trend, we present all variables in detrended form through division by *g*. In each region the CPI is the numéraire of the economy and all national prices are expressed in terms of domestic consumption units.

In the model described below, subscripts denote region and/or time. The time index, *t*, is omitted when all variables in an equation are with the same time index. Regional subscript, *r*, is also omitted where doing so does not lead to confusion.

Demand and Trade

Domestic demand in each region comprises consumption and investment by households, firms and government. A composite good, *XA*, is used for final and intermediate demand. This composite good is a constant elasticity of substitution (CES) aggregation of domestic goods, *XD*, and aggregate imports, *XM*.

$$XA = \left(\left(\alpha^d\right)^{1/\sigma^m} (XD)^{(\sigma^m-1)/\sigma^m} + \left(\alpha^m\right)^{1/\sigma^m} (XM)^{(\sigma^m-1)/\sigma^m} \right)^{\sigma^m/(\sigma^m-1)} \tag{1.}$$

where σ^m is the elasticity of substitution between imports and domestic goods. The Armington share parameters α^d and α^m reflect the preference of agents biased for home or imported products. The sales price for composite good, PA, is the tax-included dual price index defined over the prices of domestic and imported goods, *PD* and *PM*, respectively:

$$PA = \left(1+\tau^s\right)\left(\alpha^d (PD)^{1-\sigma^m} + \alpha^m (PM)^{1-\sigma^m}\right)^{1/(1-\sigma^m)} \tag{2.}$$

where τ^s is the sales tax rate.

The demand functions generated from (1) and (2) are:

$$\frac{XD}{XA} = \alpha^d \left(\frac{PA}{(1+\tau^s)PD} \right)^{\sigma^m} \tag{3.}$$

$$\frac{XM}{XA} = \alpha^m \left(\frac{PA}{(1+\tau^s)PM} \right)^{\sigma^m} \tag{4.}$$

Aggregate import demand, *XM*, is a CES aggregation of imports from each region, i.e.:

$$XM_s = \left(\sum_{r \in R} \left(\alpha_{rs} \right)^{1/\sigma_s^w} \left(XE_{rs} \right)^{(\sigma_s^w - 1)/\sigma_s^w} \right)^{\sigma_s^w / (\sigma_s^w - 1)} \quad (5.)$$

where α_{rs} is the preference of agents in region s biased for goods imported from region r; XE_{rs} represents the quantity of goods produced in region r and sold in (or exported to) the market of region s; and σ^w is the second-level Armington elasticity of substitution among imports from different regions. The dual price index of aggregate import, PM_s, is defined over the prices of each import supplier or export goods producer, PE_{rs}:

$$PM_s = \left(\sum_{r \in R} \alpha_{rs} \left(\frac{\varepsilon_s}{\varepsilon_r} (1 + \tau_{rs}) PE_{rs} \right)^{1 - \sigma_s^w} \right)^{1/(1 - \sigma_s^w)} \quad (6.)$$

where τ_{rs} is the tariff rate imposed on imports from region r and ε_r is the CPI-based real exchange rate of region r, expressed as the price of one unit of US consumption in terms of domestic consumption in region r.

The demand function generated from (5) and (6) is:

$$\frac{XE_{rs}}{XM_s} = \alpha_{rs} \left(\frac{\varepsilon_s}{\varepsilon_r} \frac{(1 + \tau_{rs}) PE_{rs}}{PM_s} \right)^{\sigma_s^w} \quad (7.)$$

Each firm is assumed to produce a differentiated product and each variety is an equally imperfect substitute for all others across all varieties. The goods produced are either domestically demanded or exported. The aggregate demand for domestic goods, *XD*, and aggregate exports, *XE,* are further decomposed into demand for variety provided by each firm, following the standard Dixit-Stiglitz framework:

$$\frac{xd_{n,s}^n}{XD_s} = \left(\frac{pd_{n,s}}{PD_s} \right)^{\sigma_s^f} \quad (8.)$$

$$\frac{xe_{n,rs}^n}{XE_{rs}} = \left(\frac{pe_{n,rs}}{PE_{rs}} \right)^{\sigma_s^f} \quad (9.)$$

where $xd_{n,s}^n$ represents the demand in region s for domestic good variety n produced in region s; $xe_{n,rs}^n$ represents the demand in region s for export variety n produced in region r; $pd_{n,s}$ is the price of domestic good variety n set by the firm in region s; $pe_{n,rs}$ is the price of export variety n in market s set by the firm located in region r; and σ^f is the substitution elasticity among varieties of each firm.

Firms

Production technology of firms is modeled using a nested CES function. At the top level, the output is produced as a combination of public capital and an aggregate private input using Cobb-Douglas technology. At the second level, the aggregate private input is split into an intermediate input and an aggregate primary factor. At the third level, the aggregate primary factor is further disaggregated into a bundle of private capital and aggregate labor. Finally, at the bottom level, aggregate labor is decomposed into the differentiated labor input by each union. The stock of public capital is identical for all firms and provided free of charge to them. As the production function exhibits decreasing returns to scale for private inputs, the return to public capital is distributed to firms as profits.

Each firm produces a different variety and sets the price of its product facing isoelastic demand functions in both domestic and foreign markets, as shown in (8) and (9). There is an adjustment cost for price setting, which, expressed as a proportion of total sales, is assumed to be given by the following functions:

$$\Gamma^{pd}_{n,r,t} = \frac{\phi^p_r}{2}\left(\pi_{r,t}\frac{pd_{n,r,t}/pd_{n,r,t-1}}{\overline{\pi}_{r,t}} - 1\right)^2 \quad (10.)$$

$$\Gamma^{pe}_{n,r,s,t} = \frac{\phi^p_s}{2}\left(\pi_{r,t}\frac{\varepsilon_{t,s}}{\varepsilon_{t,r}}\frac{\varepsilon_{t-1,r}}{\varepsilon_{t-1,s}}\frac{pe_{n,r,s,t}/pe_{n,r,s,t-1}}{\overline{\pi}_{s,t}} - 1\right)^2 \quad (11.)$$

where ϕ^p_r and ϕ^p_s are respectively adjustment cost coefficients in region *r* and region *s*; and $\pi_{r,t}$ is the inflation rate in region *r* at time *t*. These adjustment cost functions indicate that the cost is related to changes in nominal prices of products relative to the contemporaneous inflation target for the CPI, shown by $\overline{\pi}_{r,t}$. (11) indicates that the export price is set in the currency of the destination market, i.e., local-currency pricing.

A firm *n* is assumed to maximize the discounted value of current and future profits, denoted as div_n, which are distributed as dividends to shareholders:

$$\begin{aligned}
&\max \sum_{t=0}^{\infty}\left(\prod_{\tau=0}^{t}\frac{g_\tau \pi_{\tau,r}}{1+i_{\tau,r}}\right) div_{n,r,t} \\
&div_{n,r,t} = (1-\tau^k_r)R_{r,t}K_{n,r,t} - I^n_{n,r,t} + R^g_{r,t}K^g_{n,r,t} \\
&+(pd_{n,r,t} - PX_{r,t})xd_{n,r,t}(1-\Gamma^{pd}_{n,r,t}) + \sum_{s\in R}(pe_{n,r,s,t} - PX_{r,t})xe^n_{n,r,s,t}(1-\Gamma^{pe}_{n,r,s,t})
\end{aligned} \quad (12.)$$

subject to CES production technology, the demand functions of (8) and (9), and the adjustment costs in price setting of (10) and (11), and given the price of aggregate output, *PX*, and the law of motion of capital:

$$K_{n,t+1}g_{t+1} = (1-\delta)K_{n,t} + \Gamma^I_{n,t}K_{n,t} \quad (13.)$$

where $K_{n,r,t}$ and $I^n_{n,r,t}$ are respectively private capital stock and investment of firm *n* in region *r* at time *t*; $K^g_{n,r,t}$ is the stock of public capital; $R_{r,t}$ and $R^g_{r,t}$ are respectively the prices of private and public capital; δ is the depreciation rate of capital. Γ^I_n is the adjustment cost of investment, which is a function of the investment-to-capital ratio and takes on value zero in the steady state:

$$\Gamma^{I}_{n,t} = \frac{I^{n}_{n,t}}{K_{n,t}} - \frac{\phi^{I}}{2}\left(\frac{I^{n}_{n,t}}{K_{n,t}} - \frac{I_{t-1}}{K_{t-1}}\right)^{2} \tag{14.}$$

As shown in (12), the firm's profits (or dividends) include the after-tax return to its private capital, the return to public capital captured, and the gains the firm obtains from selling products in the domestic and foreign markets. The optimization problem of the firm is to set its levels of investment, the labor input, the intermediate input, and the nominal prices of its products in domestic and exporting markets in order to maximize the discounted present value of its profits (or dividends). The resulting first order conditions with respect to *I* and *K* are:

$$\frac{1}{q_t} = 1 - \phi^{I}\left(\frac{I^{n}_{n,t}}{K_{n,t}} - \frac{I_{t-1}}{K_{t-1}}\right) \tag{15.}$$

$$(1-\tau^{k}_{t})R_t + q_t\left(1-\delta+\Gamma^{I}_{n,t}\right) - \frac{I_t}{K_t} - q_{t-1}\frac{1+i_t}{\pi_t} = 0 \tag{16.}$$

where q is the shadow price of private capital, i.e., Tobin's *q*.

The resulting first order conditions with respect to *pd* and *pe* are:

$$\begin{aligned}\left(1-\Gamma^{pd}_{n,r,t}\right)\left(pd_{n,r,t}(1-\sigma^{f}_{r}) + PX_{r,t}\sigma^{f}_{r}\right) &= (pd_{n,r,t} - PX_{r,t})\phi^{p}_{r}\left(\frac{\pi^{pd}_{n,r,t}}{\overline{\pi}_{r,t}} - 1\right)\frac{\pi^{pd}_{n,r,t}}{\overline{\pi}_{r,t}} \\ &- \frac{g_{t+1}\pi_{t+1}}{1+i_{t+1}}\frac{XD_{r,t+1}}{XD_{r,t}}(pd_{n,r,t+1} - PX_{r,t+1})\phi^{p}_{r}\left(\frac{\pi^{pd}_{n,r,t+1}}{\overline{\pi}_{r,t+1}} - 1\right)\frac{\pi^{pd}_{n,r,t+1}}{\overline{\pi}_{r,t+1}}\end{aligned} \tag{17.}$$

$$\begin{aligned}\left(1-\Gamma^{pe}_{n,r,s,t}\right)\left(pe_{n,r,s,t}(1-\sigma^{f}_{s}) + PX_{r,t}\sigma^{f}_{s}\right) &= (pe_{n,r,s,t} - PX_{r,t})\phi^{p}_{s}\left(\frac{\pi^{pe}_{n,r,s,t}}{\overline{\pi}_{s,t}} - 1\right)\frac{\pi^{pe}_{n,r,s,t}}{\overline{\pi}_{s,t}} \\ &- \frac{g_{t+1}\pi_{t+1}}{1+i_{t+1}}\frac{XE_{r,s,t+1}}{XE_{r,s,t}}(pe_{n,r,s,t+1} - PX_{r,t+1})\phi^{p}_{s}\left(\frac{\pi^{pe}_{n,r,s.t+1}}{\overline{\pi}_{s,t+1}} - 1\right)\frac{\pi^{pe}_{n,r,s.t+1}}{\overline{\pi}_{s,t+1}}\end{aligned} \tag{18.}$$

where $\pi^{pd}_{n,r,t}$ is the inflation rate of variety *n* in domestic market and $\pi^{pe}_{n,r,s,t}$ is the inflation rate of variety *n* produced in country *r* and sold in region *s*.

The first order conditions with respect to production inputs lead to the following demand functions and price indices of aggregate inputs:

$$XN = \alpha^{n} \cdot X \cdot PX/PN \tag{19.}$$

$$K^{g} = (1-\alpha^{n}) \cdot X \cdot PX/R^{g} \tag{20.}$$

$$X = A \cdot \left(K^{g}\right)^{1-\alpha^{n}} XN^{\alpha^{n}} \tag{21.}$$

$$VA = \alpha^{v} \cdot XN \tag{22.}$$

$$XI = \alpha^{n} \cdot XN \tag{23.}$$

$$PN = \alpha^{v} PV + \alpha^{n} PI \tag{24.}$$

$$L = \alpha^{l} \left[\frac{PV}{W} \right]^{\sigma^{v}} VA \qquad (25.)$$

$$K = \alpha^{k} \left[\frac{PV}{R} \right]^{\sigma^{v}} VA \qquad (26.)$$

$$PV = \left[\alpha^{l} (W)^{1-\sigma^{v}} + \alpha^{k} (R)^{1-\sigma^{v}} \right]^{1/(1-\sigma^{v})} \qquad (27.)$$

where α^{n} and α^{v} are respectively the share parameters for the aggregate primary factor and the intermediate input in the production function of aggregate private input; α^{l} and α^{k} are respectively the share parameters for the aggregate labor input and private capital in the production function of the aggregate primary factor; *X*, K^{g}, *XN*, *VA*, *XI*, *L, K* represent output, public capital, aggregate private input, aggregate primary factor, intermediate input, aggregate labor and private capital, respectively; and *PX*, R^{g}, *PN*, *PV*, *PI*, *W* and *R* are their corresponding price indices. σ^{v} is elasticity of substitution between labor and capital.

Firms have the CES aggregator of the differentiated labor varieties provided by labor unions. As firms are assumed to be identical, the aggregate labor demand, *L*, can be expressed as:

$$L = \left[\int_{0}^{1} (l_{\mu})^{\frac{\sigma^{l}-1}{\sigma^{l}}} d\mu \right]^{\frac{\sigma^{l}}{\sigma^{l}-1}} \qquad (28.)$$

where l_{μ} is the quantity of labor provided by union μ and σ^{l} is the elasticity of substitution across labor varieties. Cost minimization of firms implies that demand for labor μ is a function of the relative wage:

$$\frac{l_{\mu}}{L} = \left[\frac{w_{\mu}}{W} \right]^{-\sigma^{l}} \qquad (29.)$$

where w_{μ} is the wage paid to union μ and the region's wage, *W*, is defined as:

$$W = \left[\int_{0}^{1} (w_{\mu})^{1-\sigma^{l}} d\mu \right]^{\frac{1}{1-\sigma^{l}}} \qquad (30.)$$

Households

In each period, $m_r(1-\theta)$ individuals are born in region *r* and they face a constant probability of death $(1-\theta)$ after their birth. This implies that the total number of population is m_r in region *r*. We distinguish two types of households, forward-looking ones denoted by *FL*, and liquidity-constrained ones denoted by *LC*. For a representative household of age *a*, its period utility in time *t*, $u_{a,t}$, is a function of its (detrended) consumption *c* and labor effort l^{h}.

$$u_{a,t}(c_{a,t}, l^{h}_{a,t}) = \frac{1}{1-\sigma} \left[\left(c_{a,t} / (\tilde{c}_{t-1})?^{v} \right)^{\eta} \left(1 - l^{h}_{a,t} \right)^{1-\eta} \right]^{1-\sigma} \qquad (31.)$$

where σ is the inverse elasticity of intertemporal substitution and η is the weight of consumption in the utility function. The term $\tilde{c}_{t-1}$ represents past per capita consumption of household *h*'s peers, i.e. *FL* households or *LC* households. *v* parameterizes the degree of habit persistence. This exhibits the “catching up with the Joneses” type of external habit formation.

The lifetime utility of age *a* household at time *t*, $U_{a,t}$, is the sum of discounted period utility:

$$U_{a,t} = \sum_{\tau=0}^{\infty} \left(g^{1-\sigma}\beta\theta\right)^{\tau} u_{a+\tau,t+\tau} \tag{32.}$$

where β is the subjective discount rate, possibly time-variable but converging to a steady state constant in the long run.

The decision problem of a forward-looking household is to maximize its lifetime utility (32) subject to the following sequences of period budget constraints:

$$\begin{aligned} \theta\left(B_{a+1,t+1}\pi_{t+1} + \varepsilon_t B^*_{a+1,t+1}\pi^*_{t+1} + V_{t+1} z_{a,t+1}\pi_{t+1}\right) g_{t+1} &= (1+i_t)B_{a,t} \\ + (1+i^*_t)(1-\zeta_t)\varepsilon_t B^*_{a,t} &+ (V_{t+1}\pi_{t+1} g_{t+1}\theta + Div_t) z_{a,t} \\ + TR^{FL}_{a\ t} + (1-\tau_l) w^h_t \phi_a l^h_{a,t} &- c_{a,t} - TT_{a,t} \end{aligned} \tag{33.}$$

In the above expression, B_a is the amount of domestic government bonds held by the representative household at age *a*, denominated in domestic currency; B^*_a is the amount of international bonds held by household *a*, denominated in the US dollar; *V* denotes the value of a claim to firm profits in current and all future periods; z_a is the share of firms owned by the represent household at age *a;* *π* and *π** are respectively domestic and US CPI inflation rates; *i* and *i** are respectively the domestic and US nominal interest rates; ζ is the risk premium on international bonds; *Div* is the total dividends paid by all firms to households; TR^{FL}_a represents revenue from unions’ profits rebated to forward-looking household *a* in a lump-sum way; and TT_a is the lump-sum net tax for household *a*. Labor incomes $w^h \phi_a l^h_a$ are taxed at the rate τ^l . And ϕ_a is the labor productivity of age *a* household, given by:

$$\phi_a = \frac{1-\theta\chi}{1-\theta}\chi^a \tag{34.}$$

where *θ* is the constant probability of survival in each period and *χ* (<1) determines the speed of decline of an individual household’s labor productivity throughout his lifetime.

The first order conditions of the forward-looking household’s optimization problem with respect to *B*, *B**, *c*, *l* and *z* yield the following arbitrage equations:

$$\frac{\pi_{t+1}}{1+i_{t+1}} = \frac{\pi^*_{t+1}}{(1+i^*_{t+1})(1-\zeta)}\frac{\varepsilon_t}{\varepsilon_{t+1}} \tag{35.}$$

$$J_{t+1} = \frac{g_{t+1}c_{a,t+1}}{c_{a,t}} = \left(\frac{(1+i_t)\beta_{t+1}}{\pi_{t+1}}\right)^{1/\gamma} \left(\frac{w^h_{t+1}}{w^h_t}\chi\right)^{(1-\eta)(1-1/\gamma)} \left(\frac{c_t}{c_{t-1}}g_{t+1}\right)^{\nu\eta(1-1/\gamma)} \tag{36.}$$

$$\frac{c_{a,t}}{1-l^h_{a,t}} = \frac{\eta^{FL}}{1-\eta^{FL}} w^h_t \phi_a \tag{37.}$$

$$V_t(1+i_t) = Div_t + V_{t+1} g_{t+1}\pi_{t+1} \tag{38.}$$

With some algebraic derivations, the aggregate consumption of all forward-looking households can be expressed as a fraction of the sum of their financial wealth, *FW*, and human wealth, *HW*. Human wealth is composed of two parts, the expected present discounted value of future labor income, *HWL*, and the expected present discounted value of future transfer incomes, *HWT*.

$$C_t^{FL}\Theta_t = (1+i_t)(HW_t + FW_t) \tag{39.}$$

$$FW_t = B_t + \varepsilon_{t\text{-}1}B_t^* + V_t \tag{40.}$$

$$HW_t = HWL_t + HWT_t \tag{41.}$$

$$HWL_t(1+i_i) = w_t^h L_t^{FL} + HWL_{t+1}g_{t+1}\pi_{t+1}\theta\chi \tag{42.}$$

$$HWT_t(1+i_i) = TR_t^{FL} + HWT_{t+1}g_{t+1}\pi_{t+1}\theta \tag{43.}$$

Θ^{-1} is the marginal propensity to consume out of total wealth. This inverse of the marginal propensity of consume evolves according to,

$$\Theta_t = \frac{1}{\eta^{Fl}} + \frac{\theta J_{t+1}\pi_{t+1}}{1+i_{t+1}}\Theta_{t+1} \tag{44.}$$

where *J* is already defined in (36).

A liquidity-constrained household has no access to capital markets. Its decision problem is purely static, confined to the choices of labor supply. Its budget constraint is:

$$c_{a,t} = (1-\tau^l)w_t^h\phi_a l_{a,t}^h + TR_{a\ \ t}^{LC} - TT_{a,t} \tag{45.}$$

where TR_a^{LC} is the lump-sum revenue from union's profits rebated to the liquidity-constrained household *a*. The first order conditions with respects to consumption and labor supply yield the following relationship between aggregate consumption and labor supply:

$$\frac{c_t^{LC}}{\mathrm{m}\cdot \mathrm{s}^{\mathrm{LC}} - L_t^{LC}} = \frac{\eta^{LC}}{1-\eta^{LC}}w_t^h \tag{46.}$$

where s^{LC} is the share of liquidity-constrained agents in total households and L^{LC} is the effective aggregate labor supply of liquidity-constrained households.

Unions

In each region, there is a continuum of unions which buy labor from households and sell labor to firms. They are perfectly competitive in their input markets and monopolistically competitive in their output market. Each union has power to set the nominal wage of the labor they provide. Similarly to the price setting by firms, wage changes are subject to adjustment costs. The adjustment cost function of nominal wage change is assumed as follows:

$$\Gamma_{\mu,t}^w = \frac{\phi^w}{2}\left(\pi_t\frac{w_{\mu,t}/w_{\mu,t-1}}{\overline{\pi}_t} - 1\right)^2 \tag{47.}$$

The decision problem of each union is to maximize the present discounted value of nominal wages paid by firms, w_u, minus nominal wages paid out to households, w^h, minus wage change adjustment cost, by setting the nominal wage:

$$\max\sum_{t=0}^{\infty}\left(\prod_{\tau=0}^{t}\frac{g_\tau\pi_{\tau,r}}{1+i_{\tau,r}}\right)\left(w_{\mu,t}(1-\Gamma_{\mu,\mathrm{t}}^{\mathrm{w}}) - w_t^h\right)l_{\mu,t} \tag{48.}$$

subject to the demand function (29). The resulting wage setting equation is:

$$\frac{w_t^h \sigma^l}{(1-\tau^w) w_{\mu,t}} = (\sigma^l - 1)(1 - \Gamma_{\mu,t}^w) + \phi^w \left(\frac{\pi_{\mu,t}^w}{\bar{\pi}_t} - 1 \right) \frac{\pi_{\mu,t}^w}{\bar{\pi}_t} - \frac{g_{t+1}\pi_{t+1}}{1+i_{t+1}} \frac{L_{t+1}}{L_t} \phi^w \left(\frac{\pi_{\mu,t+1}^w}{\bar{\pi}_{t+1}} - 1 \right) \frac{\left(\pi_{\mu,t+1}^w\right)^2}{\bar{\pi}_{t+1}} \tag{49.}$$

where $\pi_{\mu,t}^w = \pi_t \cdot w_{\mu,t} / w_{\mu,t-1}$ is the wage inflation rate.

Government

Government in region *s* has the following budget constraint:

$$\begin{aligned} B_{s,t+1} g_{t+1} \pi_{t+1} &= (1+i_{s,t}) B_{s,t} + G_{s,t}^C + G_{s,t}^I - \tau_s^k R_{s,t} K_{s,t} - \tau_s^l W_{s,t} L_{s,t} - TT_{s,t} m_s \\ &- \tau_s^s PA_{s,t} XA_{s,t} - \sum_r \left(\tau_{rs} PE_{rs,t} XE_{rs,t} \, \varepsilon_{s,t} / \varepsilon_{r,t} \right) \end{aligned} \tag{50.}$$

where G^C and G^I are government consumption and investment, respectively. The accumulation of public capital follows:

$$K_{t+1}^g g_{t+1} = (1-\delta) K_t^g + G_t^I \tag{51.}$$

The central bank in each region is assumed to set the nominal interest rate by employing the following monetary policy rule:

$$i_t = i_{t-1} + \omega_\pi (\pi_{t-1} - \bar{\pi}_{t-1}) + \omega_y (\Delta GDP_{t-1} - \Delta \overline{GDP}_{t-1}) + \omega_e (\Delta \varepsilon_{t-1} - \Delta \bar{\varepsilon}_{t-1}) \tag{52.}$$

where ω_π, ω_y and ω_e are the weights for the inflation gap, the output growth gap and the exchange rate gap, respectively. The variables with bars are target values of the respective variables. Note that $\omega_e > 0$ for the emerging East Asian central bank, while $\omega_e = 0$ for the central banks in other regions of the world.

Equilibrium

The equilibrium condition in the composite good market is that the supply of the composite good, *XA*, is equal to the sum of household consumption demand, government demand for consumption and investment, and private demand for intermediate inputs:

$$XA = C^{FL} + C^{LC} + G^C + G^I + I \tag{53.}$$

The equilibrium condition in the labor market in each region is:

$$L = L^{FL} + L^{LC} \tag{54.}$$

The international bond is in zero net supply internationally. The market clearing condition for international bonds requires:

$$0 = \sum_r B^*{}_r \tag{55.}$$