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FOREIGN EXCHANGE RESERVE DIVERSIFICATION AND THE “EXORBITANT PRIVILEGE”

by Pietro Cova*, Patrizio Pagano* and Massimiliano Pisani*

Abstract

We assess the global macroeconomic implications of different strategies of official reserve management by developing a large scale new-Keynesian dynamic general equilibrium model of the world economy, calibrated on the euro area, the United States, China, Japan and the rest of the world. An increase in global demand for euros would boost euro-area aggregate demand because of the reduction in euro-area interest rates (the main benefit associated with the “privilege” of being a global currency). If the higher demand for euros is associated with lower demand for US dollars, then US economic activity falls because of higher interest rates, which depress domestic aggregate demand, while the external balance improves; countries accumulating reserves continue to run a trade surplus, as exports to the euro-area increase. We also compute welfare gains/costs for all economies.

JEL Classification: F33, F41, C51, E52.
Keywords: global imbalances, global currency, dynamic general equilibrium modelling.

Contents

* Bank of Italy, Directorate General for Economics, Statistics and Research.

1 Introduction[1]

The current international monetary system is often described as a non-system of floating exchange rates in which some countries attempt to maintain fixed exchange rates — or to manage their exchange rate movements mainly against the US dollar — by accumulating exchange rate reserves in the form of internationally traded assets (Fahri, Gourinchas and Rey, 2011, Palais-Royal Initiative, 2011). After a short-lived break in 2008, reserve accumulation has resumed and as at the end of 2012 the outstanding amount was more than five times larger than that of the previous decade (Fig. 1).[2]

The currency composition of global official holdings of exchange rate reserves has not greatly changed over time. In particular, the US dollar continues to be *the* key currency, a status that provides benefits to the US economy in terms of lower borrowing interest rates with respect to those of other countries (so called "exorbitant privilege").

On the basis of the IMF's currency composition of official reserves database (COFER), if one looks only at reported dollar holdings, the demand for dollar denominated assets seems to be slowing down with respect to the overall increase in foreign exchange rate reserves and consequently the dollar share appears to be declining rapidly (Fig. 1). Yet, there is a large – and increasing – share of "unallocated" reserves, that is of unknown composition, most of which is held by China and oil-exporting countries and is commonly taken as being largely denominated in U.S. dollars. Assuming that 60 percent of those "unallocated" holdings are dollars (cf. e.g. Chinn and Frankel, 2008) yields an increase in dollar denominated assets almost unabated.[3]

At the same time, the role of the euro as international currency has increased. After its debut, the euro saw a rapid increase in its use in international transactions, related to

[1]The views expressed are those of the authors and do not necessarily reflect those of the Bank of Italy. We thank for useful comments Pietro Catte, Pierre-Olivier Gourinchas, Ruy Lama and seminar participants at the Bank of Italy, at the Bank of Spain, at the International Conference on Pacific Rim Economies and the Evolution of the International Monetary Architecture (Hong Kong) and at the ECB-IMF workshop on International Dimensions of Conventional and Unconventional Monetary Policy (Frankfurt). E-mails: pietro.cova@bancaditalia.it (corresponding author); patrizio.pagano@bancaditalia.it; massimiliano.pisani@bancaditalia.it

[2]The motives behind this reserve accumulation pointed out in policy discussions are polarized between a precautionary and a mercantilist motive. An analysis of these motivations is beyond the scope of this paper.

[3]There are two important observations. These shares incorporate valuation changes, and so when the dollar loses value against other currencies, that shows up in the shares. Truman and Wong (2006) have argued that one should also look at the constant value, or "quantity", shares. Bagnall (2013) has calculated the quantity shares for the dollar from the end of 2010 through the end of 2012: the quantity share (adjusted for the effects of changes in exchange rates on the stock of reserves) of the US dollar has decreased slightly for all countries from about 64 percent to 63 percent of all reported foreign exchange reserves. While this two-year snapshot shows a slight decline in official holdings of US dollar assets, the dollar's share has been steadily decreasing at least since 1999.

the rapid integration of euro money markets, government bond markets, equity markets and banking and the large issuance of euro-denominated corporate bonds. As a result, in its first decade, the euro advanced quickly into the rank of the top reserve currencies, also considering the fact that about a quarter of COFER's unallocated reserves may be denominated in euro (Chinn, 2012). This process came abruptly to a halt in 2010 with the emergence of the sovereign debt crisis that has severely dented the expectations of the euro's future. But the solution to the crisis, coming through a renewed confidence in European institutions, may give a new boost to its role as an international reserve currency.[4]

Given the size of international reserve holdings, any change in their allocation may potentially have large effects on global exchange rates and interest rates and, ultimately, on economic activity and welfare of different countries. This paper addresses these issues by quantitatively assessing the global macroeconomic effects of changes in official foreign exchange reserves in a bipolar international monetary system, one in which not only the US dollar acts as an international reserve currency, but also the euro.

The analysis is performed by simulating a multi-country dynamic general equilibrium model calibrated on the euro area (EA), the United States (US), China, Japan and the rest of the world (RW). Building on a recent contribution by Canzoneri, Cumby, Diba and Lopez-Salido (2013, henceforth CCDLS), we introduce in the model, otherwise standard, two novel features. First, US and EA government bonds are accumulated as official foreign currency reserves.[5] Second, US and EA government bonds provide liquidity services to households in all countries, as they facilitate transactions for consumption purposes.[6] Specifically, it is assumed that in each region "liquidity" is a combination, according to a transaction technology, of domestic money balances issued by the local central bank, domestic government bonds, US government bonds, and EA government bonds. As such, the Chinese, Japanese and RW government bonds and currencies are not internationally traded.[7]

[4] In the longer term also the renminbi may become an international currency, as this is a stated goal of Chinese authorities. However, the prospects for its internationalization will likely encounter major challenges, also related to the process of liberalization of capital controls (Eichengreen, 2013).

[5] In what follows we treat the EA as a single country in our model, alongside the US, Japan, China, and the RW. As such EA government bonds are meant to denote bonds denominated in euro issued by the (hypothetical) EA government.

[6] It is possible to imagine a richer model including optimizing banks managing the deposits of households, by allocating them between different asset classes (money and government bonds), which would subsume the more simplified setup assumed here, where households directly hold a composite of money balances and government bonds to satisfy their transaction needs period by period. See Canzoneri et al. (2008).

[7] The role of bonds in providing transaction services has been quantified by Krishnamurthy and

Alongside the domestic government and the internationally tradable government bonds denominated in US dollars and euros, households in each country can also invest in private sector bonds denominated in dollars whose rate of return — the Consumption Capital Asset Pricing Model (CCAPM) rate — does not incorporate any liquidity services and, as such, is higher than the yield on government bonds. We also allow for the presence of these "risky" private international bonds, together with the "safe" internationally tradable government bonds, as they too represent an important source of variation of a country's current account and net foreign asset position. But contrary to privately issued bonds, given the international liquidity service they provide, government bonds in reserve currency areas pay a low rate of interest; this reflects their non-pecuniary return, i.e. the fact that investors value the liquidity and safety of key currency bonds (see Krishnamurthy and Vissing-Jorgensen, 2012). As in CCDLS, in this model the "exorbitant privilege" is the combination of the non-pecuniary externality embedded in Government bond yields in key currency areas and asymmetric global portfolios: the non resident holders of key currency bonds pay a bond seigniorage tax on reserve currency government bonds.

In all the simulated scenarios considered China, Japan and the RW simultaneously and permanently modify their holdings of official reserves by one percent. Simulations are run under perfect foresight. So there is no uncertainty, policies are fully credible and agents perfectly anticipate the future path of shocks (the only exception is the initial period, as the shock is initially unexpected). In the first scenario, the authorities keep constant the shares of dollars and euros in their portfolios ("so far, so good" scenario). The second scenario features a one percent reduction in US dollar reserves, more than offset by a correspondingly larger increase in euro reserves (so that overall reserves still increase by one percent, "rebalancing" scenario). To further assess the impact on countries other than the US and the EA, we simulate alternative scenarios where reserve management is asymmetric across China (the main holder of US dollar reserves), Japan and the RW: (1) China is the only country increasing reserves in dollars and euros; (2) Japan and RW increase their reserves, but China maintains a fixed nominal exchange

Vissing-Jorgensen (2012). Intuitively, a number of financial institutions, besides banks, use government bonds to manage their day-to-day liquidity holdings. Recently, both the IMF(2010, 2012) and the BIS (2011) have included government bonds among the different indicators relevant for measuring liquidity at both the domestic and international level. A number of "private-label" assets compete, to different degrees and with time-varying relevance, with government bonds in the provision of liquidity services, as highlighted among other by Bernanke et al. (2011). Similarly Chen et al. (2012), highlight the importance of the components of global liquidity, distinguishing between core and noncore liabilities. Their focus is also on the impact of liquidity on financial and economic stability. We do not take up these very interesting issues in the present work.

rate against the US dollar by endogenously setting its reserves ("Bretton Woods II" scenario); (3) China reduces its reserves in dollars and euros while Japan and RW keep increasing their own.

Our main results are as follows. First, an increase in the demand for euro reserves would lower euro interest rates (the benefit associated with the "privilege" of being a global currency), appreciate the euro's exchange rate and boost domestic aggregate demand and the trade deficit in the EA. Second, similar results hold for the US as long as the US dollar reserves also increase. Third, countries accumulating reserves would run larger trade surpluses. Fourth, the Chinese economy reaps net benefits when Japan and RW increase their reserves, and at the same time China maintains a fixed exchange rate regime vis-à-vis the dollar, as it then faces lower interest rates and hence higher domestic aggregate demand. This is even more evident in the scenario featuring a reduction of Chinese foreign exchange holdings. Finally, welfare costs/gains, measured in consumption equivalent terms, are not trivial. To put them into context, one should take into account that official reserves denominated in US dollars increased by 10 per cent per year in the period 2009-2012. In the scenario of rebalancing of international reserves, a 10 per cent reduction in the demand for dollar holdings, more than offset by a correspondingly larger increase in euro reserves (so that overall reserves increase by 10 percent), raises permanently EA residents' consumption up to 0.23 percentage points in each quarter and lowers consumption in the US by 0.07 percentage points per quarter. Countries that accumulate reserves face costs: a 10 per cent increase would cost up to 0.15 percentage points of quarterly consumption for China and Japan due to their large holdings.[8] A 10 per cent reduction of Chinese foreign exchange holdings – while other economies keep accumulating reserves – would raise the country's permanent consumption up to 0.24 percentage points per quarter. Overall, increasing demand for euros as reserve currency would lift aggregate demand in the EA as it would reap some of the "exorbitant privilege" so far enjoyed by the United States. This shift in the "exorbitant privilege" would not hurt the US economy as long as the demand for US dollar reserves increases as well, and it would not greatly affect macroeconomic outcomes in countries accumulating reserves.

Our contribution adds to the literature on the "exorbitant privilege" of the United States (Gourinchas and Rey, 2007) and on the future of the international monetary system. It has been argued that the dominance of the dollar is not guaranteed (Obstfeld, 2011). In fact, against the large demand for the dollar and for dollar-denominated assets,

[8] Given that, as mentioned before the motivations of reserve accumulation is beyond the scope of this paper, these welfare costs neglect possible benefits deriving, e.g., from a better diversification of risk.

the fiscal capacity of the United States — which defines its capacity to provide reserve assets — is bound to decline relative to the size of the global economy. In a growing world, then, the United States will inevitably lose its reserve currency hegemony. At the same time, the severe crisis that has hit the world economy may lead to structural changes in the international monetary system. Therefore, it may only be a matter of time before the world reserve composition will become more diversified (Eichengreen, 2011).

Differently from these contributions, we focus on the macroeconomic implications of the cross-country allocation of the "exorbitant privilege" and, from a methodological point of view, we analyse this issue by simulating a state-of-the-art large-scale dynamic general equilibrium model of the world economy. From this perspective, our contribution builds on CCDLS. A key difference is that we embed their transaction technology in a large scale model and evaluate the macroeconomic implications for the main regions of the world of a recomposition of official foreign exchange portfolios away from one currency and towards another. To be clear, we do not analyse the transition from a unipolar to a multipolar international monetary system: in our model both the US dollar and the euro act as reserve currencies, and given this bipolar setup we consider the macroeconomic and welfare implications due to shifts in the relative weights of these two reserve currencies driven by changes in the composition of official reserve holdings in the other countries.

By assuming imperfect substitutability of domestic and foreign assets, our model also builds on an older literature started by Kouri (1976), who focuses on the effects of changes in portfolio preferences and the implications of imperfect substitutability between assets; more recently, the roles of imperfect substitutability have also been emphasized by Obstfeld (2004) and Blanchard Giavazzi, and Sa (2005) in their analysis of US current account deficits. Finally, the role of international currencies and their importance in determining portfolios and asset price movements is an area of active research in a general equilibrium setup with a rich asset structure, studied, among others, by Devereux and Shi (2012) and Gourinchas, Rey, and Govillot (2010).

The rest of the paper is organized as follows. Section two reports the main features of the model setup, including the calibration. Section three contains the results of the main simulations and of the sensitivity exercises. Section five recaps the results in terms of welfare. Finally, Section five concludes.

2 Model setup

We build up and simulate a five-region dynamic general equilibrium model of the world economy, calibrated on the EA, US, China, Japan and the RW. Following the theoretical framework of CCDLS we assume that "liquidity" is composed not only by domestic money and government bonds, but also by government bonds issued in key-currency economies. Hence, liquidity, which is needed for transaction services, has a domestic and an international component. Crucially, we assume that both the US dollar and the euro are "reserve" currencies. Governments accumulate official reserves, in the form of US and EA government bonds. Because of these features there is an international demand for US and euro area government bonds.

Alongside the government bonds, households in each country issue non-contingent nominal one-period bonds. These private bonds are issued in zero net supply and, except for the ones issued by the US and denominated in US currency, are not traded across countries; in contrast to the bonds issued by the US government, their yield does not embody any liquidity premium. The endogenous spread between this yield and the one on the government bonds reflects the non-pecuniary return of the transactions services – the liquidity premium – embodied in government bonds. The presence of these "risky" private bonds denominated in US dollars that can be exchanged internationally allows us in what follows to better characterize the dynamics of the current account balances and net foreign asset positions.[9]

The other features of the model are more standard and allow us to fully characterize the dynamics of the trade balance, current account and real exchange rate.[10] Households consume a final good, which is a composite of intermediate nontradable and tradable goods. The latter are domestically produced or imported. They also own domestic firms and invest in physical capital, which is rented to domestic firms in a perfectly competitive market. All households supply differentiated labor services to domestic firms and act as wage setters in monopolistically competitive labor markets by charging a markup over their marginal rate of substitution between consumption and leisure.

On the production side, there are perfectly competitive firms that produce two final goods (a consumption and an investment good) and monopolistically competitive firms that produce the intermediate (tradable and nontradable) goods. The two final goods

[9] While admittedly this is only a short-cut, in order to account for other asset classes that are riskier than government bonds and that affect countries' financial accounts, by and large US dollar denominated debt still constitutes the most important component among private international assets and liabilities.

[10] The model is similar to the Euro area and the Global economy Model (EAGLE) developed by Gomes, Jacquinot and Pisani (2010) and to the Global Economy Model (GEM) developed at the IMF (see Laxton, 2008, and Pesenti, 2008).

are sold domestically and are produced by combining all available intermediate goods using a constant-elasticity-of-substitution (CES) production function. The two resulting bundles can have different composition. Intermediate tradable and nontradable goods are produced by combining domestic capital and labor, which are assumed to be mobile across the two sectors. Intermediate tradable goods can be sold domestically and abroad. Because intermediate goods are differentiated, firms have market power and restrict output to create excess profits. We also assume that markets for tradable goods are segmented, so that firms can set country-specific prices (one for each market).

Finally, we include adjustment costs on real and nominal variables, ensuring that, in response to a shock, consumption, production and prices react in a gradual way. On the real side, habit preferences and quadratic costs prolong the adjustment of households' consumption and investment expenditures. On the nominal side, quadratic costs *à la* Rotemberg (1982) make wages and prices sticky.

2.1 Households and international liquidity

In what follows we initilly define "liquidity" and show how it affects households' decisions. Thereafter, the public sector budget constraint, the official reserves and the money policies are illustrated.

2.1.1 US households

There is a continuum of US (symmetric) households indexed by h on the interval $[0, n_{US})$. The intertemporal utility of the representative household h at time t is:

$$U_t^{US}(h) \equiv E_t \Sigma_{j=t}^{\infty} \beta^j \left\{ \frac{\left(C_j^{US}(h) - \xi C_{j-1}^{US} \right)^{1-\sigma}}{1-\sigma} - \frac{N_j^{US}(h)^{1+\chi}}{1+\chi} \right\} \tag{1}$$

where E is the expectation operator, $0 < \beta < 1$ is the discount factor, $C_j^{US}(h)$ is consumption of the final good and $N_j^{US}(h)$ measures household's labor effort. The term C_{j-1}^{US} reflects previous period's aggregate consumption and the parameter $0 \leq \xi \leq 1$ accounts for external consumption habits. The intertemporal elasticity of substitution is $1/\sigma > 0$, while the inverse of the Frisch labor supply elasticity is $\chi > 0$. As all households within each country are identical, we will drop all household indices in the following presentation and discussion of the model.

The budget constraint of the representative US household is:

$$\begin{aligned}
&M_t^{US} - M_{t-1}^{US} + B_t^{US} - R_{t-1}^{US} B_{t-1}^{US} + B_{PR,t}^{US} - \tilde{R}_{t-1}^{US} B_{PR,t-1}^{US} \\
&+ B_t^{EA,US}/S_t^{EA} - R_{t-1}^{EA} B_{t-1}^{EA,US}/S_t^{EA} \\
&= W_t^{US} N_t^{US} + r_t^{K,US} K_{t-1}^{US} + D_t^{US} - \left(1+\tau_t^{US}\right) P_t^{US} C_t^{US} - P_{I,t}^{US} I_t^{US} + TR_t^{US}
\end{aligned}$$

where M^{US} is money holdings, B^{US} is domestic government bond holdings paying the (gross) interest rate R^{US}, B_{PR}^{US} is private non-contingent nominal one-period debt paying the (CCAPM) interest rate $\tilde{R}^{US}$, and $B^{EA,US}/S^{EA}$ is the dollar amount of euro government bonds earning the interest rate R^{EA} (S^{EA} is the nominal exchange rate of the euro vis-à-vis the US dollar, defined as number of euros per one dollar). On the right-hand-side W^{US} stands for the wage rate, $r^{K,US}K^{US}$ is the income from renting the stock of physical capital K^{US} to domestic firms at the rate $r^{K,US}$, D^{US} are dividends from ownership of domestic firms, τ^{US} is the transactions cost, P^{US} is the consumption price index, I^{US} is investment in physical capital with P_I^{US} the related price index, TR^{US} are lump-sum transfers.

As in CCDLS transactions costs are proportional to consumption, with a factor of proportionality that is an increasing function of velocity:

$$\tau_t^{US} = \begin{cases} \left(\frac{A^{US}}{v_t^{US}}\right)\left(v_t^{US} - \bar{v}^{US}\right)^2 & \text{for} \quad v_t^{US} > \bar{v}^{US} \\ 0 & \text{for} \quad v_t^{US} \leq \bar{v}^{US} \end{cases} \tag{2}$$

where $\bar{v}^{US}$ is the satiation level of velocity and $A^{US} > 0$ is a cost parameter.[11] Velocity depends in turn on consumption and "effective" money holdings:

$$v_t^{US} = \frac{C_t^{US}}{\tilde{M}_t^{US}} \tag{3}$$

where the variable for effective money holdings $\tilde{M}_t^{US}$ is defined as:

$$\tilde{M}_t^{US} = \left(M_t^{US}\right)^{\zeta_1^{US}} \left(B_t^{US}\right)^{\zeta_2^{US}} \left(B_t^{EA,US}/S_t^{EA}\right)^{1-\zeta_1^{US}-\zeta_2^{US}} \tag{4}$$

The parameters $\zeta_1^{US}, \zeta_2^{US} \in [0,1]$ measure the relevance of money and US government bonds in facilitating transactions. Household's optimality conditions with respect to consumption C^{US}, money M^{US}, domestic government bond B^{US} and EA government

[11] Transactions costs are originally introduced by Schmitt-Grohe and Uribe (2004) in their analysis of optimal monetary and fiscal policy in a New-Keynesian setutp.

bond $B^{EA,US}$ holdings are respectively:

$$\left(C_t^{US} - \xi C_{t-1}^{US}\right)^{-\sigma} = \Lambda_t^{US}\left[1 + 2A^{US}\left(v_t^{US} - \bar{v}^{US}\right)\right] \tag{5}$$

$$1 - A^{US}\left[\left(v_t^{US}\right)^2 - \left(\bar{v}^{US}\right)^2\right]\zeta_1^{US}\frac{\tilde{M}_t^{US}}{M_t^{US}} = E_t\left[\beta\frac{\Lambda_{t+1}^{US}}{\Lambda_t^{US}}\frac{P_t^{US}}{P_{t+1}^{US}}\right] \equiv \frac{1}{\tilde{R}_t^{US}} \tag{6}$$

$$1 - A^{US}\left[\left(v_t^{US}\right)^2 - \left(\bar{v}^{US}\right)^2\right]\zeta_2^{US}\frac{\tilde{M}_t^{US}}{B_t^{US}} = R_t^{US}E_t\left[\beta\frac{\Lambda_{t+1}^{US}}{\Lambda_t^{US}}\frac{P_t^{US}}{P_{t+1}^{US}}\right] \equiv \frac{R_t^{US}}{\tilde{R}_t^{US}} \tag{7}$$

$$1 - A^{US}\left[\left(v_t^{US}\right)^2 - \left(\bar{v}^{US}\right)^2\right]\left(1 - \zeta_1^{US} - \zeta_2^{US}\right)\frac{\tilde{M}_t^{US}}{B_t^{EA,US}} = R_t^{EA}E_t\left[\beta\frac{\Lambda_{t+1}^{US}}{\Lambda_t^{US}}\frac{P_t^{US}}{P_{t+1}^{US}}\frac{S_t^{EA}}{S_{t+1}^{EA}}\right] \tag{8}$$

where Λ^{US} is the marginal value of wealth, $R^{US} \equiv 1 + r^{US}$ is the gross interest rate on liquid bonds and $\tilde{R}_t^{US}$ is the return on a non-contingent nominal bond, the CCAPM rate.[12]

Equation (5) states that the marginal value of wealth is lowered by the transactions costs. Equation (6) states that in equilibrium the current value of money holdings, which yield zero returns, but provides transaction services (the left-hand-side of the equation), should be equal to the present value of the return on saving (the right-hand-side of the equation) – the stochastic discount factor. Similarly, equation (7) shows that the presence of a liquidity premium, decreasing in the stock of government bonds outstanding (left-hand-side), determines the spread between the interest rate on government bonds and that on a risky asset (right-hand-side). A similar intuition applies to equation (8). Thus, the optimality conditions with respect to asset holdings show that, due to the presence of transactions services, interest rates differ from a standard model in which assets are perfect substitutes. These liquidity premia are affected by the size of the asset stocks outstanding in each period.

An alternative interpretation of the above optimizing conditions is that households can always derive a stochastic discount factor to price any possible risky asset that does not provide transactions services. Under this interpretation this pricing kernel – the CCAPM rate – reflects households' ability to evaluate at any time how much of the return received on their asset holdings reflects a liquidity premium with respect to a hypothetical risky asset which does not embody any liquidity premium. Following

[12] The remaining first order conditions are not shown for brevity and are available upon request.

this alternative interpretation one can think of the CCAPM rate as a "shadow" rate – the marginal rate of substitution between current and expected (i.e. across all possible future states of nature) consumption net of any liquidity premium – on a hypothetical risky one-period nominal bond that is not actually traded among agents. According to this interpretation, all of the above optimality conditions with respect to each asset (money and bonds) provide returns in deviation from the risky or CCAPM rate, $\tilde{R}_t$. The deviation is determined by the fact that each asset, i.e. both money and bonds, provide non-pecuniary transactions services.

2.1.2 EA households

EA households solve a problem similar to that of US households. The intertemporal utility function is analogous to that reported in equation 1. Their budget constraint is:

$$
\begin{aligned}
& M_t^{EA} - M_{t-1}^{EA} + B_t^{EA} - R_{t-1}^{EA} B_{t-1}^{EA} + S_t^{EA} B_t^{US,EA} - R_{t-1}^{US} S_t^{EA} B_{t-1}^{US,EA} \\
& + S_t^{EA} B_{PR,t}^{US,EA} - \tilde{R}_{t-1}^{US} S_t^{EA} B_{PR,t-1}^{US,EA} \left(1 - \Gamma_{PR,t}^{EA}\right) \\
& = W_t^{EA} N_t^{EA} + r_t^{K,EA} K_{t-1}^{EA} + D_t^{EA} - \left(1 + \tau_t^{EA}\right) P_t^{EA} C_t^{EA} - P_{I,t}^{EA} I_t^{EA} + TR_t^{EA}
\end{aligned}
$$

EA households not only hold bonds issued by the domestic public sector, B^{EA}, but also those issued by the US public sector, $B^{US,\,EA}$ and by the US private sector, $B_{PR}^{US,EA}$, subject to incurring a financial intermediation cost Γ_{PR}^{EA}.[13] The transaction cost is similar to the one for the US (see equation 2 above). Symmetrically, the EA private households' effective money holdings, $\tilde{M}_t^{EA}$, are defined as:

$$
\tilde{M}_t^{EA} = \left(M_t^{EA}\right)^{\omega_1^{EA}} \left(B_t^{EA}\right)^{\omega_2^{EA}} \left(S_t^{EA} B_t^{US,EA}\right)^{1-\omega_1^{EA}-\omega_2^{EA}} \tag{9}
$$

where $0 < \omega_1^{EA}, \omega_2^{EA} < 1$. The effective money holdings include not only domestic money M^{EA} and public sector bonds B^{EA}, but also US public sector bonds $B^{US,EA}$.

[13] The indeterminacy of the steady state net foreign asset position is standard in open economy models with representative households and incomplete international financial markets. See, for example, Pesenti (2008). To the opposite, along the transition dynamics the net foreign asset position endogenously adjusts to the given shock, thanks to the presence of financial intermediation costs. We assume that all the costs incurred due to this financial intermediation service accrue as a revenue to the forward-looking or Ricardian households that reside in the US. In line with most of the literature our intermediation cost assumes the following functional form: $\Gamma_{PR}^{J} = \frac{\phi_1 \left[\exp^{\phi_2 \left(S_t^J B_{PR,t}^{US,J}/GDP_t^J - \bar{B}_{PR}^{US,J}\right)} - 1\right]}{\exp^{\phi_2 \left(S_t^J B_{PR,t}^{US,J}/GDP_t - \bar{B}_{PR}^{US,J}\right)} + 1}$ where $\bar{B}_{PR}^{US,J}$ is the "desired" *net* asset position in the "non-liquid" or "risky" bond denominated in US dollars of country J expressed as a ratio of its own GDP. A more complete discussion of this functional form can also be found in Faruquee et al. (2007).

Optimality conditions are analogous to the corresponding ones for the US households:

$$1 - A^{EA}\left[\left(v_t^{EA}\right)^2 - \left(\bar{v}^{EA}\right)^2\right]\omega_1^{EA}\frac{\tilde{M}_t^{EA}}{M_t^{EA}} = E_t\left[\beta\frac{\Lambda_{t+1}^{EA}}{\Lambda_t^{EA}}\frac{P_t^{EA}}{P_{t+1}^{EA}}\right] \tag{10}$$

$$1 - A^{EA}\left[\left(v_t^{EA}\right)^2 - \left(\bar{v}^{EA}\right)^2\right]\omega_2^{EA}\frac{\tilde{M}_t^{EA}}{B_t^{EA}} = R_t^{EA}E_t\left[\beta\frac{\Lambda_{t+1}^{EA}}{\Lambda_t^{EA}}\frac{P_t^{EA}}{P_{t+1}^{EA}}\right] \tag{11}$$

$$1 - A^{EA}\left[\left(v_t^{EA}\right)^2 - \left(\bar{v}^{EA}\right)^2\right]\left(1 - \omega_1^{EA} - \omega_2^{EA}\right)\frac{\tilde{M}_t^{EA}}{S_t^{EA}B_t^{US,EA}} = R_t^{US}E_t\left[\beta\frac{\Lambda_{t+1}^{EA}}{\Lambda_t^{EA}}\frac{P_t^{EA}}{P_{t+1}^{EA}}\frac{S_{t+1}^{EA}}{S_t^{EA}}\right] \tag{12}$$

Combining the linearized versions of the last two optimality conditions shows that in this model there is a departure from the standard uncovered interest-parity condition (UIP), due to the imperfect substitutability of US and EA bonds, as highlighted by Canzoneri, Cumby, and Diba (2013).

2.1.3 Households in China, Japan and the RW

Equations for the households in the other three regions are slightly different from the previous ones. In particular, they hold not only domestic money and government bonds, but also US and EA government bonds, as they provide international liquidity services. So in each region J (= China, Japan, RW) the effective money holdings are:

$$\tilde{M}_t^J = \left(M_t^J\right)^{\omega_1^J}\left(B_t^J\right)^{\omega_2^J}\left(S_t^J B_t^{US,J}\right)^{\omega_3^J}\left(S_t^{J,EA}B_t^{EA,J}\right)^{1-\omega_1^J-\omega_2^J-\omega_3^J} \tag{13}$$

where ω_1^J, ω_2^J, ω_3^J are parameters ($0 < \omega_1^J, \omega_2^J, \omega_3^J < 1$), and S_t^J and $S_t^{J,EA}$ are, respectively, the nominal exchange rates vis-à-vis the US dollar and the euro (number of local currency per unit of dollar and euro). M^J, B^J, $B^{US,J}$, $B^{EA,J}$ are, respectively, the amounts of domestic money, domestic government bonds, US and EA government bonds.

2.2 Fiscal and monetary policy rules

In the following we will consider a variety of monetary and fiscal policy rules. As a matter of reference we describe in this section the benchmark policy rules.

2.2.1 US fiscal policy

The US government's flow budget constraint is

$$M_t^{US} + B_{G,t}^{US} + \frac{B_{G,t}^{EA,US}}{S_t^{EA}} = M_{t-1}^{US} + R_{t-1}^{US} B_{G,t-1}^{US} + \frac{R_{t-1}^{EA} B_{G,t-1}^{EA,US}}{S_t^{EA}} + P_t^{US} G_t^{US} + TR_t^{US}$$

where B_G^{US} is the total supply of US government bonds, $B_G^{EA,US}$ is the exogenous stock of US official reserves in euro denominated government bonds, and G_t^{US} is the public consumption. Public consumption is exogenous and is kept constant at its initial steady state level. Governments consume only the national final good. Lump sum transfers TR^{US} assure fiscal solvency:

$$TR_t^{US} - \overline{TR}^{US} = -\varphi_b^{YS} \left(B_{G,t-1}^{US} - \bar{B}_G^{US} \right) \tag{14}$$

where $\varphi_b^{US} > 0$ is a parameter that determines the tightness of the fiscal policy rule, i.e. the speed at which debt is returned to the target level.

2.2.2 Fiscal policy in other regions

The EA (US) government holds US (EA) government bonds as reserves, while Chinese, Japanese and the RW governments hold both EA *and* US government bonds. For the EA we have:

$$\begin{aligned} & M_t^{EA} + B_{G,t}^{EA} + S_t^{EA} B_{G,t}^{US,EA} \\ &= M_{t-1}^{EA} + R_{t-1}^{EA} B_{G,t-1}^{EA} + R_{t-1}^{US} S_t^{EA} B_{G,t-1}^{US,EA} + P_t^{EA} G_t^{US} + TR_t^{EA} \end{aligned}$$

where B_G^{EA} is the bond issued by the euro fiscal authority and denominated in euros, while $B_G^{US,EA}$ denotes reserves holdings of dollars, assumed to be exogenous. An analogous budget constraint holds for the US

For China, Japan and the RW the goverment budget constraint is:

$$\begin{aligned} & M_t^J + B_{G,t}^J + S^{EA,J} B_{G,t}^{EA,J} + S_t^J B_{G,t}^{US,J} \\ &= M_{t-1}^J + R_{t-1}^J B_{G,t-1}^J + S^{EA,J} R_{t-1}^{EA} B_{G,t-1}^{EA,J} + R_{t-1}^{US} S_t^J B_{G,t-1}^{US,J} + P_t^J G_t^J + TR_t^J \end{aligned}$$

where B_G^J is the bond issued by the local government in local currency, while $B_G^{US,J}$ and $B_G^{EA,J}$ represent dollar- and euro-denominated reserves, both exogenously set. Finally, in each country lump-sum transfers endogenously adjust to stabilize the corresponding domestic public debt according to a (fiscal) rule similar to (14).

2.2.3 Monetary policy

In each economy a standard Taylor rule holds. For the US, it is:

$$\log\left(R_t^{US}/\bar{R}^{US}\right) = \rho_R^{US}\log\left(R_{t-1}^{US}/\bar{R}^{US}\right) + \left(1-\rho_R^{US}\right)\varphi_\pi^{US}\log\left(\Pi_t^{US}/\bar{\Pi}\right) \tag{15}$$

where $\rho_R^{US} > 0$ is a parameter capturing inertia in the monetary policy conduct while $\varphi_\pi^{US} > 0$ is the parameter measuring the response of the policy rate to the domestic inflation rate Π^{US} (variables are expressed as deviation from the corresponding steady state variables, denoted by an upper-bar). Similar Taylor rules hold for the other regions.

2.3 Calibration

Tables 1 to 7 report the (quarterly) calibration of the model. Parameters are set accordingly to match the main empirical evidence and by following the existing literature. In particular, similarly to CCDLS, we calibrate the parameters of transactions costs and the transactions technology to match some key monetary and fiscal statistics.

Table 1 reports the model implied great ratios for the five regions. In the Table we show separately the consumption shares of forward-looking and liquidity-constrained consumers. To calibrate these shares we follow N'Diaye et al. (2010). These authors assume in the calibration of their multi-country model that the share of consumers facing liquidity constraints in China is approximately twice as large as in the remaining regions.

Table 2 shows the implied preference and technology parameters. Preferences are the same across households of different regions. The habit parameter is set to 0.85, the intertemporal elasticity of substitution to 1.0 and the Frisch elasticity to 0.50. We further assume a quarterly depreciation rate of capital to 0.02, consistently with an annual depreciation rate of 8 percent.

As for the final goods, the degree of substitutability between domestic and imported tradables is higher than that between tradables and non-tradables, consistently with the existing literature. We set the (long-run) elasticity of substitution between tradables and non-tradables to 0.5 and the long-run elasticity between domestic and imported tradables to 2.5.

Table 3 reports real and nominal rigidities. For real rigidities, parameters of the adjustment costs on investment changes are set to 3.5 in all countries. For nominal rigidities, we set the Rotemberg (1982) price and wage adjustment parameters in the tradable and non-tradable sectors to 400. This value for quadratic adjustment costs in prices is roughly equivalent to a four-quarter contract length under Calvo-style pricing, as highlighted, among others, by Faruquee et al. (2007).

The weight of domestic tradable goods in the consumption and investment tradable baskets is different across countries, to match multilateral import-to-GDP ratios. In particular, we rely on the United Nations' Commodity Trade Statistics (COMTRADE) data on each region's imports of consumer and capital goods, to derive a disaggregated steady-state matrix delineating the pattern and composition of trade for all regions' exports and imports. We then set the weights of bilateral imports to match this trade matrix, reported in Table 4. It is interesting to note that trade with the RW region clearly dominates trade patterns for all the other countries.

Note that due to the presence of USD and EUR government bonds that provide transactions services internationally and act as official reserves we report both *overall* NFA positions – the standard measure that includes both the outstanding net stocks in the reserve currency bonds and in the other "riskier" components of the NFA – and a *net* measure of the NFA which includes only privately issued assets. These two different measures of the NFA position show that the US is a net debtor in government bonds and a net creditor in privately-issued assets: its overall NFA position amounts to a deficit of 27 percent relative to GDP, whereas the corresponding net measure which excludes government bonds from its international assets and liabilities exhibits a 13.3 percent surplus. China's net position in privately-issued "risky" assets is instead negative: the overall position exhibits a surplus of 21%, whereas the NFA excluding private and official holdings of USD and EUR govt bonds reveals a 6.5% deficit. A similar picture emerges for the RW bloc when comparing the two different NFA measures. Finally, the EA exhibits a balanced position when excluding governement bond positions from its NFA measurement (-0,4% vs. -17.6%), while Japan's creditor status is more than halved (23%), compared to its overall NFA position (57%). The values chosen for the parameters governing the dynamics of these "non-liquid" components of the NFA, ϕ_1 and ϕ_2, are reported at the end of this table.

Table 5 contains price and wage markup values. We identify the non-tradable and tradable intermediate sectors in the model with the services and manufacturing sectors in the data, respectively. In each region the markup in the non-tradable sector is higher than that in the tradable sector and labor market, which we instead assume to be equal. Our values are in line with other existing similar studies, such as Bayoumi et al. (2004), Faruqee et al. (2007), Everaert and Schule (2008). Many, if not all, of these studies refer to Jean and Nicoletti (2002) and Oliveira Martins and Scarpetta (1999) for estimates of markups.

Table 6 reports the parameters of the policy rules. For monetary policy rules, the interest rate reacts to the its lagged value (inertial component of the monetary policy), gross inflation and output growth (see equation 15). For fiscal policy, the parameter governing the speed of speed of adjustment of public debt is assumed equal across countries and allows to stabilize the debt in the long run.

Table 7 shows the ratios for the different asset stocks that enter into the model: currency in circulation, total general government debt levels and, in the case of the United States and the EA, for foreign private holdings of government debt issued in US dollars and in euros. The ratios are matched by calibrating the parameters affecting the transactions technology, which involves money and government bonds held by private agents. Following CCDLS we first compute the ratios reported in Table 7 (i.e. $M^J/B^J, M^J/B^{R_i,J}$ where $J = EA, US, CH, JP, RW$ and $R_i = EA, US$) using the data available on currency in circulation, total general government debt levels and, for the United States and the euro area, on foreign private holdings of government debt issued in US dollars and in euros. The specific data sources used to compute these stocks are reported in the Appendix. Second, we use these asset ratios, together with the transactions costs (τ), which we set as in CCDLS to 0.8 percent of consumption, and with our choice of the liquidity premium, to jointly pin down the parameters entering the transactions costs and transactions technology (i.e. the cost parameters A^J, the satiation levels of velocity v^J, and the shares of the various assets – denoted above by ζ and ω – in the definitions of the effective transactions balances, $\tilde{M}^J$). We also compute foreign official holdings of US and EA government bonds to calibrate separately the stocks of foreign official reserves ($B_G^{R_i,J}$). These values are also reported in Table 7.

Finally, we set the discount factor so that the steady-state annualized real interest rate on risky (or "non-liquid") assets, i.e. the CCAPM rate, is about 7 percent. Given this choice for the risky rate we then set the yield on the government bonds, which in our model command an endogenous liquidity premium, such that the resulting steady state liquidity premia on government bonds – assumed to be equal across all regions – amounts to 3.6 percentage points.[14]

[14] While this value is admittedly too high for Japan, it seems consistent with the average values for liquidity premia reported for the other countries in our model, as can be seen, e.g., in Table 5.5 of the World Development Indicators published by the World Bank.

3 Results

In what follows we simulate the model to assess the macroeconomic implications of an increase in US dollar and/or euro reserves in countries other than the US and the EA. To increase comparability, in each of the following scenarios we assume that the aggregate level of reserves in each region other than the US and the EA is increased by 1 percentage point. In the first scenario, it is assumed that China, Japan and the RW permanently and simultaneously increase their reserves by one percent, equally distributed between euro and dollar denominated government bonds. In the second scenario, a one percent increase in overall reserves is achieved via a one percent decrease in US dollar reserves and a more than offsetting increase in euro ones. Three further scenarios study the effects of asymmetric reserve management across China, Japan and the RW.

All simulations start from 2012 and are run under perfect foresight. Therefore, there is no uncertainty, policies are fully credible and households and firms perfectly anticipate the future. We assume that the monetary and fiscal policy authorities in all countries follow the benchmark policy rules specified above (equations 15 and 14). Thus, as the monetary authorities follow an interest rate rule the changes in official reserves holdings are not sterilized interventions, because they are not perfectly offset by variations in domestic government bonds.[15] As such, authorities in China, Japan and the RW finance their purchases (sales) of official reserves through temporary issuance (purchase) of domestic government bonds and tax increases (cuts). The tax increases (cuts) are dictated by the benchmark fiscal policy rule, which requires that over time the debt be stabilized at its target value.

3.1 "So far, so good" scenario

Figure 2 shows current account, trade balance and real exchange rate responses when China, Japan and the RW increase their official reserves both in dollars and in euros, by one percent of the corresponding initial level. The euro and the dollar appreciate versus all other currencies, as the demand for euro and dollar increases. The euro depreciates vis-à-vis the US dollar as in absolute terms the demand for the latter increases relative to the demand for the former. Given the exchange rate appreciations, the US and EA trade balances deteriorate.

Current accounts – which here are defined as changes in the international investment

[15] As explained also in CCDLS (2013) if the monetary authorities were instead to follow a constant money growth rule then the official reserves changes (i.e. the purchases or sales) would be sterilized foreign exchange interventions.

position and therefore include valuation changes – move on impact much more than the corresponding trade balances. This is mainly because of valuation effects. In fact, the initial real depreciation translates into valuation gains – notwithstanding the fall in US and EA yields – on the outstanding positions in reserve currency bonds held by China, Japan, RW, and the EA, and a corresponding valuation loss for the US on its holdings of EA government bonds. The reaction on impact of the current account is particularly striking for both the EA and the US. For the former the current account improves on impact, due to the valuation effects on its dollar denominated bond holdings (notwithstanding the lower interest payments received), and subsequently turns negative, as the trade balance, which immediately falls on impact, progressively dominates the current account dynamics. In the case of the US, the current account worsens much more on impact than in the successive periods (both due to the dollar's real appreciation and the lower interest payments received on EA government bond holdings), due to the negative valuation effects. Also for Japan, and, to a lesser extent, for China, and the RW, the initial responses of the current accounts, when compared to the corresponding movements in the respective trade balances, are initially strongly affected by the valuation effects. Portfolio rebalancing on behalf of households in response to the shock also plays a role in driving the current account changes. For example, US investors tend to dump domestic assets in favor of EA bonds whose yields have increased relative to the ones on US bonds.

Figure 3 reports results for the US economy. GDP and aggregate demand gradually increase. Consumption increases at the peak by slightly more than 0.03 percent, investment by nearly 0.15 percent with respect to their respective initial steady state values. US exports decrease because of the dollar appreciation (negative expenditure switching effect). US imports increase because of the higher domestic aggregate demand and the dollar appreciation. The increase in US aggregate demand is driven by the higher demand for US assets by foreign authorities, which raises the dollar value of domestic bonds in US households' portfolios. The latter also experience an increase in their purchasing power, associated with the appreciation of the dollar. Moreover, the higher demand for US assets reduces the US interest rate on a permanent basis, making borrowing cheaper in domestic assets and increasing the seigniorage collected by the US government from abroad on the low interest rate bonds that it issues. The reduction in the US interest rate, as already highlighted in CCDLS, reduces the lump-sum tax burden (or equivalently increases the lump-sum transfers) faced by US residents (not shown) further sustaining their consumption.[16] Differently than in CCDLS in our model

[16]Note that US consumption increases both with respect to domestically produced and imported

with capital, the fall in the US interest rate on the liquid bonds, pictured in Figure 3 as the monetary policy rate, by also pushing down the CCAPM rate favors investment spending.

Simultaneously, US households increase their holdings of EA bonds, that pay a relatively high interest rate, and their holdings of money. The overall liquidity held by households, that closely tracks the holdings of US bonds, slightly decreases. However, measured in terms of the interest rate spread (not shown) – the difference between the risky CCAPM rate and the rate on the bonds embodying liquidity services – aggregate liquidity conditions in the US relax following the shock: the spread rises on average, but *both* interest rates fall, more so the liquid bond rate than the CCAPM rate.

Figure 4 shows results for the EA. There are positive effects on GDP, domestic consumption and investment. Net exports decrease, because the euro appreciates against currencies other than the US dollar. As for the US, EA households' consumption and investment increase because of the persistent decrease in the interest rate and the appreciation of the euro. These changes are associated with the permanent change in international households' portfolios. Households decrease their position in US bonds, whose expected returns have fallen, in favor of euro-denominated bonds and domestic money holdings. Overall liquidity does not greatly change, but again, as for the US, the interest rate spread faced by EA residents rises, driven by *falls* both in the liquid and in the CCAPM rates.

Figures 5 shows the effects of the increase in reserves for the main domestic macroeconomic variables in China (in Japan and the RW results are similar and are omitted to save on space).

Chinese GDP falls slightly, following the decrease in consumption and investment, partially compensated by the increase in net exports. Households reduce consumption and investment demand because they are taxed more and buy the newly issued government bonds, so as to finance the increase in official reserves. Gross exports mainly increase towards the US and the EA, because exporters benefit from the US dollar and euro appreciation and the increase in US and EA aggregate demand. Imports decrease, mainly from the US and the EA, because of the dollar and euro appreciation and the decrease in domestic aggregate demand.

Households in China increase domestic bonds and money holdings. They reduce their holdings of US dollars and euros, because the corresponding returns have decreased (the decrease in US bonds is larger because of the larger decrease in the expected return).[17]

goods.

[17] Households do not completely offset the increase in currency reserves, since assets are imperfect

Overall liquidity does not greatly change. As in the previous case the spread (not shown) measuring the liquidity premium rises, but contrary to what happens in the US, it is driven by a *fall* in the liquid bond rate and a *rise* in the CCAPM rate.

The real exchange rate depreciation experienced by China determines a relative negative wealth effect, as it makes US and EA goods more expensive and as the fall in interest rates induced by the shock – both on foreign and domestic bonds – reduces the (real) interest payments on Chinese, Japanese, and RW households' bond holdings. It also has a positive valuation effect, because the depreciation makes the initial holdings of foreign assets, denominated in dollars and euros, more valuable in domestic currency. The wealth effect clearly dominates over the valuation effect.

To sum up, the increase in official demand of US dollars and euros favors the appreciation of the two currencies, the deterioration of the US and EA current account and trade balance, and the increase in aggregate demand in the two regions, financed by the increase in borrowing. The remaining regions show an increase in their trade surpluses against the EA and the US.[18]

3.2 "Rebalancing" scenario

It is now assumed that China, Japan and the RW decrease their reserves in dollars and increase the reserves in euros. In particular, in this scenario, the increase in euro denominated reserves is calibrated in such a way that for a given 1 percent decrease in the level of US dollar denominated reserves the resulting increase in the aggregate level of reserves amounts to 1 percentage point. As reserves in euro are much lower than the corresponding ones in US dollars, this scenario *de facto* corresponds to a very asymmetric variation in the size of reserves.

As shown in Figure 6 the euro now appreciates against all the other currencies, US dollar included. This implies a larger deterioration of the EA trade balance, by 0.14 percent of GDP at its peak, because of the large crowding-out of EA tradables. The US trade balance, instead, improves, by 0.02 percent. As before note that the dynamics of the current account is intially dominated by the large valuation effects.

substitutes. In case of perfect substitutability the additional demand in reserves would be fully accommodated by households without any effect on relative returns and exchange rates. A swap between authorities and households would simply occur.

[18] Results are qualitatively similar if the increase in reserves is only in US dollars. In fact, the euro area, being a reserve currency region, partly benefits from the increased demand in official reserves, even if it is exclusively directed towards reserves denominated in US dollars, as the induced changes in asset prices and their returns determine an increase in the global private demand for euro-denominated bonds. Results are available upon request.

Figure 7 shows the outcome for the US economy. The interest rate increases, because of the decrease in demand for US bonds by foreign central banks. As a consequence, consumption and investment decrease and drive down GDP. The contraction of aggregate demand is partially compensated by the increase in net exports, favored by the exchange rate depreciation. Now US households reduce their EA bond holdings, whose return is lower, and domestic money, and increase the holdings of domestic government bonds, whose returns have increased.

EA variables show a dynamics opposite to that of the corresponding ones for the US (see Figure 8). The interest rate decreases because of the increase in global demand for EA bonds. The exchange rate appreciation and the lower interest rate have positive effects on GDP, because they induce an increase in consumption and investment. Consistently, households reduce their holdings of domestic bonds and increase their demand for money and US bonds. The exchange rate appreciation has negative effects on tradables' price competitiveness. As a result, EA net exports decrease.

Figure 9 shows results for China (for Japan and RW results are similar to those for China and to save on space we do not report them). Exports increase while imports decrease. The increase in exports is due to the higher EA aggregate demand and the depreciation of the exchange rate against the euro.

To conclude, there is a rebalancing of global aggregate demand in favor of EA aggregate demand, as the latter benefits from the increasing global demand for euro-denominated assets. By contrast, US aggregate demand contracts due to the reduction in the global demand for US dollar assets. The external balance of the EA deteriorates, to satisfy the increase in demand for euros. Symmetrically, the US external balance improves. Compared to the previous scenario, featuring a simultaneous increase in US dollar and euro reserves holdings, the rebalancing of official reserves from dollars into euros hurts US aggregate demand and greatly expand EA's, as the "exorbitant privilege" enjoyed by the former country recedes while, at the same time, that of the latter surges.

3.3 Asymmetric reserve management

The two previous simulations assume that China, Japan and the RW simultaneously and symmetrically increase their reserves in US dollars and euros or rebalance their reserves towards the euro. The resulting macroeconomic performance of the three countries is similar.

We now evaluate whether cross-country asymmetric changes in the composition of official reserves would affect results. We simulate three scenarios. In the first one, China is the only region to exogenously increase its reserves in euros and dollars by one percent. In the second, Japan and the RW increase their reserves of euros and dollar by one percent, while China pegs its exchange rate to the US dollar (and its exchange rate reserves become endogenous). Finally, we assume that China decreases its reserves by one percent, while the other two non-reserves countries keep increasing their foreign exchange rate holdings by one percent.

3.3.1 Unilateral Chinese increase in reserves

It is now assumed that China is the only region to increase its reserves of euros and dollars. As in the benchmark simulations, the increase is equal to one percent of the initial level.

Figure 10 reports the responses of nominal exchange rates and current account balances. The depreciation of the Chinese exchange rate vis-à-vis the US dollar is large (0.18 percent). It is also considerable vis-à-vis the euro and other currencies that depreciate against the dollar to a much lower extent. The Chinese trade balance improves by close to 0.05 percent. Other countries show trade deficits, in particular the US. The reason is the price-competitiveness gain of Chinese tradables, associated with the exchange rate depreciation.

The effects on the US and EA macroeconomic variables are similar to those reported in the previous section and we do not report them to save on space. They are expansionary but less strong, as the overall increase in euro and US dollar demand is smaller since it is now only China that increases its demand for euros and dollars by one percent. Relative to the case of cross-country simultaneous increase in reserves, results for the Chinese economy do not greatly change (see Figure 11). The fall in Chinese GDP is smaller than in the previous cases, because of the persistent increase in net exports. The latter now increase not only towards the US and the EA, but also towards Japan and the RW, because of the larger depreciation of the Chinese currency towards all other currencies. Effects on Japan and RW macroeconomic variables are very small. The main effect is on their (gross and net) exports, that are crowded-out by the renminbi depreciation.

3.3.2 "Bretton Woods II"

We now assess the role of the exchange rate regime for the macroeconomic effects of the increase in global demand for euro and US dollar reserves. It is assumed that Japan and RW increase their US dollar and euro reserves by one percent, while China keeps its nominal exchange rate fixed against the US dollar by appropriately adjusting its dollar reserves (that become endogenous). This scenario is designed to closely resemble the so-called "Bretton Woods II" system (Dooley, Folkers-Landau and Garber, 2003).

Figure 12 shows results for trade balances and real exchange rates. Compared to the previous simulations, the renminbi now depreciates, in real terms, to a much lower extent, relative to the US dollar. This is because it is now pegged to the dollar, in nominal terms. Vis-à-vis the other currencies, the Chinese real exchange rate intially appreciates and the Chinese trade balance deteriorates, as Chinese tradables lose price competitiveness and Chinese households' purchasing power improves. Effects on the US, EA, Japan and RW are similar to those obtained in the previous sections and to save on space they are not reported.[19] Figure 13 reports results for Chinese macroeconomic variables. Consumption and investment slightly increase in the medium run, because the very small depreciation of the real exchange rate has a less negative wealth effect. In fact, the renminbi's real appreciation versus all the other currencies improves Chinese consumers' purchasing power. Moreover, Chinese authorities sell their US dollar reserves to avoid any renminbi depreciation with respect to the US currency. This implies that there is no need by Chinese households to increase their savings as, contrary to the previous scenarios, there is no need by Chinese authorities to issue debt to their citizens, thereby mobilizing domestic saving, and then to use the proceeds to buy U.S. Treasury securities. As noted above, because of the initial real exchange rate appreciation vis-à-vis the other currencies and the increase in domestic aggregate demand, Chinese exports decrease and imports increase, in the short to medium run.

3.3.3 China sells some of its reserves

Finally, we analyze the case in which China reduces its official holdings of dollars and euros (by one percent each), while Japan and RW keep increasing theirs (by one percent).

Results are striking. The renminbi appreciates in real terms against all currencies, especially the yen, given that Japan is assumed to keep selling domestic for foreign currency assets (Figure 14). The euro is little changed against the dollar in real terms. As a consequence, the trade balance deteriorates in China, while it improves in Japan and RW. Main EA and US macroeconomic variables are to a large extent unaffected, as the higher Japanese and RW demand for dollar- and euro-denominated assets is offset by the Chinese reduction. If anything, EA and US consumption and investment

[19] As in previous simulations, US and euro area exchange rates appreciate, their current account deteriorates and their aggregate demands increase. Symmetrically, Japan and the RW trade balances improve and their savings increase.

slightly increase, while net exports decrease (not shown for brevity). Chinese GDP increases following the increase in consumption and investment (Figure 15). The latter benefit from the reduction in domestic interest rates. Chinese net exports decrease. Symmetrically, consumption and investments fall in Japan and RW, as the financing of the increase in foreign exchange reserves weighs on the domestic sector.

4 Welfare

In this section we show welfare results. Welfare is measured as the fraction of permanent consumption that must be given up in order to equal the welfare attained under a particular scenario (e.g. the "so far, so good" scenario) to that of the initial (suboptimal) steady state. Following Leith et al. (2012) and Rieth (2014), we compute the quarterly welfare cost as a percentage of initial steady state consumption, Ψ, for a generic country J as follows:

$$\Psi = \left\{1 - \exp\left[(1-\beta)\, W_t^J + \frac{\bar{N}^{J1+\chi}}{1+\chi} - \log\left((1-\xi)\, \bar{C}^J\right)\right]\right\} * 100$$

where W^J is the welfare of country J under a particular scenario, computed as the discounted sum of household utility under perfect foresight conditional on the state of the economy in the initial period *0* being the initial nonstochastic steady state. Upper bars denote initial steady state values of the variables. Since our scenarios are all constructed as one-time permanent shocks, implying that the steady state permanently changes from period *1* onwards, Ψ measures the cost (or benefit) associated with a permanent change from the initial to the new and terminal steady state under perfect foresight.

Welfare costs for all of the scenarios considered in the previous Section are reported in Table 8. A build-up in official reserves always increases the welfare of the reserve currency countries, while it always hurts the accumulating countries. The benefits for the EA and the United States amount respectively to 0.004 and 0.008 percentage points of (initial steady state) consumption in each quarter, under the "so far, so good" scenario (row [1]). They are lower when we consider the scenarios under which only China (row [3]) or only Japan and the RW (row [4]) increase their US dollar and euro official reserves holdings; they are lowest, as one would expect, when in addition and at the same China is decreasing its reserves holdings (row [5]). In this latter case China would experience substantial welfare benefits, as its consumption would increase permanently by 0.02 percentage points in each quarter. A quantitatively similar welfare gain would accrue to the EA if it were to increase its share in global reserve holdings (row [2]).

Under this “rebalancing" scenario, the concurrent decrease in US dollar denominated official reserves holdings would cost US citizens approximately 0.007 percentage points of consumption in each quarter. The costs are even higher for those countries that are actively accumulating official reserves. Permanent consumption losses are around 0.015 percentage points for Japan and China, while they are around one half or one-third this size for the RW, due to its lower reserves holdings.

These numbers are not trivial. as they mainly reflect the size of the shock. To put them into context, one should take into account that actual changes in foreign exchange reserve holdings have been a multiple of our shock. For instance, official reserves denominated in US dollars increased by 10 per cent per year in the period 2009-2012, that is ten times more than our shock on impact and 30 times more cumulatively.

5 Conclusions

We have assessed the macroeconomic effects for the global economy of different foreign exchange reserve management strategies in countries that have accumulated large holdings of foreign assets. In an international monetary system in which the euro plays a larger role, the EA would benefit from lower interest rates. Interestingly, the US economic activity would not suffer as long as the demand for US dollar-denominated assets continues to increase. Economic activity in countries that accumulate reserve assets would not be damaged in such a bipolar system, as they will continue to benefit from an increase in net exports to the EA.

A management of foreign exchange holdings that is asymmetric among non-reserve countries would not greatly modify the macroeconomic performance of the EA and US economies, relative to the case of a symmetric increase. However, it would make asymmetric the macroeconomic performance of the countries holding reserves and increase imbalances between them. In particular, if China sells reserves, its consumers benefit because there is no need to increase savings to finance the larger stock of foreign exchange reserves and because of the positive wealth effect associated with the appreciation of the exchange rate.

To simplify the analysis, we deliberately neglected exploring alternative formulations of several important features of the model, which would deserve to be analyzed in greater depth. For instance, the analysis may be extended to delve deeper into the degree of substitutability among the different assets. Moreover, we did not touch on the potential strategic interactions between international liquidity providers, between them and the holders of international reserves, and among reserve holders themselves in terms of the timing and/or extent of currency portfolios changes. These questions also raise important policy implications for international cooperation and coordination. We leave all these interesting issues for future research.

Appendix

A Data sources

We rely on several data sources in order to compute the different asset holdings that characterize the model. In particular, money balances held by households are computed as 2001-2012 averages using the variable "Currency in circulation" from the IMF's *International Financial Statistics* database. Data on foreign private and official holdings of US government bonds is taken from the April 2013 issue on *Foreign Portfolio Holdings of US Securities* published jointly by the Department of the Treasury, the Federal Reserve Bank of New York, and the Board of Governors of the Federal Reserve System. The outstanding holdings refer to June 2012. We include both short- and long-term debt issued both by the Treasury and by the Government-sponsored Agencies. The latter have been taken over or placed into conservatorship by the U.S. Treasury in September 2008, and as such should command a liquidity premium equal or, at least, very close to that on U.S. Treasury bonds. As the information provided for China only refers to the aggregate holdings, with no distinction between private and official holdings being available, we assume that the entire holdings are official, except for a small part which we arbitrarily assume is being held by private households: alternatively, we would have needed to modify the model in order to set private Chinese household holdings of US bonds equal to zero, but this would have added some complications to our calibration procedure. Foreign holdings of euro denominated government bonds are computed from Tables A1 and A2 in *The International Role of the Euro*, July 2013, ECB. As we have no information on the different types of holders, we apply the same percentage shares used for US government bonds, taken from the aforementioned publication, to compute private versus official holdings of euro denominated government bonds. Finally, data on domestic holdings of government bonds are computed by combining the IMF's *Fiscal Monitor* database and the information on the different types of holders (private vs. official) reported in Andritzky (2012).

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Table 1: Steady state national accounts (percent)

	EA	US	CHN	JAP	RW
Private consumption	54.3	58.5	38.8	55.1	56.7
Liquidity-constrained	13.7	13.7	24.2	13.8	13.8
Forward-looking	40.6	44.8	14.6	41.4	42.9
Private investment	20.0	15.0	40.0	20.0	20.0
Public expenditure	20.0	20.0	20.0	20.0	20.0
Imports	23.8	14.3	22.2	14.8	19.2
Consumption goods	13.1	7.8	10.3	8.2	11.1
Investment goods	10.7	6.5	11.9	6.6	8.1
Public debt (% of yearly GDP)	92.8	102.7	26.1	238.0	80.8
Share of world GDP	14.1	21.1	14.9	9.2	40.7

Note: EA=euro area; US=United States; CHN=China; JAP=Japan; RW=Rest of the world.

Table 2: Households and Firms Behavior

	EA	US	CHN	JAP	RW
Households					
Subjective discount factor	0.9901	0.9901	0.9901	0.9901	0.9901
Depreciation rate	0.02	0.02	0.02	0.02	0.02
Intertemporal elasticity of substitution	1.00	1.00	1.00	1.00	1.00
Habit persistence	0.85	0.85	0.85	0.85	0.85
Inverse of the Frisch elasticity of labor	2.00	2.00	2.00	2.00	2.00
Tradable Intermediate Goods					
Bias toward capital	0.40	0.40	0.50	0.40	0.40
Non-tradable Intermediate Goods					
Bias toward capital	0.35	0.35	0.45	0.35	0.35
Final consumption goods					
Substitution btw domestic and imp. goods	2.50	2.50	2.50	2.50	2.50
Bias toward domestic goods	0.52	0.83	0.34	0.67	0.77
Substitution btw tradables and non-trad.	0.50	0.50	0.50	0.50	0.50
Bias toward tradable goods	0.50	0.50	0.60	0.50	0.50
Final investment goods					
Substitution btw domestic and imp. goods	2.50	2.50	2.50	2.50	2.50
Bias toward domestic goods	0.28	0.59	0.24	0.47	0.60
Substitution btw tradables and nontr.	0.50	0.50	0.50	0.50	0.50
Bias toward tradable goods	0.50	0.50	0.70	0.50	0.50

Note: EA=euro area; US=United States; CHN=China; JAP=Japan; RW=Rest of the world.

Table 3: Real and nomianl rigidities

	EA	US	CHN	JAP	RW
Real Rigidities					
Investment adjustment	3.50	3.50	3.50	3.50	3.50
Nominal Rigidities					
Households					
Wage stickiness	400	400	400	400	400
Manufacturing					
Price stickiness (domestically produced goods)	400	400	400	400	400
Price stickiness (imported goods)	400	400	400	400	400
Services					
Price stickiness	400	400	400	400	400

Note: EA=euro area; US=United States; CHN=China; JAP=Japan; RW=Rest of the world.

Table 4: International linkages (percent of GDP)

	EA	US	CHN	JP	RW
Substitution between consumption imports	2.50	2.50	2.50	2.50	2.50
Imported consumption goods from					
EA	...	1.1	1.0	0.8	3.4
US	0.9	...	0.8	0.7	4.3
CHN	1.3	1.4	...	1.8	2.5
JAP	0.3	0.5	0.9	...	0.9
RW	10.5	4.9	7.6	5.9	...
Substitution between investment imports	2.50	2.50	2.50	2.50	2.50
Imported investment goods from					
EA	...	0.8	1.1	0.4	2.9
US	0.9	...	0.9	0.6	1.7
CHN	1.2	1.3	...	1.4	2.7
JAP	0.3	0.4	1.3	...	0.9
RW	8.4	4.0	8.6	4.3	...
Net foreign assets (%yearly GDP)	−17.6	−27.4	21.0	57.3	5.3
Net foreign assets (%yearly GDP) (1)	−0.4	13.3	−6.5	23.0	−9.9
Financial intermediation cost function ($\phi_1; \phi_2$)	$0.15; 0.3$	$0.15; 0.3$	$0.15; 0.3$	$0.15; 0.3$	$0.15; 0.3$

Note: EA=euro area; US=United States; CHN=China; JAP=Japan; RW=Rest of the world.
(1) net of private and official holdings of USD and EUR government bonds

Table 5: (Gross) Price and wage markups

	EA	US	CHN	JAP	RW
Manufacturing (tradables) price markup	1.20	1.20	1.20	1.20	1.20
Services (non-tradables) price markup	1.30	1.30	1.30	1.30	1.30
Wage markup	1.20	1.20	1.20	1.20	1.20

Note: EA=euro area; US=United States; CHN=China; JAP=Japan; RW=Rest of the world.

Table 6: Monetary and fiscal policy

	EA	US	CHN	JAP	RW
Inflation target	1.02	1.02	1.02	1.02	1.02
Interest rate inertia	0.87	0.87	0.87	0.87	0.87
Interest rate sensitivity to inflation gap	1.70	1.70	1.70	1.70	1.70
Interest rate sensitivity to output growth	0.10	0.10	0.10	0.10	0.10
Lump-sum tax sensitivity to debt gap	0.60	0.60	0.60	0.60	0.60

Note: EA=euro area; US=United States; CHN=China; JAP=Japan; RW=Rest of the world.

Table 7: Asset ratios

	US	EA	CHN	JAP	RW
Private agents					
curr. in circ./domestic govt bond holdings	0.27	0.22	0.48	0.06	0.19
curr. in circ./USD govt bond holdings	...	8.39	2.53	2.22	4.86
curr. in circ./EUR govt bond holdings	8.77	...	3.14	2.70	6.21
Official holdings					
of USD govt bonds (% of GDP)	...	3.87	16.40	16.00	6.80
of EUR govt bonds (% of GDP)	0.51	...	8.05	5.56	2.42

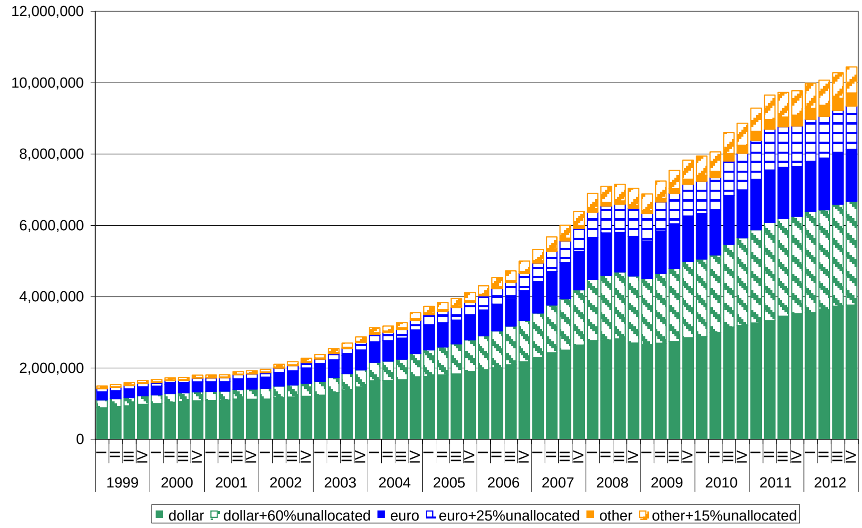
Note: EA=euro area; US=United States; CHN=China; JAP=Japan; RW=Rest of the world.

Table 8: Welfare

		EA	US	CHN	JAP	RW
[1]	"So far, so good"	-0.0040	-0.0078	0.0159	0.0141	0.0067
[2]	"Rebalancing"	-0.0229	0.0074	0.0156	0.0154	0.0053
[3]	Only CHN increases reserves	-0.0014	-0.0031	0.0198	0.0002	-0.0003
[4]	JAP and RW increase reserves, CHN pegs	-0.0025	-0.0049	-0.0034	0.0144	0.0065
[5]	JAP and RW increase reserves, CHN sells	-0.0011	-0.0016	-0.0238	0.0147	0.0063

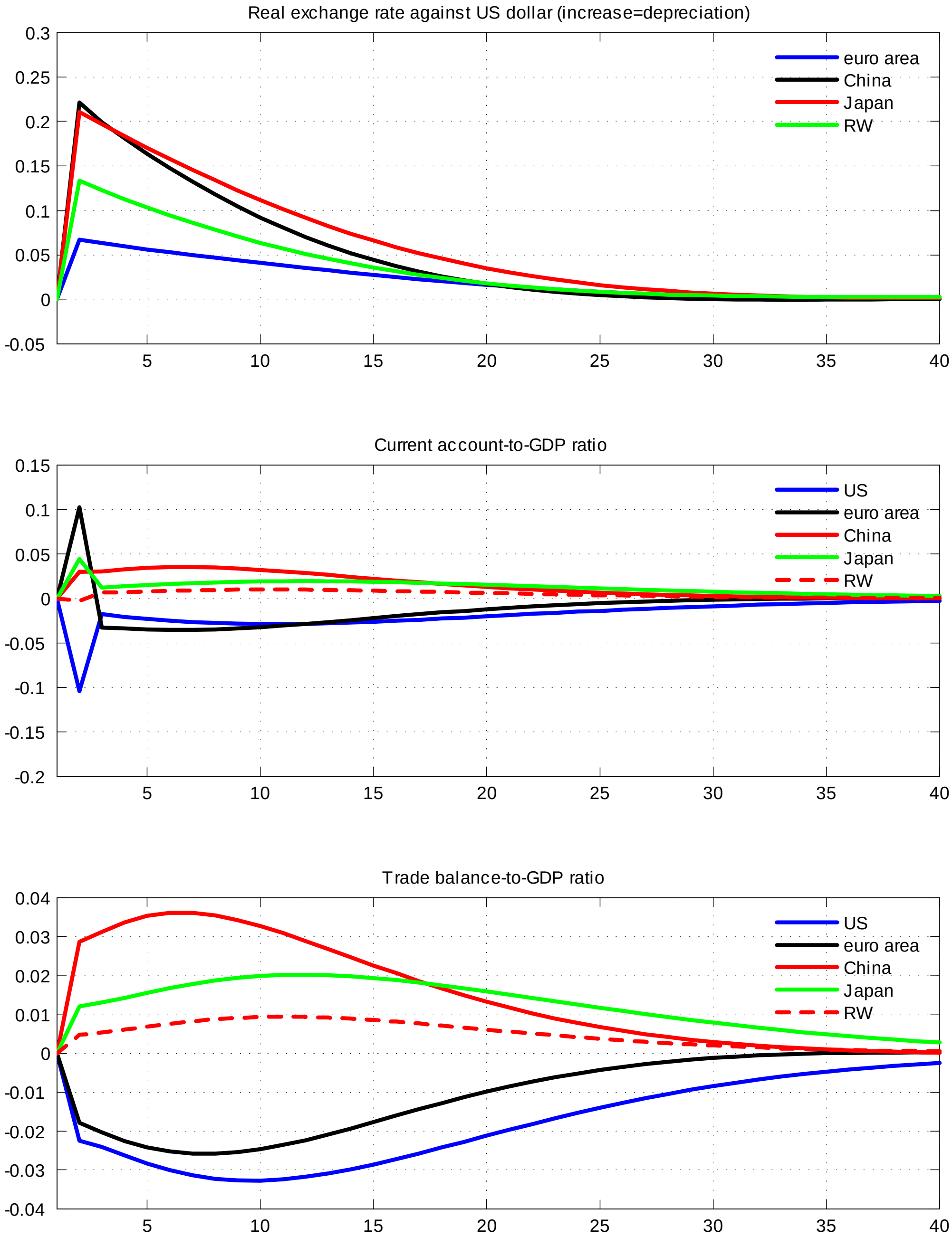
Note: percentage points; quarterly. EA=euro area; US=United States; CHN=China; JAP=Japan; RW=Rest of the world. Consumption equivalent i.e. fraction of permanent consumption that must be given up in order to equal welfare in the new regime (negative values imply that in the new regime welfare increases). In each case the assumed change in reserves is equal to one percent of the initial holdings.

Figure 1: Global exchange rate reserve allocation



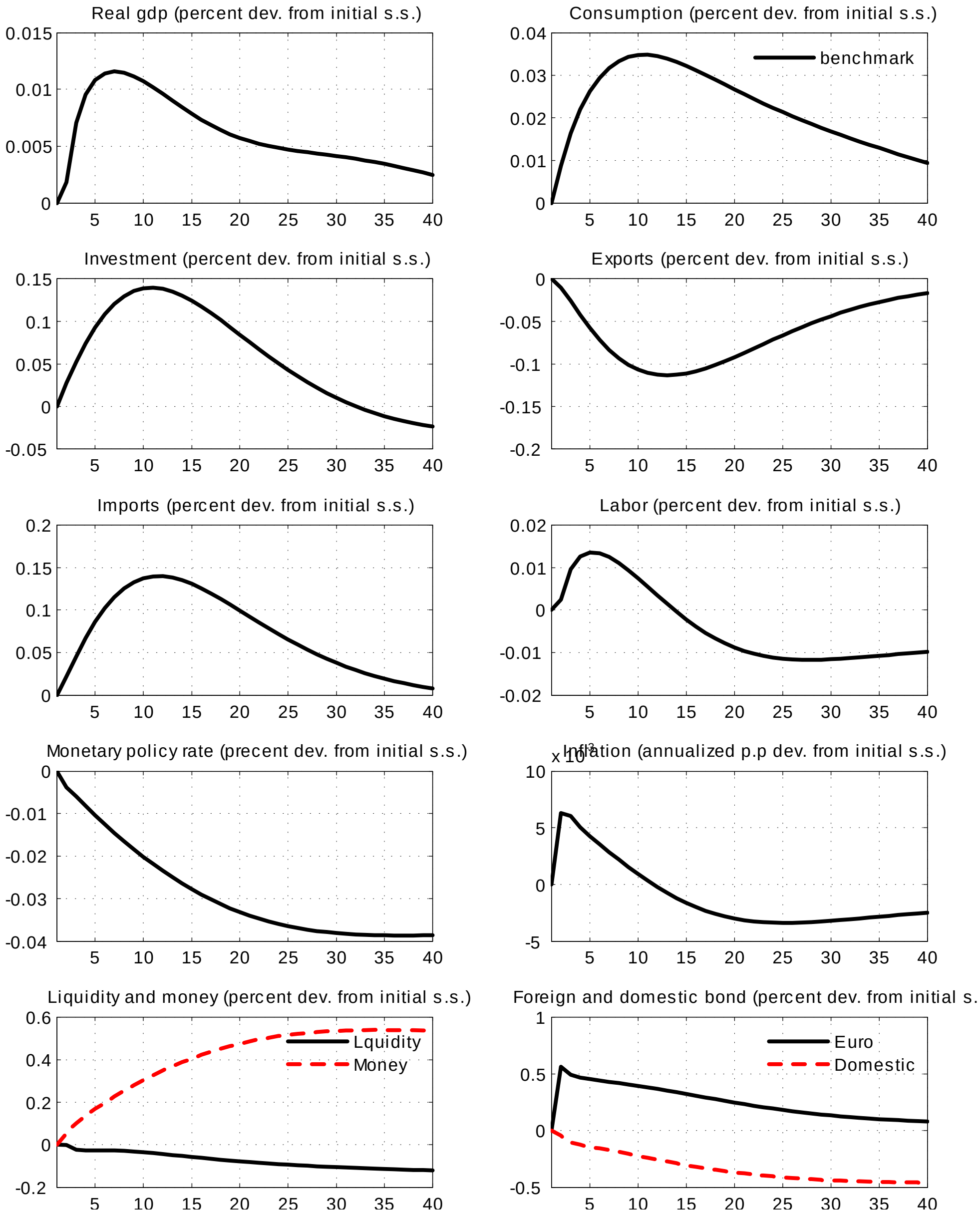
Source IMF COFER.
Note: in millions of U.S. dollars.

Figure 2: CHN, JAP and RW accumulate reserves in dollars and euros



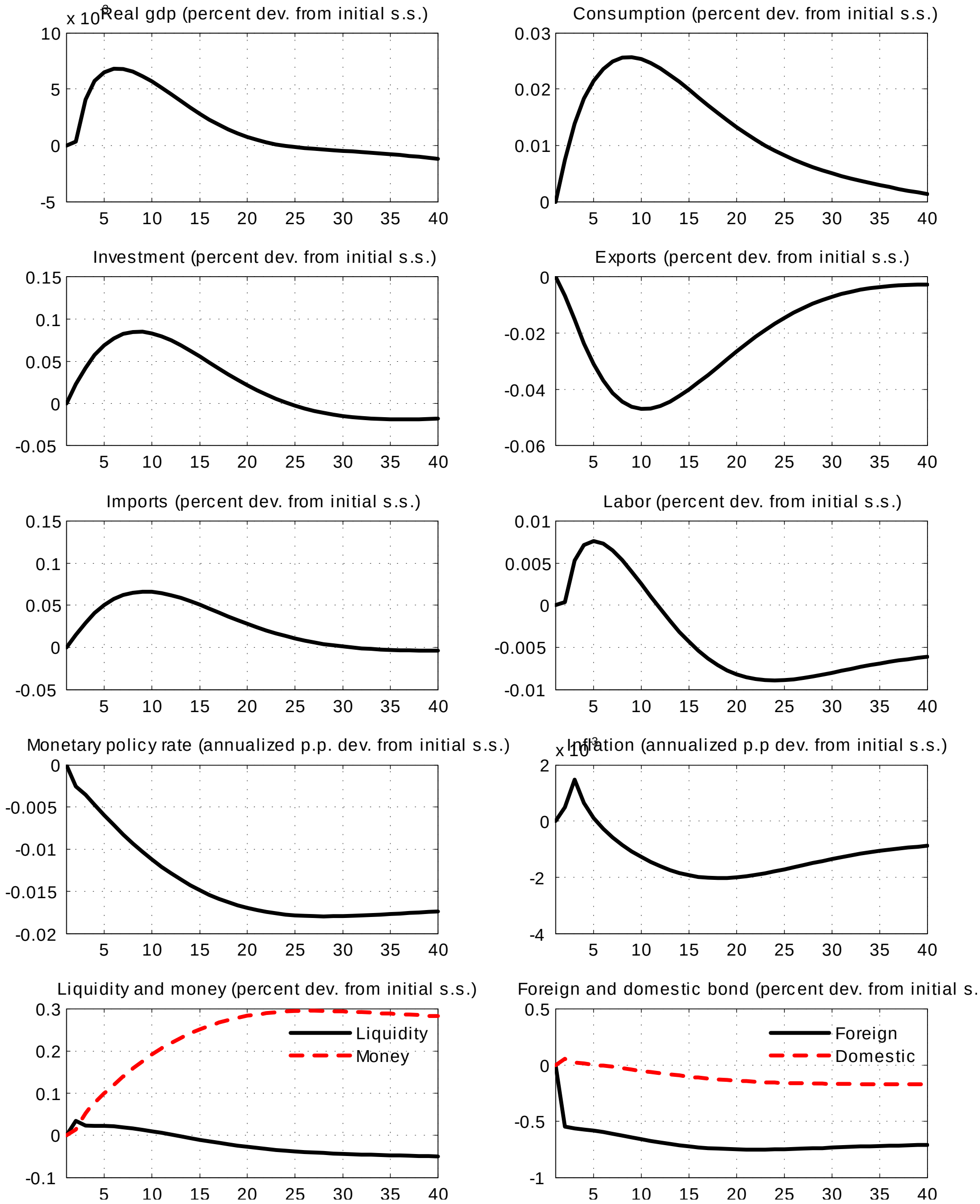
Notes: horizontal axis, quarters; vertical axis, percentage points deviations from the baseline. CHN=China; JAP=Japan; RW=rest of the world.

Figure 3: CHN, JAP and RW accumulate reserves in dollars and euros: US variables



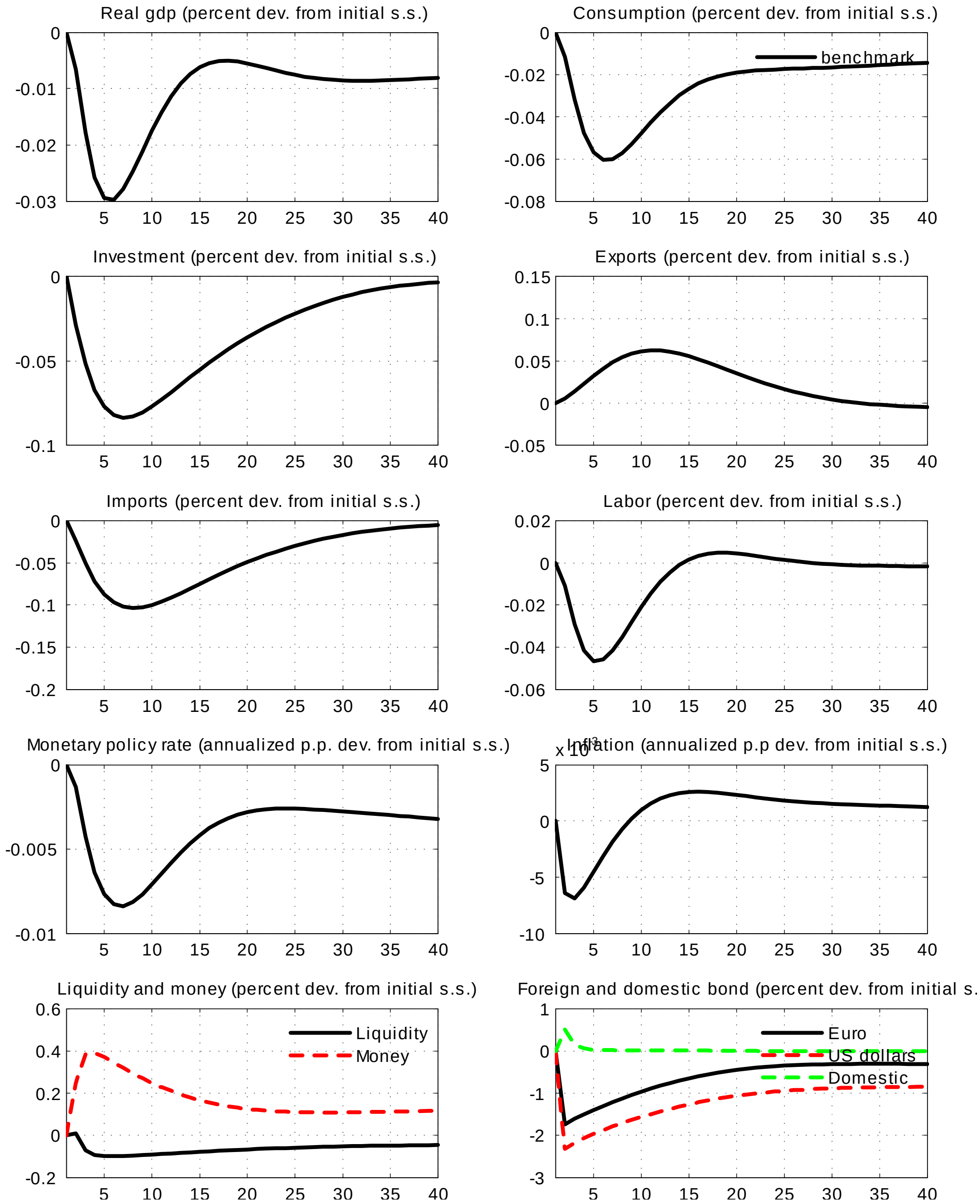
Notes: horizontal axis, quarters; vertical axis, percentage points deviations from the baseline. CHN=China; JAP=Japan; RW=rest of the world.

Figure 4: CHN, JAP and RW accumulate reserves in dollars and euros: EA variables



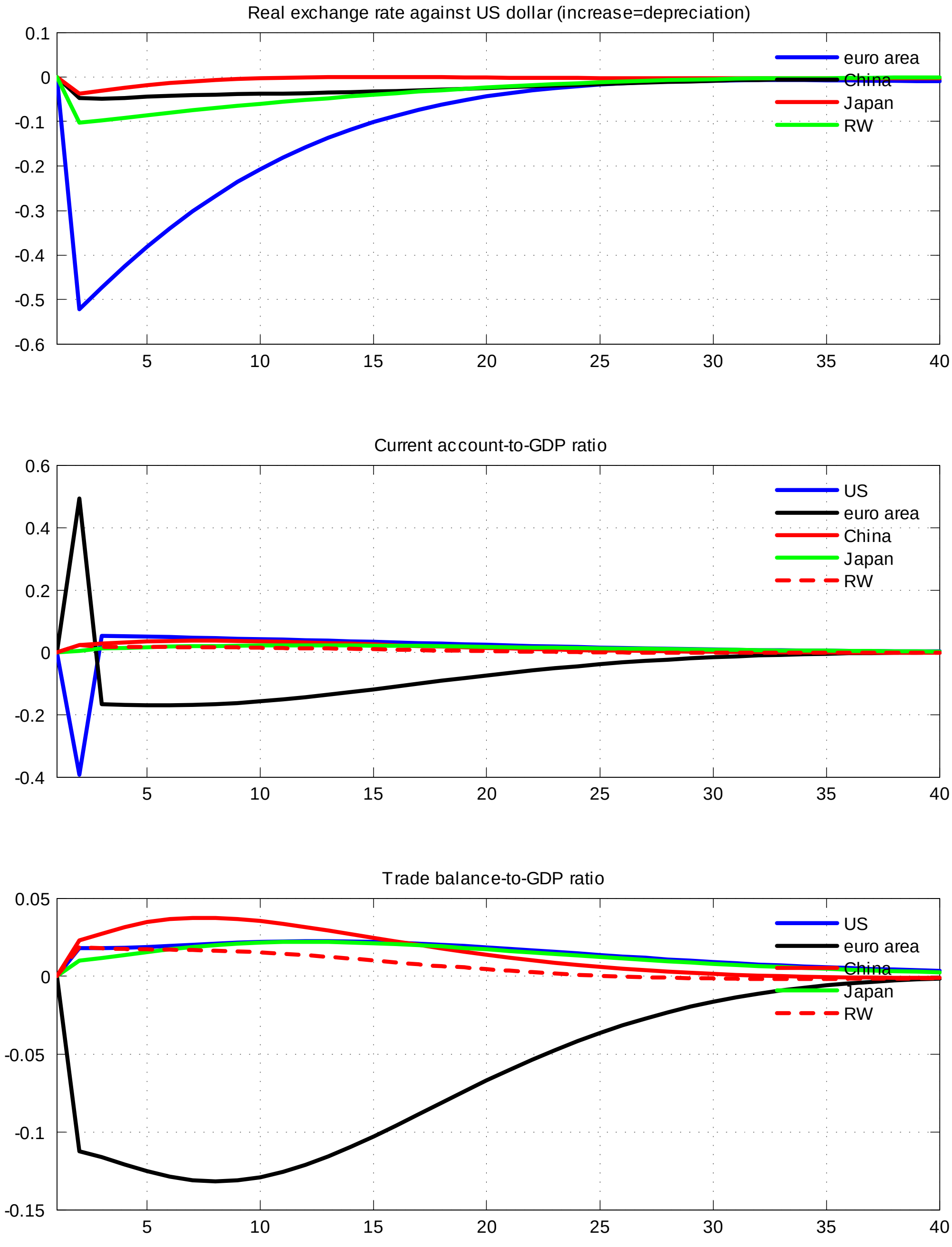
Notes: horizontal axis, quarters; vertical axis, percentage points deviations from the baseline. CHN=China; JAP=Japan; EA= euro area; RW=rest of the world.

Figure 5: CHN, JAP and RW accumulate reserves in dollars and euros: CHN variables



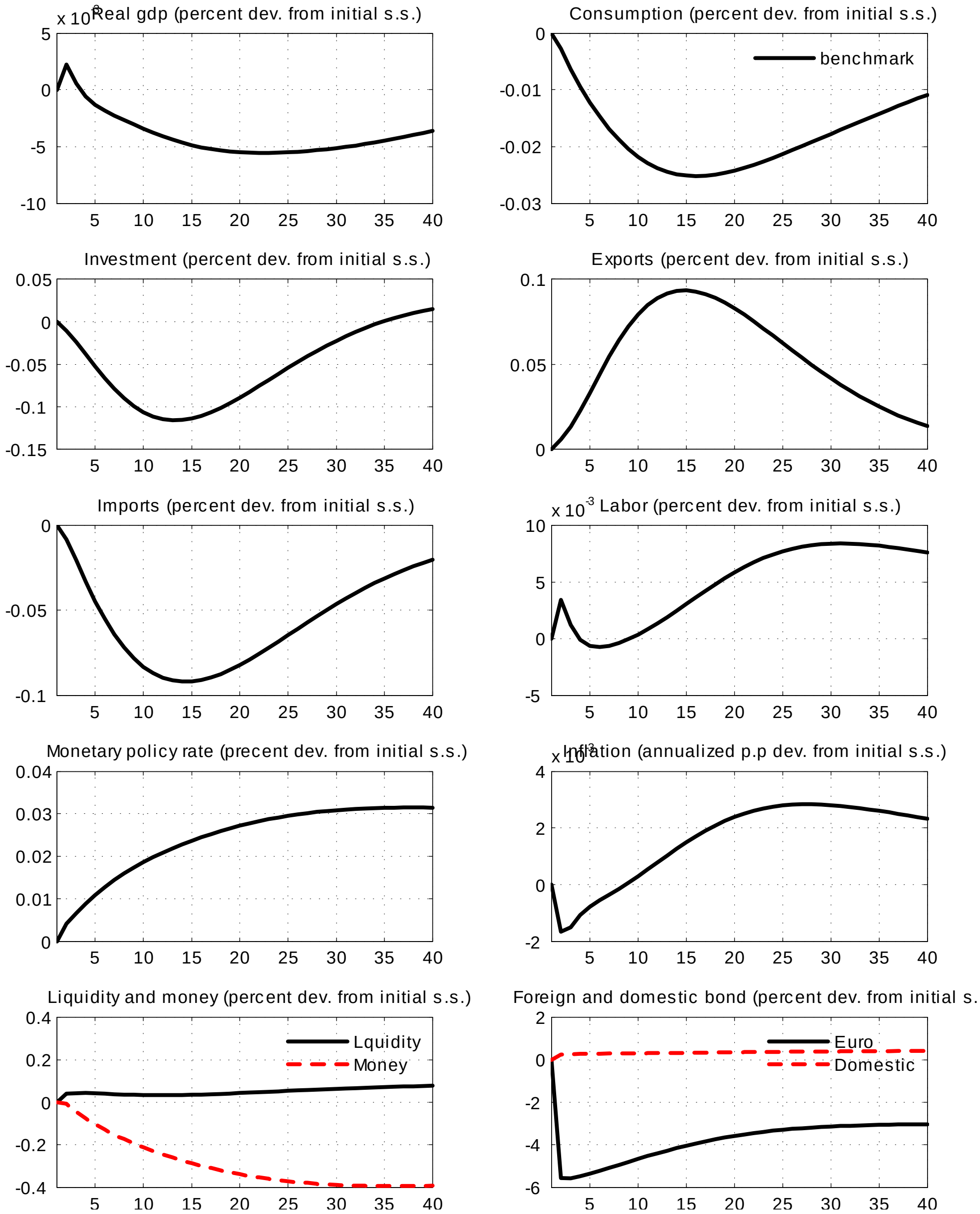
Notes: horizontal axis, quarters; vertical axis, percentage points deviations from the baseline. CHN=China; JAP=Japan; RW=rest of the world.

Figure 6: CHN, JAP and RW rebalance reserves into euro



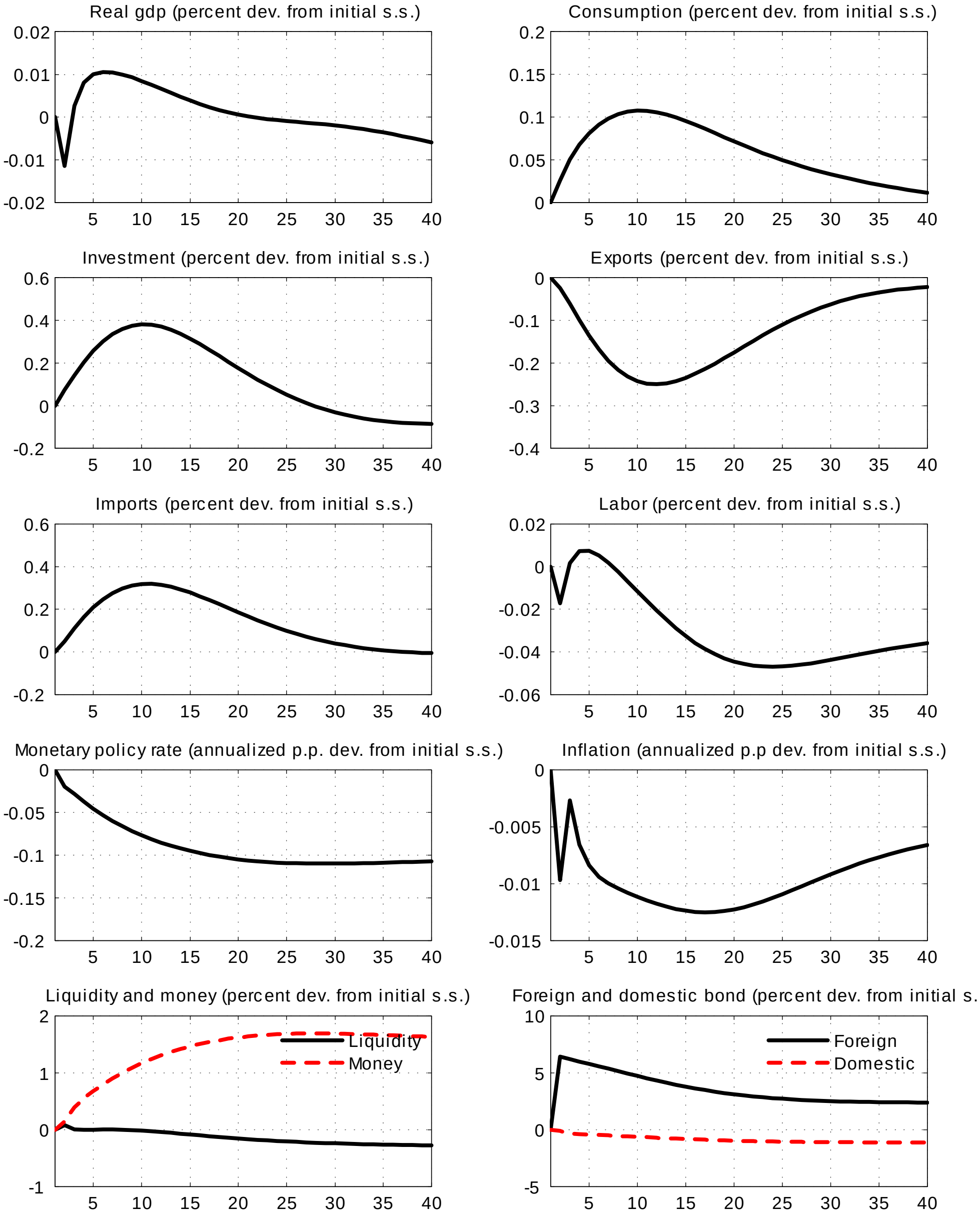
Notes: horizontal axis, quarters; vertical axis, percentage points deviations from the baseline. CHN=China; JAP=Japan; RW=rest of the world.

Figure 7: CHN, JAP and RW rebalance reserves into euro: US variables



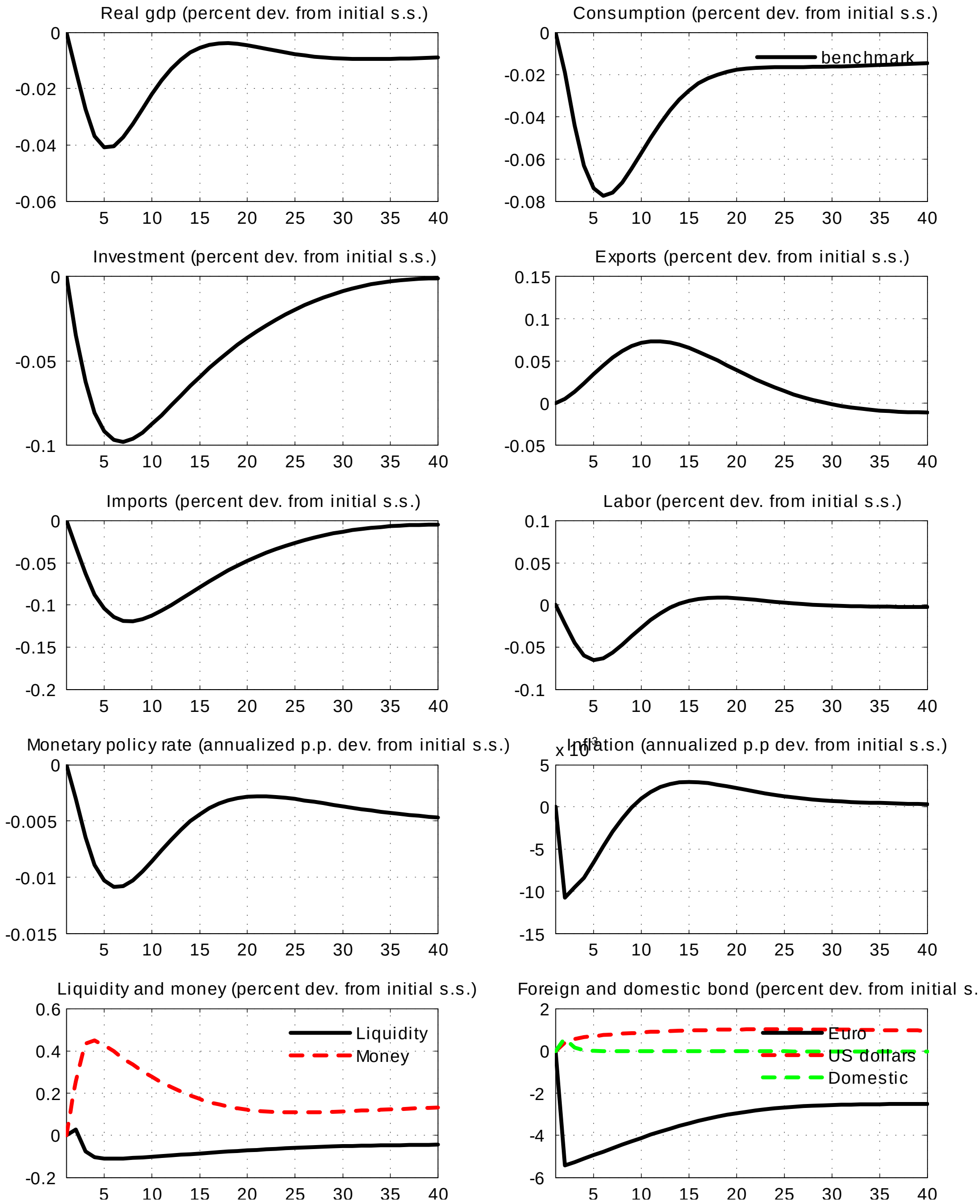
Notes: horizontal axis, quarters; vertical axis, percentage points deviations from the baseline. CHN=China; JAP=Japan; RW=rest of the world.

Figure 8: CHN, JAP and RW rebalance reserves into euro: EA variables



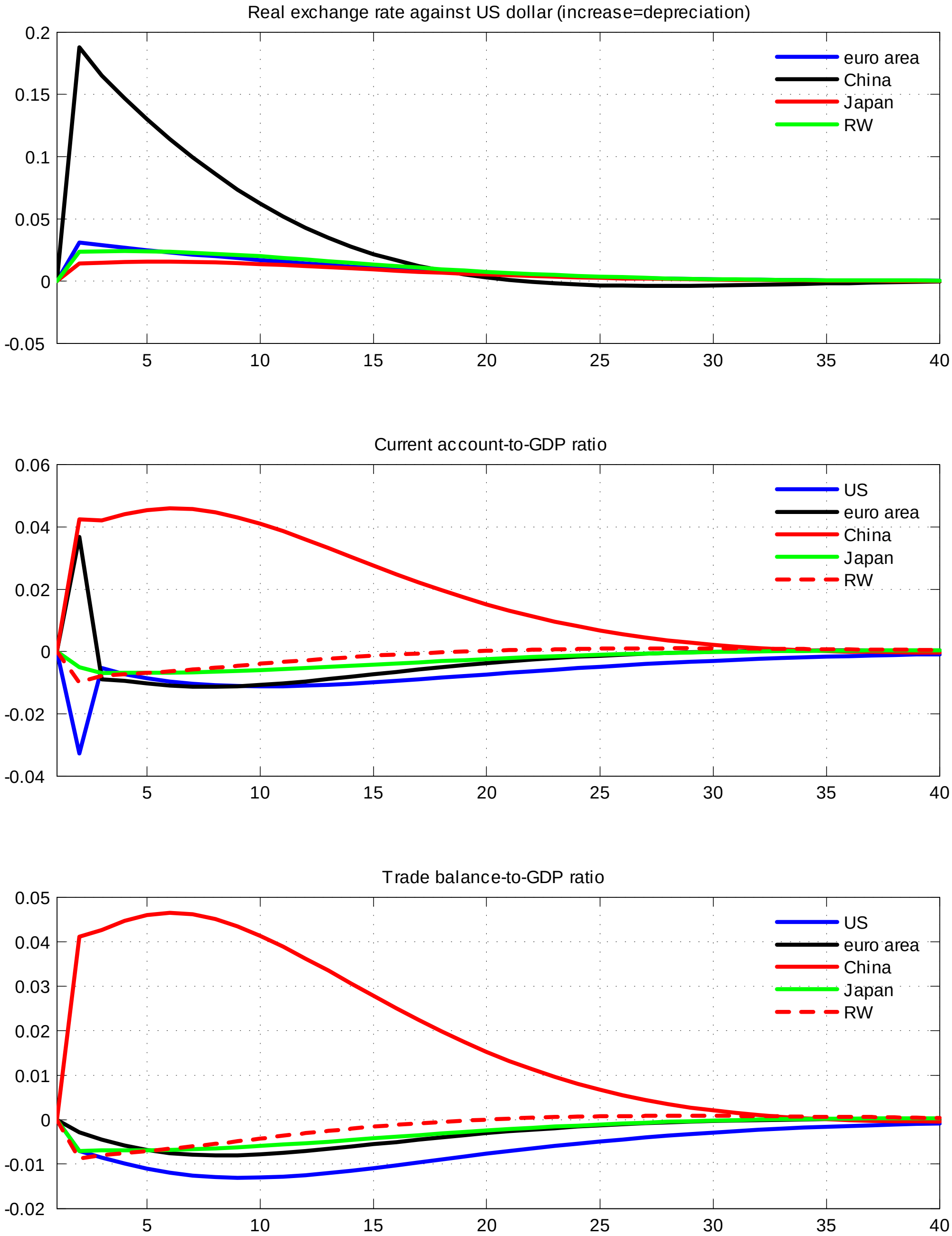
Notes: horizontal axis, quarters; vertical axis, percentage points deviations from the baseline. CHN=China; JAP=Japan; EA= euro area; RW=rest of the world.

Figure 9: CHN, JAP and RW rebalance reserves into euro: CHN variables



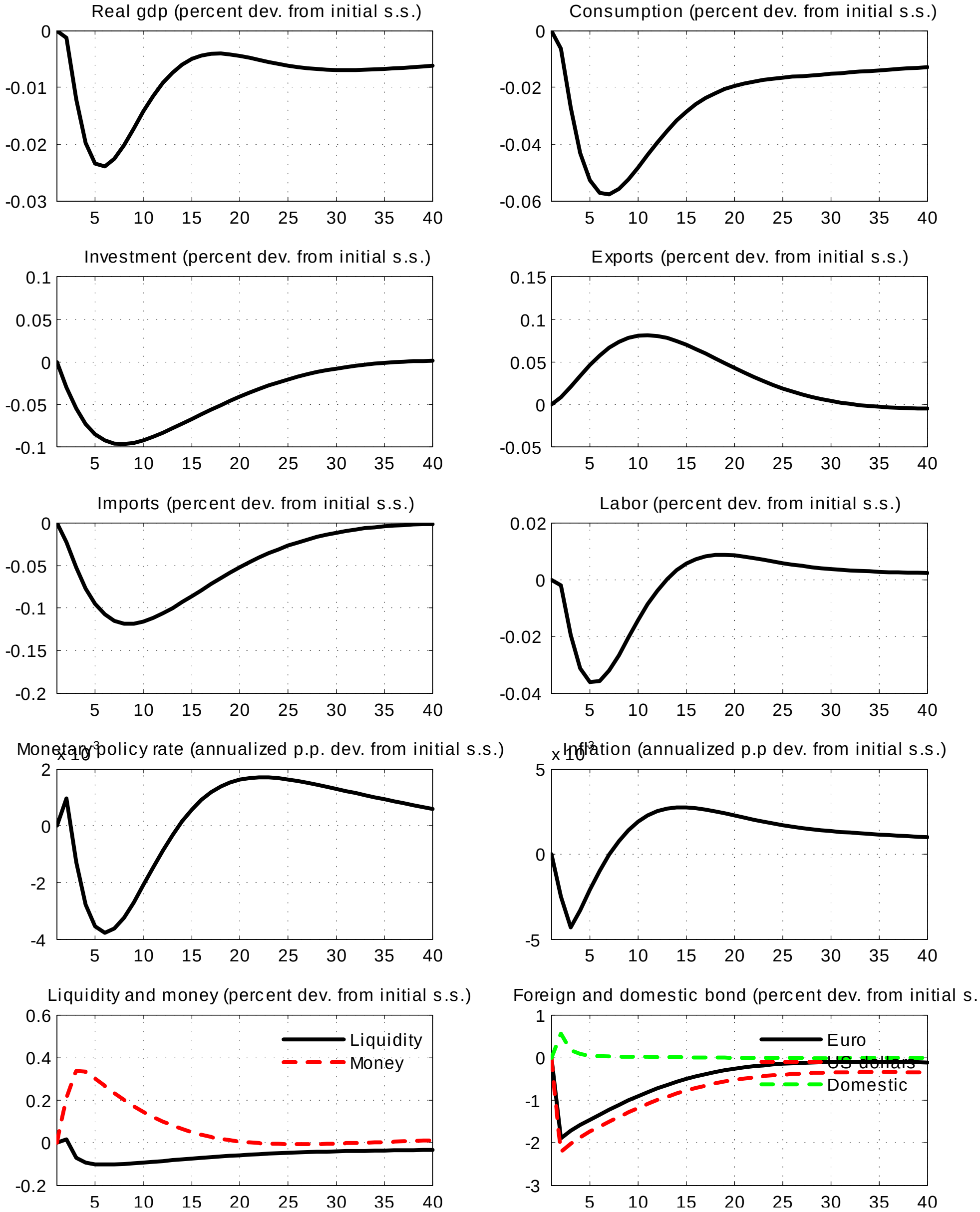
Notes: horizontal axis, quarters; vertical axis, percentage points deviations from the baseline. CHN=China; JAP=Japan; RW=rest of the world.

Figure 10: Only China accumulates reserves



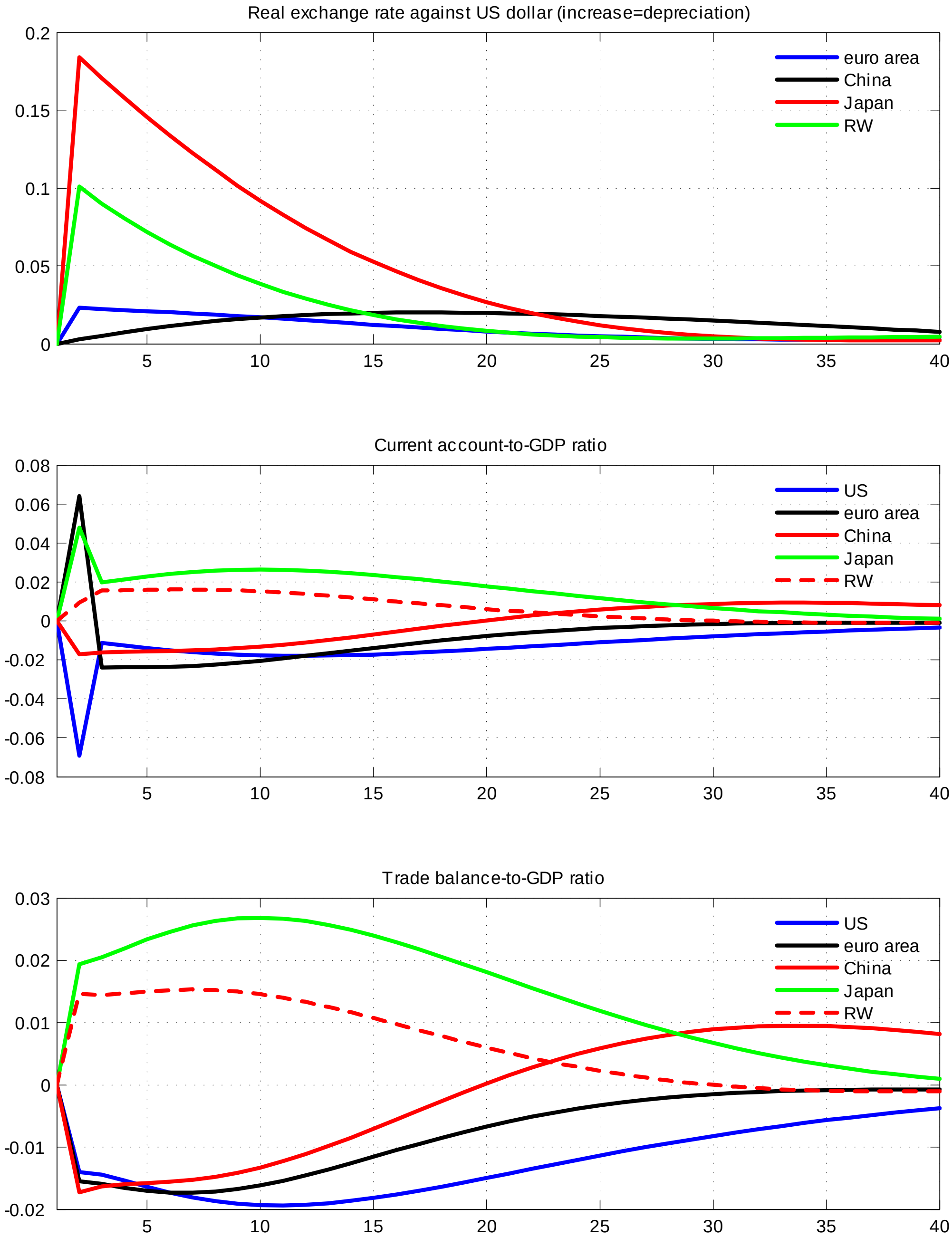
Notes: horizontal axis, quarters; vertical axis, percentage points deviations from the baseline. RW=rest of the world.

Figure 11: Only China accumulates reserves: CH variables



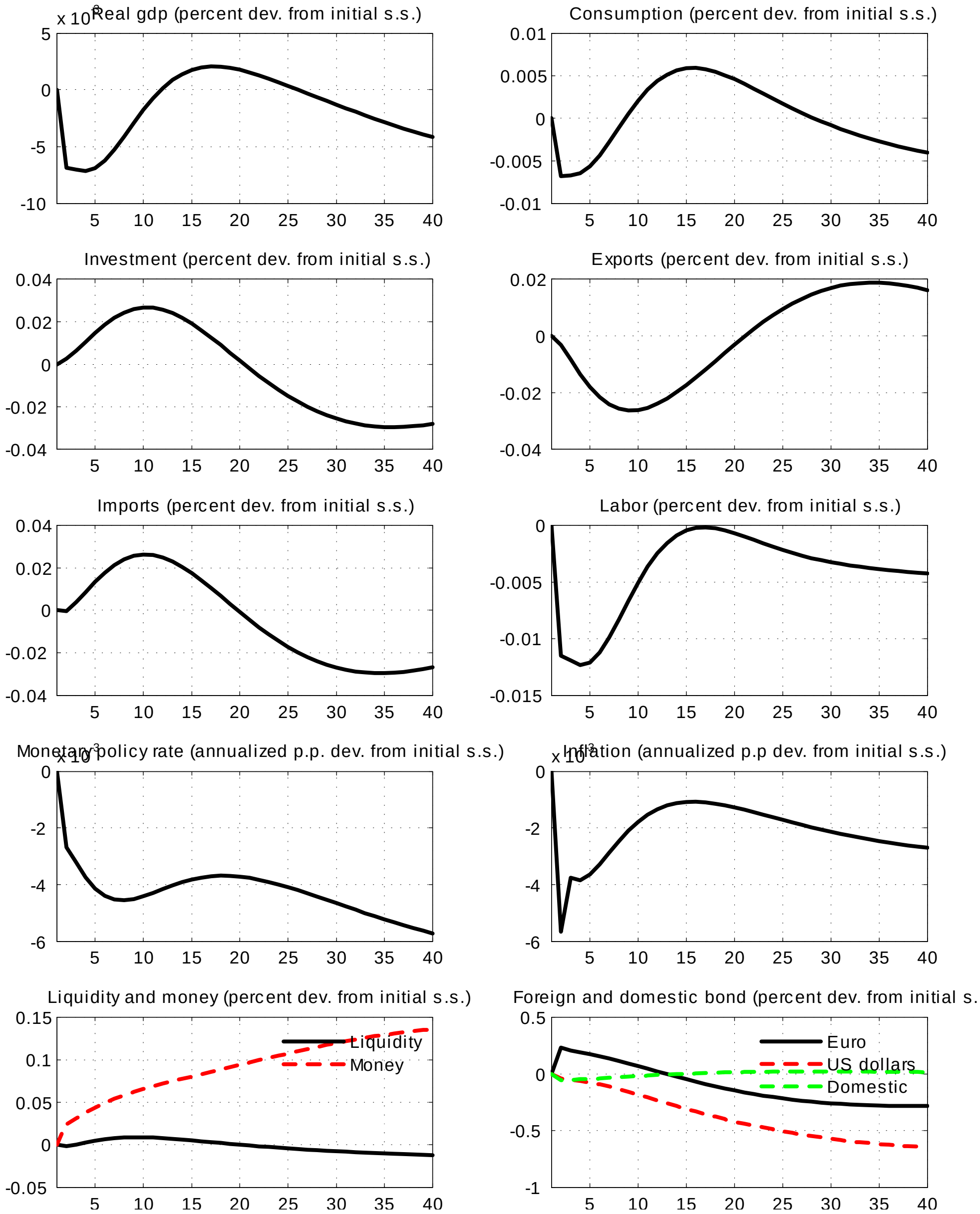
Notes: horizontal axis, quarters; vertical axis, percentage points deviations from the baseline. CHN=China; RW=rest of the world.

Figure 12: JAP and RW accumulate reserves, CHN pegs



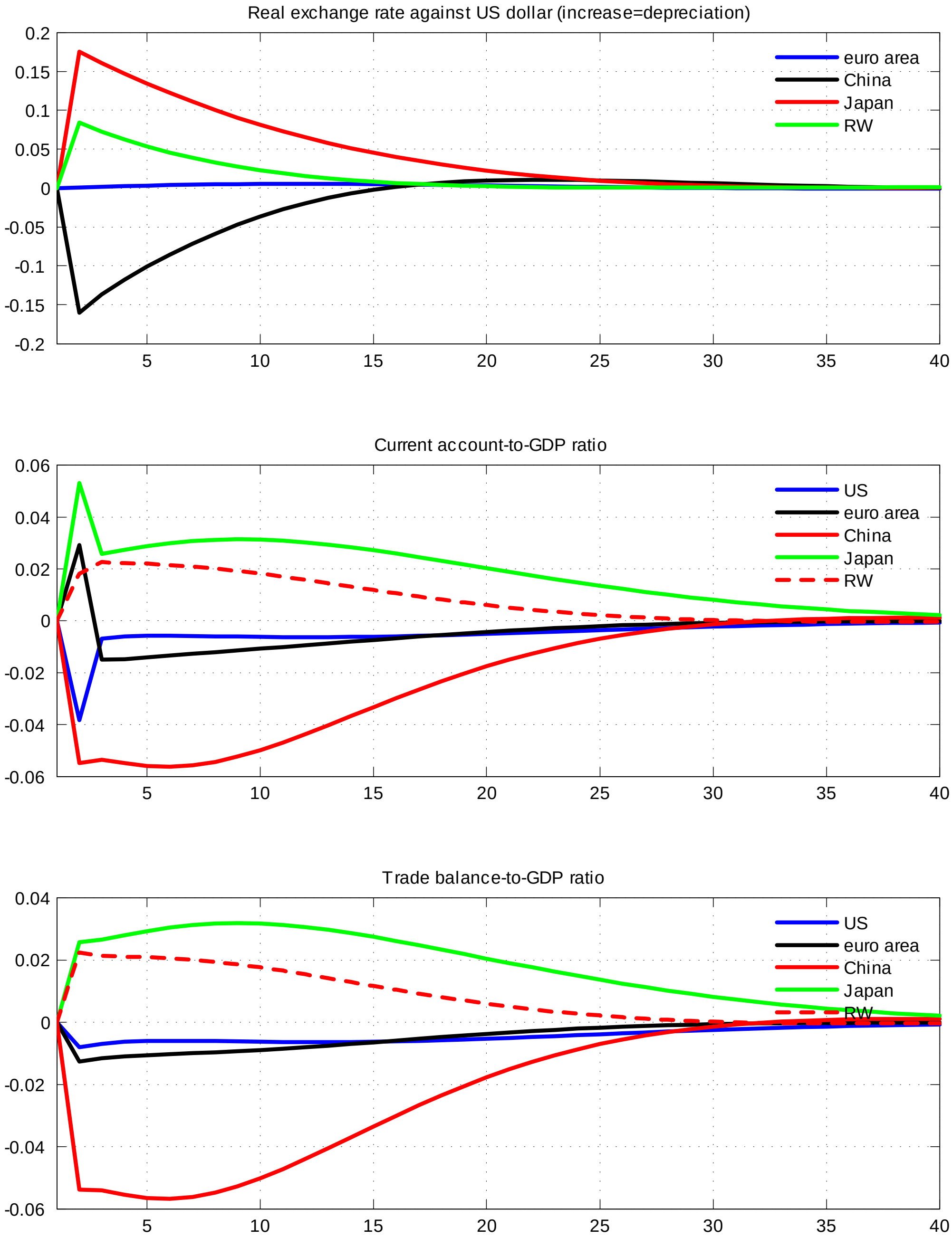
Notes: horizontal axis, quarters; vertical axis, percentage points deviations from the baseline. CHN=China; JAP=Japan; RW=rest of the world.

Figure 13: JAP and RW accumulate reserves, CHN pegs: CHN variables



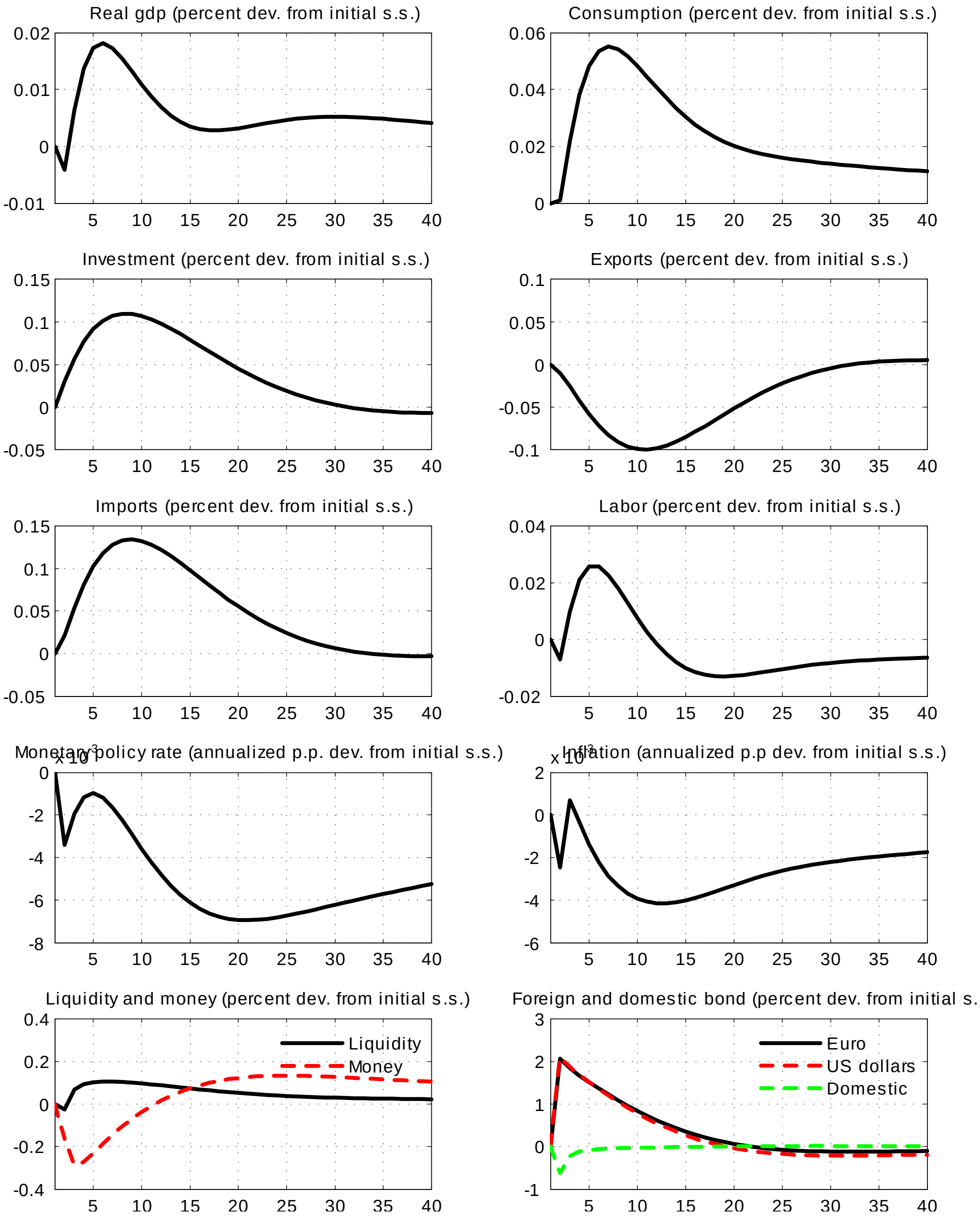
Notes: horizontal axis, quarters; vertical axis, percentage points deviations from the baseline. CHN=China; JAP=Japan; RW=rest of the world.

Figure 14: JAP and RW accumulate reserves, CHN decumulates reserves



Notes: horizontal axis, quarters; vertical axis, percentage points deviations from the baseline. CHN=China; JAP=Japan; RW=rest of the world.

Figure 15: JAP and RW accumulate reserves, CHN decumulates reserves: CHN variables



Notes: horizontal axis, quarters; vertical axis, percentage points deviations from the baseline. CHN=China; JAP=Japan; RW=rest of the world.

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