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A study of the diversification of China's foreign reserves within a three country stock-flow consistent model

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ABSTRACT: The paper presents a three-country stock-flow consistent model, with one fixed exchange rate and two flexible exchange rates. The model is within the tradition of portfolio balance models with imperfect asset substitutability. The model is applied to simulate the impact of changes in the foreign exchange policies being pursued by the central bank of China, more precisely the impact of the diversification of its foreign reserves, away from US dollars and towards euros. The simulation results show that China and the U.S. both benefit from diversification, while the Euroland economy slows down. Furthermore, we find that the long-run value of the euro against the dollar and the RMB is higher in the case of gradual diversification than it is with a one-step diversification. The model thus generates path dependency.

1. Introduction

Over the last few years there has been some concern and interest about the possible effects the diversification of foreign exchange reserves among Asian central banks. Since 2005, rumours have spread that the central banks of Korea, China, and Japan would shift some of their official holdings of US dollars into other currencies, most notably the euro. Indeed, it has even been shown that this diversification has already started, as some OECD central banks, such as the Bank of Canada, have already quietly reduced their share of US dollars held as foreign reserves between 2000 and 2005 (Wong 2007, table 3).[1] But since most of the ten largest holders of foreign exchange reserves are located in Asia, the rumours about diversification by Asian central banks have more severe implications. Indeed, the People's Bank of China – the Chinese central bank and the Bank of Japan are by far the two biggest holders of foreign exchange reserves as well as the two biggest foreign holders of US dollar securities. With Chinese foreign reserves overtaking those of Japan in February 2006, China's total foreign exchange reserves are now about twice those of Japan, having risen to US$1.7 trillion at the end of March 2008.[2] A change of policy by the Chinese monetary authorities is likely to have an impact on relative exchange rates and economic activity throughout the world.

The Chinese export boom and the inflows of foreign direct investment have been mainly responsible for the huge accumulation of reserves, although speculative capital flows are now also considered as part of the explanation. China has invested a large part of its foreign reserves in US treasury bills and bonds and other US dollar securities. Over the last few years, when Chinese foreign reserves were already much smaller than what they are now, some Chinese economists (Zheng and Yi , 2007; Wang, 2006) have argued that these foreign reserves are overly large and ought to be diversified – changing the currency composition of the reserve portfolio of the People's Bank of China or shifting it across different asset classes.

These economists have emphasized that China's huge foreign exchange accumulation has created large opportunity costs and wealth losses due to a weakening dollar, exacerbated inflationary pressures, and intensified pressure for the renminbi appreciation. They have

[1] Indeed, looking at more recent data, it seems that this trend has continued between 2005 and 2007. See the Currency Composition of Official Foreign Exchange Reserves at the IMF: http://www.imf.org/external/np/sta/cofer/eng/cofer.pdf

[2] According to a news report of the Associated Press, dated April 11, 2008, at: http://www.cbc.ca/cp/business/080411/b041186A.html

estimated that China's actual reserves have far exceeded what could be considered as their normal demand. To alleviate fears over a weakening dollar, they have suggested to diversify foreign exchange reserves, shifting more of its increasing holdings into European and Asian bonds to reduce its exposure to dollar denominated assets. However, a sudden shift away from dollar assets by China could destabilize financial markets and, in their view, put upward pressure on US interest rates. Therefore, they conclude that a gradual small–scale diversification of reserves out of dollar would be beneficial and preferable.

As Truman and Wong (2007, p. 2) point out, "rumors about actual or potential diversification of foreign exchange holdings away from the US dollar are not a new phenomenon". Concerns often arise during periods of significant dollar depreciation. These concerns arose in particular in the late 1970s, when the US dollar was under pressure, but they vanished as the dollar recovered, when diversification towards the Deutsch Mark and the Japanese Yen turned out to be quite moderate, and when researchers concluded that the impact of changes in central bank reserves would be modest relative to private capital flows (Horii 1986). The last point could still be made today, save for the huge amounts being hoarded by the Chinese central bank, which are dwarfing anything known before.

In order to assess the possible *qualitative* effects of diversification of the Chinese foreign exchange reserves, we propose the use of a stock-flow consistent model (SFC model), describing three countries each with its own currency. The three countries are presumed to be China, the USA, and the rest of the world, which we will call Euroland. China and the USA are assumed to be on a fixed exchange rate regime (although this is only partly true, because China moved onto a managed float exchange rate regime in July 2005, with the renminbi having since appreciated by about 13 percent relative to the dollar at the time of writing).[3] The USA and the Euro zone are assumed to be on a flexible exchange rate regime, as are China and the Euro zone. An important feature of our model, as in previous similar open-economy SFC models, is the assumption of imperfect asset substitutability.

The paper is organized as follows. Section 2 compares our approach to previous theoretical works that have dealt with diversification. Section 3 describes the social accounting

[3] According to the speech of the governor of the People's Bank of China, dated August 10, 2005, at: http://www.pbc.gov.cn/english//detail.asp?col=6500&ID=82&keyword=Speech%20of%20Governor%20Zhou%20 Xiaochuan.

matrices of a three-country economy. Section 4 describes our stock-flow consistent model. Section 5 presents simulation results arising from a sudden diversification, as China's foreign exchange reserve holdings are briskly shifted away from dollar securities towards euro securities. Section 6 deals with a sensitivity analysis, in an attempt to ascertain what happens when a larger proportion of reserves are diversified. Finally, section 7 presents an alternative sensitivity analysis, based on another closure, by assuming that diversification occurs gradually rather than as a one-step affair.

2. Other works on diversification

After having been neglected for nearly 25 years, open-economy models that drop the interest parity assumption, adopting instead the assumption that financial assets are imperfect substitutes, now seem to be back in fashion, with its relevance being now admitted by various commentators.[4] Two sets of papers – the paper by Dullien (2007) and the two papers by Blanchard, Giavazzi, and Sa (2005a. 2005b) – now deal with the issue of the Chinese peg and the possible diversification of foreign exchange reserves. These papers are in the tradition of Branson (1979) and Tobin and De Macedo (1980), with a complete two-country portfolio balance model, as also developed by Allen and Kenen (1980), Kenen (1985) and Branson and Henderson (1985). In these papers the world comprises two economies, each with its own currency, which enjoy trade with one another in both merchandise and financial assets. As pointed out above, a key assumption is that the various domestic and foreign assets are imperfect substitutes. These studies take supplies of bonds on the open market as exogenous and concentrate on the way in which an equilibrium exchange rate could be determined via resolution of a confrontation between demands and supplies of internationally tradable assets.

Starting out from the same assumption that financial assets are imperfect substitutes are a series of open-economy models in the stock-flow consistency tradition, arising from the work of Godley (1999), as can be found in Izurieta (2003), Lequain (2003), and Godley and Lavoie (2005-06; 2007a; 2007b, ch. 12). These models, as those in the Branson tradition, pay considerable attention to portfolio balance, while at the same time entertaining Keynesian

[4] For a critique of interest parity assumptions from a post-Keynesian perspective which is consistent with the present paper, see Lavoie (2000; 2002-03).

assumptions by taking into account the way in which exchange rates, once determined in asset markets, feed back so as to change relative prices and therefore trade flows, and hence the demand for and supply of assets, income flows, and so back to exchange rates themselves. The present model is part of that tradition.

Several authors have recently made the claim that diversification of the foreign reserves of the central bank of China is likely to lead to a depreciation of the American dollar relative to the euro within a three-region framework. Dooley, Folkerts-Landau, and Garder (2004) first argued that a portfolio shift in the foreign reserves of Asian countries would induce an appreciation of the euro, but without a formal model. By contrast, Dullien (2007) constructs a simple three-asset-portfolio model to examine the impact of the diversification of the reserve holdings of Asian central banks, focusing on answering the questions raised from a European perspective both graphically and mathematically.[5] He shows that: (1) the dollar would plunge against the euro if Asian central banks stop buying dollars; (2) the diversification of the reserve holdings of Asian central banks would lead to a depreciation of the dollar against the euro; and (3) Asian central banks can keep the peg against the dollar intact and diversify their portfolios by buying euros and selling their own currency. Dullien concludes that a more threatening scenario from the European perspective would be for Asian central banks to move from buying dollars towards buying euros, because the euro would then strongly appreciate against the dollar and the competitiveness of European industries in the world markets would be affected negatively.

Based on imperfect substitutability in both goods and assets markets, Blanchard and al. (2005a) develop a simple portfolio balance model of exchange rate and current account determination, extending the model to four regions such as the U.S., China, Japan, and the Euro Area in Blanchard et al. (2005b). They use the model to discuss the changes in the composition of reserves by Asian central banks, changes in U.S. interest rates, and changes in the peg of the Renminbi. They find that the path of adjustment is likely to be associated primarily with a further appreciation of the euro vis-à-vis the dollar, and with an appreciation of Asian currencies such as the yen and renminbi. They conclude that a large fall in the dollar leads to higher demand and higher output and offers the opportunity to reduce budget deficits without triggering a recession for the United States. A result for the authors is that it is not by itself a catastrophe for the U.S., while the danger is more serious for Japan and Western Europe.

[5] The three currencies used by Dullien are Euro, Dollar, and Yen.

The main differences between the present work and that of Blanchard et al. (2005a; 2005b) and also of Dullien (2007) are that in this paper,

- The model is based on an explicit stock-flow consistent approach;
- There are five explicit sectors in our model, instead of a set of portfolio equilibrium conditions, to which Blanchard et al. add a current account definition and a dynamic equation tracking the evolution of the net foreign asset position;
- All relevant variables are endogenous, such as GDP, debt servicing, wealth, the money supply, imports and exports, the current account and the capital account, as well as the exchange rate;
- The model is solved numerically, by making simulations;
- Both the short-run and long-run impacts of internal and external shocks are examined, while Dullien (2007) only looked at short-run effects.

3. The matrices of a three-country economy

As is common in the SFC approach, we start out by examining the two major matrices of the model. As already pointed out, there are three countries in the model, which we shall call the U.S., Euroland, and China. Each economy contains five sectors, which are: households, firms, commercial banks, a central bank, and government. China and the U.S. are tied up by a fixed exchange rate, while Europe is on a floating exchange rate regime with China and the U.S.

< Table 1 >

Table 1 is the stock matrix of the three countries. As shown in Table 1, all the columns sum to zero and all the rows related to assets, liabilities, and net worth sum to zero except tangible capital K and wealth balance.[6] The notations can be read off the first column. The only notation that warrants an explanation is that of bills. Each government issues bills denominated

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[6] Tangible capital is not simultaneously an asset and a liability. Since $\sum K + \sum (-V) = 0$, the last column also sums to zero.

in its own currency. B_i describes the bills issued by the government of country i (i=1,2,3). 1, 2, and 3 denote the U.S., Euroland, and China respectively. B_1 , B_2 and B_3 are denominated in Dollar ($), Euro (€) and RMB, respectively. $Bh_{i,j}$ denotes the bills issued by the government of country j, but held by the households of country i. $Bcb_{i,j}$ denotes the bills issued by the government of country j, but held by the central bank of country i.

Households are assumed to hold a diversified portfolio of assets. The households' assets consist of high powered money (cash) and deposits, both held only in domestic currency, as well as bills issued by their domestic government and bills issued by foreign governments.[7] As pointed out already, we assume that these assets are imperfect substitutes. The allocation of the assets varies in response to changes in rates of return and risk considerations.

Firms do not hold cash money, deposits, and bills. They only hold tangible capital K. The net investment of firms is wholly financed by loans, taken from commercial banks.

The commercial banking system is highly simplified in our model. Commercial banks have zero net wealth, and we shall see that they make zero profit. This implies that interest rates on deposits, loans, Treasury bills and central bank advances are all equal. These are all simplifying assumptions, used to reduce the number of equations, and which in our view are innocuous. There are no bank reserves at the central bank. All banks only make loans to firms, making none to households. These loans are supplied on demand. In the U.S. and in Euroland, commercial banks also hold Treasury bills, which act as a buffer, and their only liability are the deposits of households. In China, commercial banks only hold loans as assets. We suppose that China is an overdraft economy: Chinese commercial banks take advances from the central bank of China., which provides them on demand, advances acting as the buffer of the Chinese banking system.

Each central bank issues cash money, and holds bills issued by the domestic government and possibly bills issued by foreign governments. These foreign bills are the foreign reserves of the central banks. We assume that the U.S. central bank and that of Euroland hold no bills issued by the Chinese government.

< Table 2 >

[7] We assume that even Chinese households can hold foreign bills, and that foreigners can hold bills issued by the Chinese government. This may provide excessive capital mobility, but we doubt that removing these two assumptions would change much in the results of the model simulations.

Table 2 shows the flow matrix that describes all the transactions that take place among the three countries in any given period of time *t*. All rows and columns sum to zero in the matrix. It reflects the crucial feature of the stock-flow consistent approach that "everything comes from somewhere, and everything goes somewhere" (Lavoie and Godley, 2001-2002, p.278). All sources of funds appear with a plus sign, and all uses of funds with a minus sign. The top section of the table describes the variables corresponding to the components of the national income and product accounts. The middle section describes flows of interest payments. The bottom section describes the changes in stocks of financial assets and liabilities corresponding to the flow of funds account.

4. The Model

This model is a modification and an extension of the three-country model of Godley and Lavoie (2007a). There are a few additions of more realistic features, such as the introduction of commercial banks, fixed investment, and advances by the central bank of China. The key difference of course is that there are three currencies instead of only two.

4.1 National income identity and trade

(1) $$Y_{i,t} \equiv C_{i,t} + G_{i,t} + I_{i,t} + X_{i,t} - IM_{i,t}$$

(2) $$X_{i,t} = \sum_{j(j \neq i)} X_{i,j,t} \qquad i, j=1,2,3$$

(3) $$X_{1,2,t} = IM_{2,1,t} / E_{1,t}$$

(4) $$X_{1,3,t} = IM_{3,1,t} / E_{2,t}$$

(5) $$X_{2,1,t} = IM_{1,2,t} \cdot E_{1,t}$$

(6) $$X_{2,3,t} = IM_{3,2,t} / E_{3,t}$$

(7) $$X_{3,1,t} = IM_{1,3,t} \cdot E_{2,t}$$

(8) $$X_{3,2,t} = IM_{2,3,t} \cdot E_{3,t}$$

$$(9) \quad IM_{i,t} = \sum_{j(j\neq i)} IM_{i,j,t} \qquad i, j = 1, 2, 3$$

$$(10) \quad im_{1,2,t} = \mu_{10} + \mu_{11} \cdot y_{1,t} + \mu_{12} \cdot e_{1,t}$$

$$(11) \quad im_{1,3,t} = \mu_{13} + \mu_{14} \cdot y_{1,t} + \mu_{15} \cdot e_{2,t}$$

$$(12) \quad im_{2,1,t} = \mu_{20} + \mu_{21} \cdot y_{2,t} + \mu_{22} \cdot (1/e_{1,t})$$

$$(13) \quad im_{2,3,t} = \mu_{23} + \mu_{24} \cdot y_{2,t} + \mu_{25} \cdot e_{3,t}$$

$$(14) \quad im_{3,1,t} = \mu_{30} + \mu_{31} \cdot y_{3,t} + \mu_{32} \cdot (1/e_{2,t})$$

$$(15) \quad im_{3,2,t} = \mu_{33} + \mu_{34} \cdot y_{3,t} + \mu_{35} \cdot (1/e_{3,t})$$

$$(16) \quad e_{1,t} = E_{1,t}$$

$$(17) \quad e_{2,t} = E_{2,t}$$

$$(18) \quad e_{3,t} = E_{3,t}$$

Here Y denotes nominal gross domestic products *(GDP), C* is nominal consumption, G is nominal government spending, I is investment, X is nominal export, and IM is nominal import. The subscript *"i"* on a variable stands for the country, with i=1, 2, 3, representing the U.S., Euroland, and China respectively. The subscript *"t"* stands for a time index. X_i is the exports of country i which are the sum of exports to the other two countries. $X_{i,j}$ stands for the exports of country i to country j. The exports of one country are the imports of the other country. E_1 (the nominal exchange rate between the Dollar and the Euro) denotes the price of the Dollar in terms of the Euro. E_2 (the nominal exchange rate between the Dollar and the RMB) denotes the price of the Dollar in terms of the RMB. E_3 (the nominal exchange rate between the Euro and the RMB) denotes the price of Euro in terms of the RMB. IM_i stands for the imports of country I, which are the sum of the imports from the other two countries. $IM_{i,j}$ stands for the imports of the country i from country j. Import functions are standard. Lower-case letters $im_{i,j}$ and y_i denote natural logs. e_1 denotes the real exchange rate between the Dollar and the Euro, e_2 denotes the real exchange rate between the Dollar and the RMB, e_3 denotes the real exchange rate between the Euro and the RMB. Imports are determined in each country by the relevant income and exchange rate.

We suppose that the domestic and foreign price levels are fixed; there is no inflation.[8] If we assume that $P_{1,t}=P_{2,t}=P_{3,t}=1$ (where P_i denotes the price level of economy i), then the nominal exchange rate is equal to real exchange rate, and the real exchange rates can be replaced by the nominal exchange rate. Equations (16)-(18) reflect the assumption.

4.2 Households

The personal income of households, *YP*, is defined inclusive of capital gains. This income is made up of wages, interest income, and capital gains arising from changes in the exchange rates. Their disposable income, in the Haig-Simons sense, defined as *YD*, is thus equal to personal income less income taxes, with ϑ_i denoting the tax rate in the tax equation. As a result, the change in their net wealth *V* is the straightforward difference between the household disposable income and consumption. The consumption function is of the Modigliani type, with consumption depending on current disposable income and past accumulated wealth, with the propensity to consume on the latter being much smaller than the propensity to consume on the former ($\alpha_{i,1} > \alpha_{i,2}$). As shown in equation (33`), this is equivalent to saying that households target a certain level of wealth, and that their saving, in the Haig-Simons sense, responds to a partial adjustment mechanism.[9] The rest of the box lists a whole list of equilibrium conditions about assets. Equation (22) implies that banks accept to take in all deposits demanded by households. Equations (23)-(29) mean that the government supplies bills to households on demand.

(19) $$YP_{1,t} = W_{1,t} + r_{b,1,t-1} \cdot Bh^d_{1,1,t-1} + r_{b,2,t-1} \cdot Bh^d_{1,2,t-1} + r_{b,3,t-1} \cdot Bh^d_{1,3,t-1}$$
$$+ r_{m,1,t-1} \cdot M_{1,t-1} + Bh^d_{1,2,t-1} \cdot \Delta(1/e_{1,t}) + Bh^d_{1,3,t-1} \cdot \Delta(1/e_{3,t})$$

(20) $$YP_{2,t} = W_{2,t} + r_{b,1,t-1} \cdot Bh^d_{2,1,t-1} + r_{b,2,t-1} \cdot Bh^d_{2,2,t-1} + r_{b,3,t-1} \cdot Bh^d_{2,3,t-1}$$

8 For an SFC model where import and export prices as well as domestic prices change with variations in the exchange rate, see Godley and Lavoie (2007b, ch. 12)

9 $\alpha_{i,3}$ is a target wealth to income ratio, with $\alpha_{i,3} = (1-\alpha_{i,1})/\alpha_{i,2}$. See Godley and Lavoie (2007, p. 74).

$$+ r_{m.2,t-1} \cdot M_{2,t-1} + Bh^{d}_{2,1,t-1} \cdot \Delta(e_{1,t}) + Bh^{d}_{2,3,t-1} \cdot \Delta(1/e_{3,t})$$

(21) $$YP_{3,t} = W_{3,t} + r_{b,1,t-1} \cdot Bh^{d}_{3,1,t-1} + r_{b,2,t-1} \cdot Bh^{d}_{3,2,t-1} + r_{b,3,t-1} \cdot Bh^{d}_{3,3,t-1}$$

$$+ r_{m,3,t-1} \cdot M_{3,t-1} + Bh^{d}_{3,1,t-1} \cdot \Delta(e_{2,t}) + Bh^{d}_{3,2,t-1} \cdot \Delta(e_{3,t})$$

(22) $$M^{s}_{1,t} = M^{d}_{1,t} = M_{1,t}$$

(23) $$Bh^{s}_{i,i,t} = Bh^{d}_{i,i,t} \qquad i=1,2,3$$

(24) $$Bh^{s}_{1,2,t} = Bh^{d}_{1,2,t} \cdot e_{1}$$

(25) $$Bh^{s}_{1,3,t} = Bh^{d}_{1,3,t} \cdot e_{2}$$

(26) $$Bh^{s}_{2,1,t} = Bh^{d}_{2,1,t} / e_{1}$$

(27) $$Bh^{s}_{2,3,t} = Bh^{d}_{2,3,t} \cdot e_{3}$$

(28) $$Bh^{s}_{3,1,t} = Bh^{d}_{3,1,t} / e_{2}$$

(29) $$Bh^{s}_{3,2,t} = Bh^{d}_{3,2,t} / e_{3}$$

(30) $$YD_{i,t} = YP_{i,t} - T_{i,t}$$

(31) $$T_{i,t} = \vartheta_{i} \cdot YP_{i,t}$$

(32) $$V_{i,t} = V_{i,t-1} + YD_{i,t} - C_{i,t}$$

(33) $$C_{i,t} = \alpha_{i,1} YD_{i,t} + \alpha_{i,2} V_{i,t-1}$$

(33') $$\Delta V_{i,t} = \alpha_{i,2} (\alpha_{i,3} YD_{i,t} - V_{i,t-1})$$

Here r_b denotes the interest rate of bills, r_m denotes the interest rate of deposits, *W* denotes the wage incomes of the households, *M* denotes deposits, and $Bh^{d}_{i,j}$ denotes bills demanded by country *i* households, but issued by the country *j* government. The superscript "s" on a variable stands for supply, and the superscript "d" stands for demand. $Bh^{s}_{i,j}$ denotes bills supplied to the country i households, but issued by the country j government. As already pointed out, all bill supplies are denominated in the currency of the issuing party, while all bill demands are expressed in the domestic currency of the purchaser.

According to the Brainard-Tobin (1968) pitfalls approach and to the Post-Keynesian version developed by Godley (1996), in each country households allocate their wealth among domestic high powered money, domestic deposits, and government bills issued by the domestic government and/or bills issued by foreign governments. The portfolio equations for the U.S. households are:

(34) $Hh^{d}_{1,t} / V_{1,t} = \lambda_{1,00} + \lambda_{1,01} \cdot r_{b,1,t} + \lambda_{1,02} \cdot r_{b,2,t} + \lambda_{1,03} \cdot r_{b,3,t} + \lambda_{1,04} \cdot r_{m,1,t}$

(34') $Hh^{d}{}_{1,t} = V_{1,t} - Bh_{1,1,t} - Bh^{d}{}_{1,2,t} - Bh^{d}{}_{1,3,t} - M^{s}{}_{1,t}$

(35) $Bh^{d}_{1,1,t} / V_{1,t} = \lambda_{1,10} + \lambda_{1,11} \cdot r_{b,1,t} + \lambda_{1,12} \cdot r_{b,2,t} + \lambda_{1,13} \cdot r_{b,3,t} + \lambda_{1,14} \cdot r_{m,1,t}$

(28) $Bh^{d}_{1,2,t} / V_{1,t} = \lambda_{1,20} + \lambda_{1,21} \cdot r_{b,1,t} + \lambda_{1,22} \cdot r_{b,2,t} + \lambda_{1,23} \cdot r_{b,3,t} + \lambda_{1,24} \cdot r_{m,1,t}$

(36) $Bh^{d}_{1,3,t} / V_{1,t} = \lambda_{1,30} + \lambda_{1,31} \cdot r_{b,1,t} + \lambda_{1,32} \cdot r_{b,2,t} + \lambda_{1,33} \cdot r_{b,3,t} + \lambda_{1,34} \cdot r_{m,1,t}$

(37) $M^{d}_{1,t} / V_{1,t} = \lambda_{1,40} + \lambda_{1,41} \cdot r_{b,1,t} + \lambda_{1,42} \cdot r_{b,2,t} + \lambda_{1,43} \cdot r_{b,3,t} + \lambda_{1,44} \cdot r_{m,1,t}$

Where *Hh* is the high powered money issued by the central bank, and where $0 < | \lambda_{1, ij} | < 1$, for i,j=0,1,2,3,4.[10]

The portfolio equations for the households of Euroland, where $0 < | \lambda_{2, ij} | < 1$, with i,j=0,1,2,3,4, are:

(38) $Hh^{d}{}_{2,t} / V_{2,t} = \lambda_{2,00} + \lambda_{2,01} \cdot r_{b,1,t} + \lambda_{2,02} \cdot r_{b,2,t} + \lambda_{2,03} \cdot r_{b,3,t} + \lambda_{2,04} \cdot r_{m,2,t}$

(38') $Hh^{d}{}_{2,t} = V_{2,t} - Bh^{d}{}_{2,1,t} - Bh^{d}{}_{2,2,t} - Bh^{d}{}_{2,3,t} - M^{s}{}_{2,t}$

(39) $Bh^{d}{}_{2,1,t} / V_{2,t} = \lambda_{2,10} + \lambda_{2,11} \cdot r_{b,1,t} + \lambda_{2,12} \cdot r_{b,2,t} + \lambda_{2,13} \cdot r_{b,3,t} + \lambda_{2,14} \cdot r_{m,2,t}$

(40) $Bh^{d}{}_{2,2,t} / V_{2,t} = \lambda_{2,20} + \lambda_{2,21} \cdot r_{b,1,t} + \lambda_{2,22} \cdot r_{b,2,t} + \lambda_{2,23} \cdot r_{b,3,t} + \lambda_{2,24} \cdot r_{m,2,t}$

(41) $Bh^{d}{}_{2,3,t} / V_{2,t} = \lambda_{2,30} + \lambda_{2,31} \cdot r_{b,1,t} + \lambda_{2,32} \cdot r_{b,2,t} + \lambda_{2,33} \cdot r_{b,3,t} + \lambda_{2,34} \cdot r_{m,2,t}$

(42) $M^{d}{}_{2,t} / V_{2,t} = \lambda_{2,40} + \lambda_{2,41} \cdot r_{b,1,t} + \lambda_{2,42} \cdot r_{b,2,t} + \lambda_{2,43} \cdot r_{b,3,t} + \lambda_{2,44} \cdot r_{m,2,t}$

[10] The vertical adding-up constraint was emphasized by Tobin (1969). The vertical adding-up constraint must hold. We also suppose that the horizontal adding-up constraint also hold, as emphasized by Godley (1996). The horizontal constraint is that in each portfolio equation, the sum of all the coefficients on rates of return should be zero.

Portfolio equations for China's households, where $0 < |\lambda_{3,ij}| < 1$, and j,k=0,1,2,3,4, are given below:

$$(43) \quad Hh^d{}_{3,t} / V_{3,t} = \lambda_{3,00} + \lambda_{3,01} \cdot r_{b,1,t} + \lambda_{3,02} \cdot r_{b,2,t} + \lambda_{3,03} \cdot r_{b,3,t} + \lambda_{3,04} \cdot r_{m,3,t}$$

$$(43') \quad Hh^d{}_{3,t} = V_{3,t} - Bh^d{}_{3,1,t} - Bh^d{}_{3,2,t} - Bh^d{}_{3,3,t} - M^s{}_{3,t}$$

$$(44) \quad Bh^d{}_{3,1,t} / V_{3,t} = \lambda_{3,10} + \lambda_{3,11} \cdot r_{b,1,t} + \lambda_{3,12} \cdot r_{b,2,t} + \lambda_{3,13} \cdot r_{b,3,t} + \lambda_{3,14} \cdot r_{m,3,t}$$

$$(45) \quad Bh^d{}_{3,2,t} / V_{3,t} = \lambda_{3,20} + \lambda_{3,21} \cdot r_{b,1,t} + \lambda_{3,22} \cdot r_{b,2,t} + \lambda_{3,23} \cdot r_{b,3,t} + \lambda_{3,24} \cdot r_{m,3,t}$$

$$(46) \quad Bh^d{}_{3,3,t} / V_{3,t} = \lambda_{3,30} + \lambda_{3,31} \cdot r_{b,1,t} + \lambda_{3,32} \cdot r_{b,2,t} + \lambda_{3,33} \cdot r_{b,3,t} + \lambda_{3,34} \cdot r_{m,3,t}$$

$$(47) \quad M^d{}_{3,t} / V_{3,t} = \lambda_{3,40} + \lambda_{3,41} \cdot r_{b,1,t} + \lambda_{3,42} \cdot r_{b,2,t} + \lambda_{3,43} \cdot r_{b,3,t} + \lambda_{3,44} \cdot r_{m,3,t}$$

4.3 Firms

As already pointed out when describing the stock matrix, firms do not hold financial assets. They only hold tangible capital *K*. The net investment of firms is wholly financed by loans, taken from commercial banks. The firms of each country produce one type of final good. The goods are imperfect substitutes for the foreign goods, and their production requires the use of imported intermediate inputs.

$$(48) \quad S_{i,t} = C_{i,t} + G_{i,t} + I_{i,t} + X_{i,t}$$

$$(48') \quad S_{i,t} - IM_{i,t} = Y_{i,t}$$

$$(49) \quad W_{i,t} = S_{i,t} - r_{l,i,t-1} L_{i,t-1} - DA_{i,t} - IM_{i,t}$$

$$(49') \quad W_{i,t} = Y_{i,t} - r_{l,i,t-1} L_{i,t-1} - DA_{i,t}$$

$$(50) \quad K_{i,t} = (1 - \delta_i) K_{i,t-1} + I_{i,t}$$

$$(51) \quad I_{i,t} = \gamma_i (K_{i,t}{}^T - K_{i,t-1}) + DA_{i,t}$$

$$(52) \quad K_{i,t}{}^T = \kappa_{i,t} \cdot S_{i,t-1}$$

$$(53) \quad \kappa_{i,t} = \zeta_{i,1} - \zeta_{i,2} \cdot r_{i,t}$$

$$(54) \quad DA_{i,t} = \delta_i K_{i,t-1}$$

$$(55) \quad \Delta L^d_{i,t} = I_{i,t} - DA_{i,t}$$

Here DA denotes depreciation and r_l denotes loan interest rate. $L^d_{i,t}$ is demand for loans.

K denotes stock of capital, δ denotes the rate of depreciation, 0<δ<1, and K^T denotes the capital stock target, κ_i denotes the capital to sales target ratio, $0 < \gamma_i < 1$, and with both $0 < \zeta_{i,1}, 0 < \zeta_{i,2}$.

The sales of the firms are expressed in equation (48) and (48'). Because we suppose, for simplification again, that the net profits of the firms are zero, wages can be described in the form of equation (49) and (49'). Equations (51)-(54) describe the firms' investment behaviour. The targeted capital stock (K^T) depends on the sales achieved in the previous period (S_{t-1}), and on the target ratio of capital to sales (κ_i). The target ratio of capital to sales (κ_i) has a negative relationship with the interest rate. The net investment, $\gamma_i(K_{i,t}{}^T - K_{i,t-1})$, is partially adjusted to the discrepancy between the targeted capital stock and the previous capital stock. Gross investment (I) is the sum of net investment and depreciation. From equations (50) and (51), we have that: $\Delta K_{i,t} = \gamma_i(K_{i,t}{}^T - K_{i,t-1})$. Since we assume that net profits of firms are zero, net investment must be financed by loans taken from private banks.

4.4 Commercial banks

The private banking system is highly simplified in this model. We assume that the U.S. and Euroland are auto-economies, as Hicks (1974) would call them, or asset-based financial systems (Lavoie, 2006, p. 58). In the U.S. and Euroland, private banks hold loans and bills issued by the government of their own country. On the other hand China is set up as an overdraft economy. Besides the deposits from households, commercial banks in China can also borrow from the central bank of China and Chinese commercial banks only hold loans as assets. A denotes the advances made by the central bank of China, while $Bcmb_{i,i}$ stands for the bills held by commercial banks of country i and issued by the government of country i.

(56) $L^s_{i,t} = L^d_{i,t} \equiv L_{i,t}$ $\quad i$=1,2,3

(57) $M_{i,t} = L_{i,t} + Bcmb_{i,i,t}$ $\quad i$=1,2

(58) $A_{3,t} \equiv L_{3,t} - M_{3,t}$

$$(58') \quad M_{3,t} + A_{3,t} \equiv L_{3,t}$$

$$(59) \quad r_{m,i,t} = r_{l,i,t} \equiv r_{i,t} \qquad i=1,2,3$$

$$(60) \quad r_{A,3,t} = r_{3,t}$$

Equations (56) reflects the assumption that loans are supplied on demand. Equation (57) describes the balance sheet of commercial banks of the U.S. and Euroland, while Equation (58) describes that of the Chinese commercial banks. The advances from the central bank are equal to the discrepancy between loans and deposits. Equation (59) and (60) reflect the assumption that interest rates on loans, deposits and bills are all equal, while in China, interest rates on advances are also equal to the other interest rates.

4.5 Government

Each government issues bills denominated in its own currency. B_i describes bills issued by the government of country i (i=1,2,3). Thus B_1, B_2 and B_3 are denominated in Dollar, Euro and RMB, respectively.

$$(61) \quad \Delta B_{i,t} = (G_{i,t} + r_{b,i,t-1} B_{i,t-1}) - (T_{i,t} + F_{i,t})$$

$$(61a) \quad B_{i,t} = B_{i,t-1} + (G_{i,t} + r_{b,i,t-1} B_{i,t-1}) - (T_{i,t} + F_{i,t})$$

$$(62) \quad G_{i,t} = \overline{G_i} \qquad i=1,2,3$$

$$(63) \quad r_{b,i,t} = r_{i,t}$$

Equation (61) is the government budget constraint. The bills newly issued by the government are equal to government expenditures (pure government expenditure G plus debt service) minus government revenues, which consist of taxes and central bank profits F transferred to the government. Equation (62) indicates that (pure) government spending is an exogenous variable. Equation (63) reflects the assumption that the interest rate on bills is also assumed to be equal to the interest rate on deposits and loans.

4.6 The Central Bank

Each central bank issues cash money, and holds domestic and foreign bills. The central bank of China also supplies advances to Chinese commercial banks on demand, as already pointed out. High powered money is also supplied on demand. $Bcb_{i,j}$ denotes the bills issued by the government of country *j*, but held by the central bank of country *i*. We suppose that the Fed (Federal Reserve Board of the U.S.) and the ECB (the European Central Bank) do not hold bills issued by the Chinese government. Also, since the exchange rate between the Dollar and the Euro is freely floating, $Bcb^{s}{}_{1,2,t}$, and $Bcb^{s}{}_{2,1,t}$ can be set as constants. Because these foreign reserves play no fundamental role in the dynamics of a model with flexible exchange rate, we shall assume that they are equal to nil in the numerical simulations (Godley and Lavoie, 2003).

The following equations are relatively straightforward. The only tricky equations are equations (67) and (68), which describe the change in the demand for U.S. bills by the Chinese central bank. They are tricky because the change in the value of the Chinese foreign exchange reserves depend both on a flow – the Chinese balance of payments surplus – and on the appreciation (or depreciation) of their previous stocks of foreign exchange reserves. The central bank of China holds bills issued by the Chinese government ($Bcb_{3,3}$), bills issued by the U.S. government ($Bcb_{3,1}$), and bills issued by the government of Euroland ($Bcb_{3,2}$). $Bcb_{3,1}$ and $Bcb_{3,2}$ compose the foreign reserves of China's central bank. Thus, if the euro appreciates relative to the RMB, the accumulated stock of euro bills held by the Chinese central bank will rise in value, thus generating a capital gain for the Chinese central bank. Similarly, if the People's Bank of China and the Chinese government were to announce a revaluation of the RMB relative to the US dollar, this would generate a capital loss for the central bank.[11] For this reason, differences in stocks, rather than absolute stock values, need to be identified. Similar considerations need to be taken into account when dealing with the balance sheet of the Fed, but because foreign reserves supplied are constant, as mentioned in the previous paragraph, the balance sheet constraint expressed in differences comes down to equation (65). For the same reason, changes in the balance sheet of the European central bank get simplified to equation (66).

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[11] Since we have two equations (equation 67 and equation 68) to determine $Bcb^{d}{}_{3,1,t}$, equation (67) will be the hidden, or redundant, equation in the model. This equation is then used to verify that the accounting of the model is correct, and that the data (the stocks) are consistent. Equation (67) reflects the balance sheet constraint of the central bank of China..

$$(64)\quad Hh^{s}{}_{i,t} = Hh^{d}{}_{i,t}$$

$$(65)\quad \Delta Bcb^{d}{}_{1,1,t} = \Delta Hh^{s}{}_{1,t}$$

$$(66)\quad \Delta Bcb^{d}_{2,2,t} = \Delta Hh^{s}{}_{2,t}$$

$$(67)\quad \Delta Bcb^{d}{}_{3,1,t} = \Delta Hh^{s}{}_{3,t} - \Delta Bcb^{d}{}_{3,3,t} - \Delta Bcb^{s}{}_{3,2,t} \cdot e_{3,t} - \Delta A^{s}{}_{3,t} - Bcb^{s}_{3,1,t-1} \cdot \Delta e_{2,t}$$

$$(68)\quad Bcb^{d}{}_{3,1,t} = \Delta Bcb^{s}{}_{3,1,t} \cdot e_{2} + Bcb^{s}_{3,1,t-1} \cdot \Delta e_{2,t}$$

$$(69)\quad Bcb^{s}{}_{1,1,t} = Bcb^{d}{}_{1,1,t}$$

$$(70)\quad Bcb^{s}_{2,2,t} = Bcb^{d}_{2,2,t}$$

$$(71)\quad Bcb^{d}{}_{3,3,t} = Bcb^{s}{}_{3,3,t}$$

$$(72)\quad Bcb^{s}{}_{3,2,t} = Bcb^{d}{}_{3,2,t} / e_{3,t}$$

$$(73)\quad Bcb^{d}_{3,2,t} = \beta \cdot Bcb^{d}_{3,1,t} \qquad \beta \geq 0$$

Equation (64) means that the cash supplied by central banks is equal to that demanded by their domestic households. Equations (69)-(72) reflect the assumptions that the supply of bills to central banks is equal to their demand. In equation (73), if $\beta = 0$, the Chinese central bank does not hold any bills issued in the Eurozone. If $\beta > 0$, we can say that the Chinese central bank diversifies its foreign reserves ($FR_{3,t}$). Therefore, the composition of China's foreign reserves can be expressed as[12]: $Bcb^{d}_{3,1,t} = \xi_1 \cdot FR_{3,t}$, and $Bcb^{d}_{3,2,t} = \xi_2 \cdot FR_{3,t}$ where $\xi_1 = \left(\frac{1}{1+\beta}\right)$, $\xi_2 = \left(\frac{\beta}{1+\beta}\right)$, and $\xi_1 + \xi_2 = 1$.

Would such a policy threaten the dollar peg of RBM? In this paper, our experiments and simulations are based on the assumption that China's dollar reserves keep going up over time due to large trade and current account surpluses, especially in the bilateral trade with the U.S. China's dollar reserves are huge enough to maintain the peg of the RMB against the dollar.

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[12] $FR_{3,t} = Bcb^{d}_{3,1,t} + Bcb^{d}_{3,2,t} = (1+\beta)\, Bcb^{d}_{3,1,t}$

Therefore, diversification would not threaten the dollar peg of RBM. This assumption is actually consistent with what the Chinese central bank is currently facing in the real world.

The equations that follow include a bit of house cleaning identities, some of which will be useful when we define exchange rates.

(74) $$B^{s}{}_{1,t} \equiv Bh^{s}{}_{1,1,t} + Bcmb^{s}_{1,1,t} + Bcb^{s}{}_{1,1,t} + Bh^{s}{}_{2,1,t} + Bh^{s}{}_{3,1,t} + Bcb^{s}{}_{3,1,t}$$

(74a) $$Bcb^{s}{}_{3,1,t} = B^{s}{}_{1,t} - Bh^{s}{}_{1,1,t} - Bcmb^{s}_{1,1,t} - Bcb^{s}{}_{1,1,t} - Bh^{s}{}_{2,1,t} - Bh^{s}{}_{3,1,t}$$

(75) $$B^{s}{}_{2,t} \equiv Bh^{s}{}_{1,2,t} + Bh^{s}{}_{2,2,t} + Bcmb^{s}_{2,2,t} + Bcb^{s}{}_{2,2,t} + Bh^{s}{}_{3,2,t} + Bcb^{s}_{3,2,t}$$

(76) $$B^{s}{}_{3,t} \equiv Bh^{s}{}_{1,3,t} + Bh^{s}{}_{2,3,t} + Bh^{s}{}_{3,3,t} + Bcb^{s}{}_{3,3,t}$$

(76a) $$Bcb^{s}{}_{3,3,t} = B^{s}{}_{3,t} - Bh^{s}{}_{3,3,t} - Bh^{s}{}_{1,3,t} - Bh^{s}{}_{2,3,t}$$

(77) $$F_{1,t} = r_{1,t-1} \cdot Bcb_{1,1,t-1}$$

(78) $$F_{2,t} = r_{2,t-1} \cdot Bcb_{2,2,t-1}$$

(79) $$F_{3,t} = r_{1,t-1} \cdot Bcb^{d}{}_{3,1,t-1} + r_{3,t-1} \cdot (Bcb_{3,3,t-1} + A_{3,t-1}) + r_{2,t-1} \cdot Bcb^{d}_{3,2,t-1}$$

(80) $$r_{1,t} = \overline{r_1}$$

(81) $$r_{2,t} = \overline{r_2}$$

(82) $$r_{3,t} = \overline{r_3}$$

Equations (74)-(76) describe the identity components of the bills issued by each government. Equation (75) will be used to determine the exchange rate between the Dollar and the Euro in section 3.7. Equation (77)-(79) describe the profits of a central bank (F_i) which consist of interest payments from domestic bills, and/or interest payments from foreign bills. The profits of the central bank of China also include interest payments on advances. Finally, equations (80)-(82) affirm that interest rates are exogenous, as is also assumed by Blanchard et al. (2005a, 2005b). In agreement with post-Keynesian monetary theory, and as can be observed in the real world today, central banks implement monetary policy by setting an overnight interest rate target. Short-term administered and market interest rates usually follow very closely changes in the target set by the central bank.

4.7 Exchange rate dynamics

Since we assume that the Chinese currency (RMB) is pegged to the Dollar, the nominal exchange rate between the Dollar and the RMB is fixed.

(83) $e_{2,t} = \overline{e_2}$

For the determination of the flexible exchange rate between the Dollar and the Euro, we follow the approach proposed by Godley and Lavoie (2003, and 2007a).

Substituting equation (24) into equation (75), we have (75a):

(75a) $B^s{}_{2,t} \equiv Bh^d{}_{1,2,t} \cdot e_1 + Bh^s{}_{2,2,t} + Bcmb^s_{2,2,t} + Bcb^s{}_{2,2,t} + Bh^s{}_{3,2,t} + Bcb^s_{3,2,t}$

We can rewrite equation (75a) under the form:

(75b) $e_1 = (B^s{}_{2,t} - Bh^s{}_{2,2,t} - Bcmb^s_{2,2,t} - Bcb^s{}_{2,2,t} - Bh^s_{3,2,t} - Bcb^s_{3,2,t}) / Bh^d{}_{1,2,t}$

Equation (75b) describes the determination of the exchange rate between the Dollar and the Euro.

The exchange rate between the RMB and the Euro can be expressed as follows.

(84) $e_{3,t} = e_{2,t} / e_{1,t}$

Naturally, if the U.S. Dollar depreciates compared to the Euro, the value of the RMB will also fall relative to the Euro because the RMB is pegged to the U.S. Dollar.

Equation (75b) might seem to imply that the dollar-euro exchange rate is only determined by the interaction between the demand for and the supply of bills issued by Euroland. But this is not the case. The system is a fully interdependent one such that the solution of the model as a whole requires and ensures that every equation in which the exchange rate appears is satisfied at the same time. In particular the exchange rate given by equation (75b) satisfies all the trade equations and influences personal consumption through its effect on capital gains.

4.8 Current account balance and capital account balance

We can derive the following balance of payment identities. We first start with the current account balance:

$$(85)\quad CAB_{1,t} \equiv X_{1,t} - IM_{1,t} + r_{2,t-1} \cdot Bh^{d}{}_{1,2,t-1} + r_{3,t-1} Bh^{d}{}_{1,3,t-1} - r_{1,t-1}(B_{1,t-1} - Bh_{1,1,t-1} - Bcb_{1,1,t-1})$$

$$(86)\quad CAB_{2,t} \equiv X_{2,t} - IM_{2,t} + r_{1,t-1} \cdot Bh^{d}{}_{2,1,,t-1} + r_{3,t-1} Bh^{d}{}_{2,3,t-1} - r_{2,t-1}(B_{2,t-1} - Bh_{2,2,t-1} - Bcb_{2,2,t-1})$$

$$(87)\quad CAB_{3,t} \equiv X_{3,t} - IM_{3,t} + r_{1,t-1} Bh^{d}_{3,1,t-1} + r_{2,t-1} Bh^{d}_{3,2,t-1} + r_{1,t-1} Bcb^{d}{}_{3,1,t-1} + r_{2,t-1} \cdot Bcb^{d}_{3,2,t-1} - r_{3,t-1}(B_{3,t-1} - Bh_{3,3,t-1} - Bcb_{3,3,t-1})$$

Where *CAB* denotes the current account balance.

To sum up this section, we can point out that the exogenous variables include pure government spending (G_i), interest rates (r_i), and E_2 (the exchange rate between the Chinese RMB and the Dollar).[13] The endogenous variables are *GDP,* personal and disposable income, consumption, investment, fixed capital, wages, imports, exports, the budget balance and government debts, trade and current account balances, loans, deposits, advances, wealth and its allocation among the available assets, the exchange rate between the Dollar and the Euro, and the exchange rate between the RMB and the Euro. The amount of foreign reserves held by the Chinese central bank in euro assets will also be an endogenous variable if β>0.

5. Diversification following an increase in the US propensity to import goods from China

This section presents the following experiment. We start from a full steady state, where all current accounts are balanced, as the baseline case. We then increase the propensity of the U.S. to import goods from China at time T_1. Then, at time T_2 (T_2>T_1), we assume that China decides to diversify its foreign reserves, that is, it sets $\beta > 0$. More precisely, we assume that the value of β suddenly jumps from 0 to 0.2. This means that whereas, before T_2, all Chinese foreign reserves were held in US dollars, after T_2 only about 83.3% of the reserves are held in dollars,

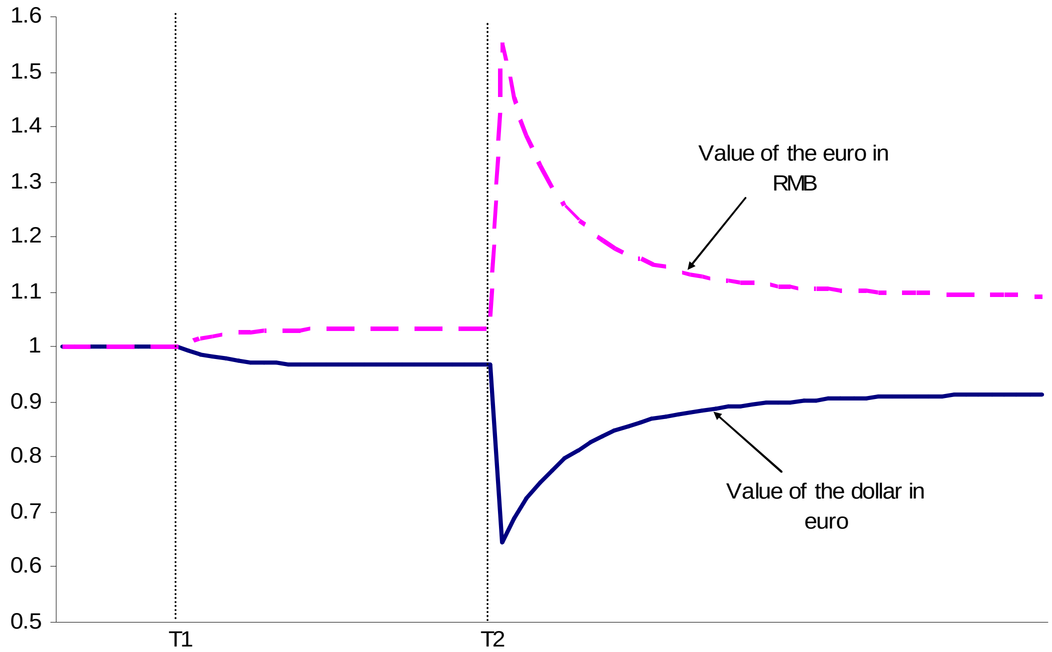
[13] Expectations about future exchange rates are set aside. But see the analysis of Daigle and Lavoie (2009), where chartist and fundamentalist expectations are introduced within a two-country SFC model.

the rest being held in euros. How will this one-step change affect the exchange rates, trade balances, and GDP of the three countries?[14]

Figure 1 shows the dynamic adjustment path for the exchange rates of the euro against the RMB and that of the dollar against the euro. The higher U.S. propensity to import Chinese goods leads to a slight appreciation of the euro with respect to the RMB and the dollar. At time T_2, exchange rates overshoot. The sudden diversification of China's foreign reserves results in a brisk appreciation in the value of the euro against the dollar and the RMB. This brisk appreciation is then followed by a gradual depreciation of the euro. However, in the new steady state, the values of the euro against the dollar and the RBM are much higher than those before diversification. This is due to the fact that the diversification of China's reserves leads to an increase in the demand for euro bills, resulting in a further appreciation of the euro vis-à-vis the dollar and the RBM. These results are similar to those achieved by Blanchard et al. (2005a), except for the overshooting effect.

[14] Very similar results are obtained when the Chinese trade surplus is assumed to be caused by enlarged US government expenditure (by the US budget deficit). The main difference arises from the evolution of GDP.

Figure 1: Impact of the diversification of China's foreign reserves on the exchange rate



Why is there overshooting? Recall the exchange rate determination equations (75b) and (84). Substituting equation (84) into equation (29) and (72) respectively, we have:

$$(29a) \quad Bh^{s}_{3,2,t} = Bh^{d}_{3,2,t} / e_3 = \frac{Bh^{d}_{3,2,t}}{e_{2,t} / e_{1,t}} = \frac{Bh^{d}_{3,2,t} \cdot e_{1,t}}{e_{2,t}}$$

$$(72a) \quad Bcb^{s}{}_{3,2,t} = Bcb^{d}{}_{3,2,t} / e_{3,t} = \frac{Bcb^{d}_{3,2,t}}{e_{2,t} / e_{1,t}} = \frac{Bcb^{d}_{3,2,t} \cdot e_{1,t}}{e_{2,t}}$$

Substituting (29a) and (72a) into equation (75b), we get:

$$e_1 = \frac{B^{s}{}_{2,t} - Bh^{s}{}_{2,2,t} - Bcmb^{s}_{2,2,t} - Bcb^{s}{}_{2,2,t}}{Bh^{d}{}_{1,2,t} + Bh^{d}_{3,2,t} / e_{2,t} + Bcb^{d}_{3,2,t} / e_{2,t}}$$

In the short run, as the Chinese central bank decides to diversify its foreign reserves, China's demand for euro bills rises immediately, that is, $Bcb^{d}{}_{3,2,t}$ increases dramatically, as shown in Figure 2. The change in $Bcb^{d}{}_{3,2,t}$ has a dominating effect on the adjustment of the exchange rate (e_1) in the short run. This induces a jump in the value of the euro against the dollar and the RMB. However, in the long run, with the adjustment of demand for and supply of euro bills, in particular the decrease in the demand from Euroland households due to changes in their disposable income, the value of the euro returns to a new level, which is lower than that its short-run value, but higher than in the scenario without diversification.

Figure 2: The impact of diversification on the foreign reserves of China

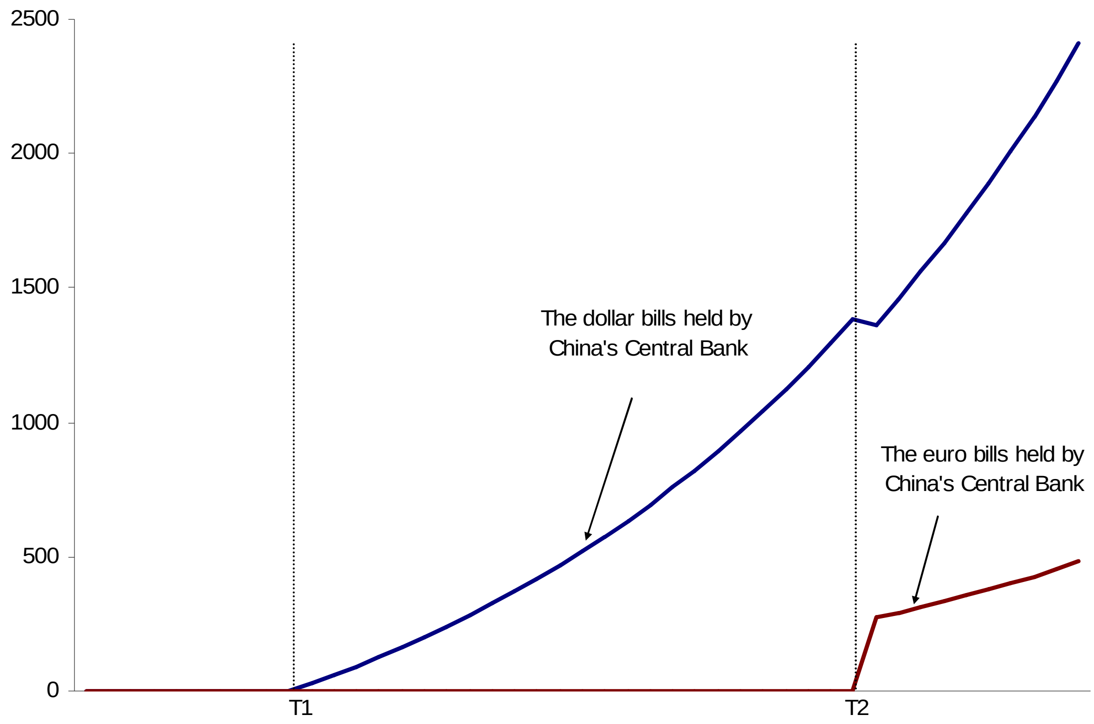


Figure 3: Impact of the diversification of China's foreign reserves on trade accounts

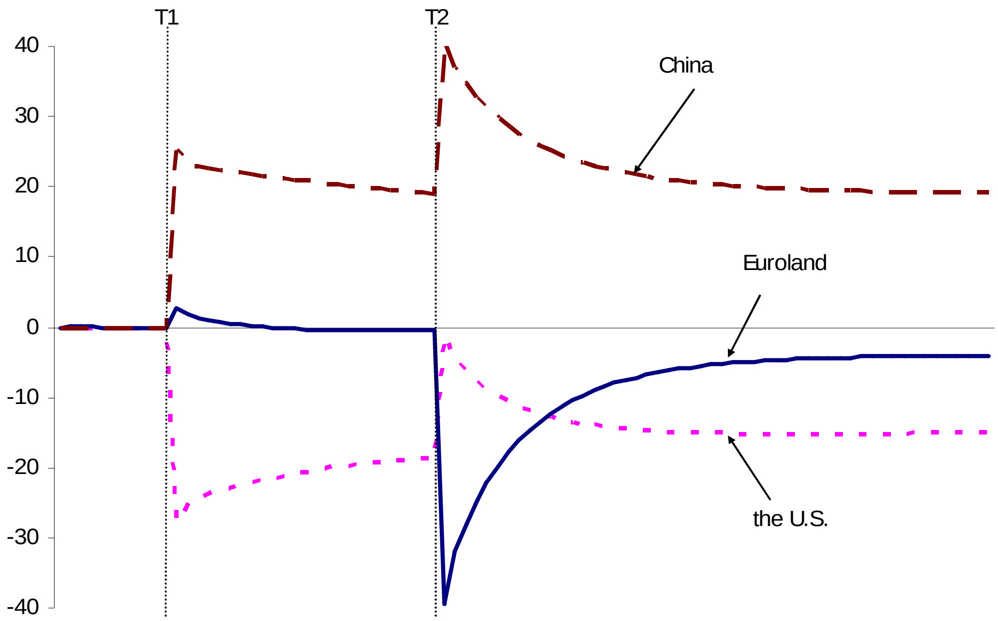
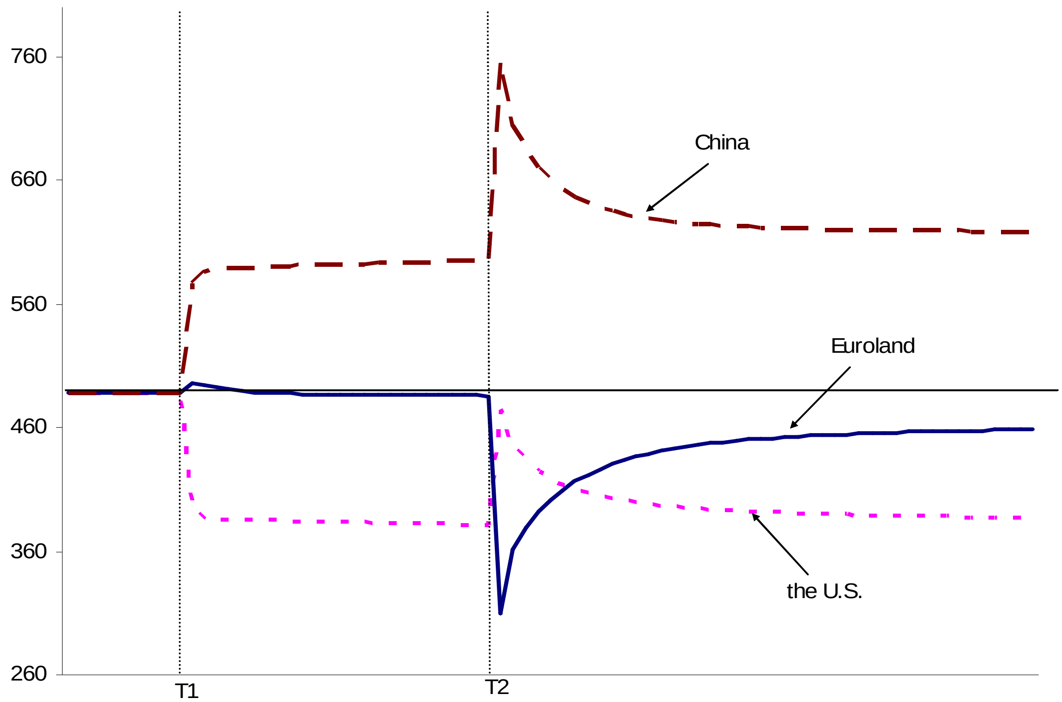


Figure 3 shows that trade imbalances get momentarily enlarged by the diversification of China's foreign reserves. This is not a surprising result. The steep appreciation of the euro against the dollar and the RMB decreases the competitiveness of Euroland on world markets, leading to the emergence of a large trade account deficit in the short run. At the same time, the Chinese trade surplus increases dramatically, while the U.S. trade deficit decreases substantially.

In the long run, as the value of the euro depreciates and reverts towards its original position, the Euroland trade account improves while the U.S. trade account goes back towards its previous deficit level. Without diversification, the Euroland trade account would have gone back to zero (as can be seen in Figure 3, between T_1 and T_2). Therefore, we can say that the diversification of China's foreign reserves leads to a trade deficit in Euroland, to a higher trade surplus in China, and to a smaller trade deficit in the U.S..

Figure 4: Impact of the diversification of China's foreign reserves on GDP



Let us now look at the impact on GDP of an increase in the US propensity to import Chinese goods. Note from Figure 4 that this has a small impact on the GDP of Euroland, a small positive impact in the short run and a small negative impact in the long run. As one would expect, the increase in the US propensity to import Chinese goods has a substantial positive impact on the GDP of China, and a negative one US GDP. Figure 4 also illustrates the impact of the diversification of China's reserves on the GDP of the three economies. Both China and the U.S. benefit from the diversification, mostly in the short run, but also in the long run. By contrast, the economy of the Euroland slows down, even in the long run, being pulled down by its trade deficit caused by the Chinese diversification of reserves towards the Euro.

6. Sensitivity analysis

We now proceed to a sensitivity analysis. We wish to determine the sensitivity of the key endogenous variables with respect to changes in the value of the β parameter. Sensitivity analysis can help us to build confidence in the model by examining the range of fluctuations that are associated with the β parameter.

Figure 5: Impact of changes in the β parameter on the value of the dollar in terms of the euro

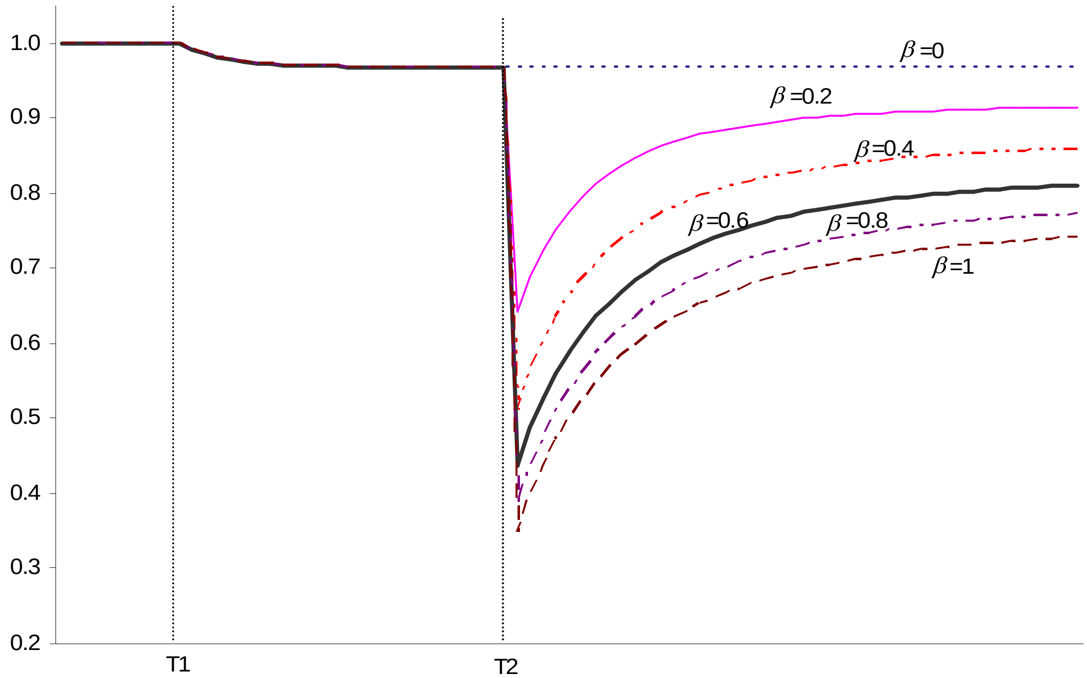


Figure 6: Impact of changes in the β parameter on the trade balance of Euroland

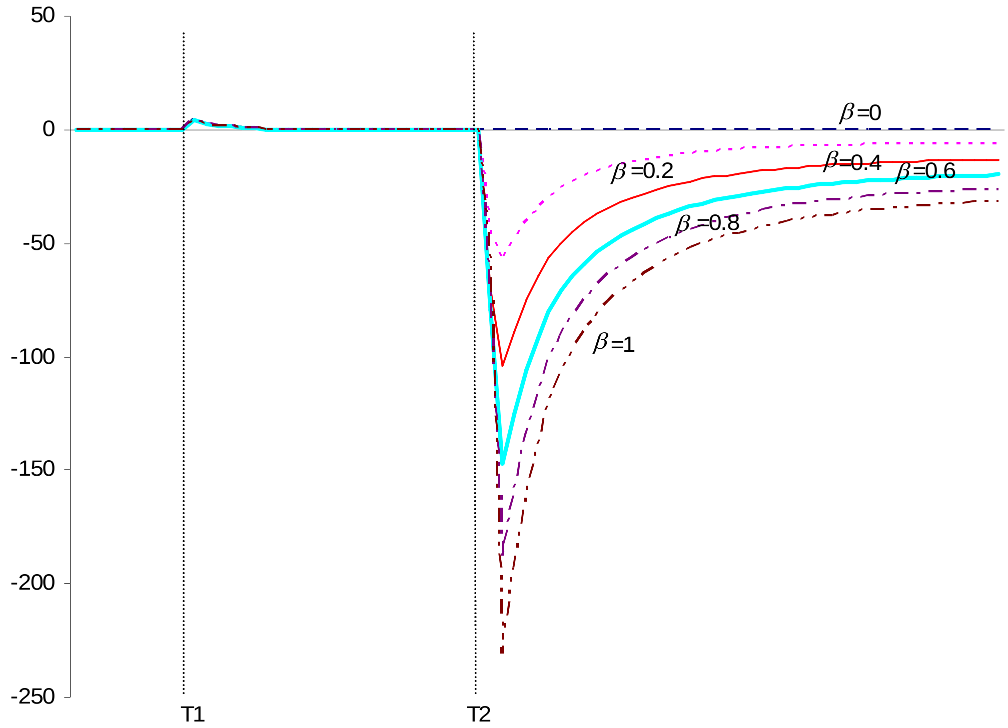
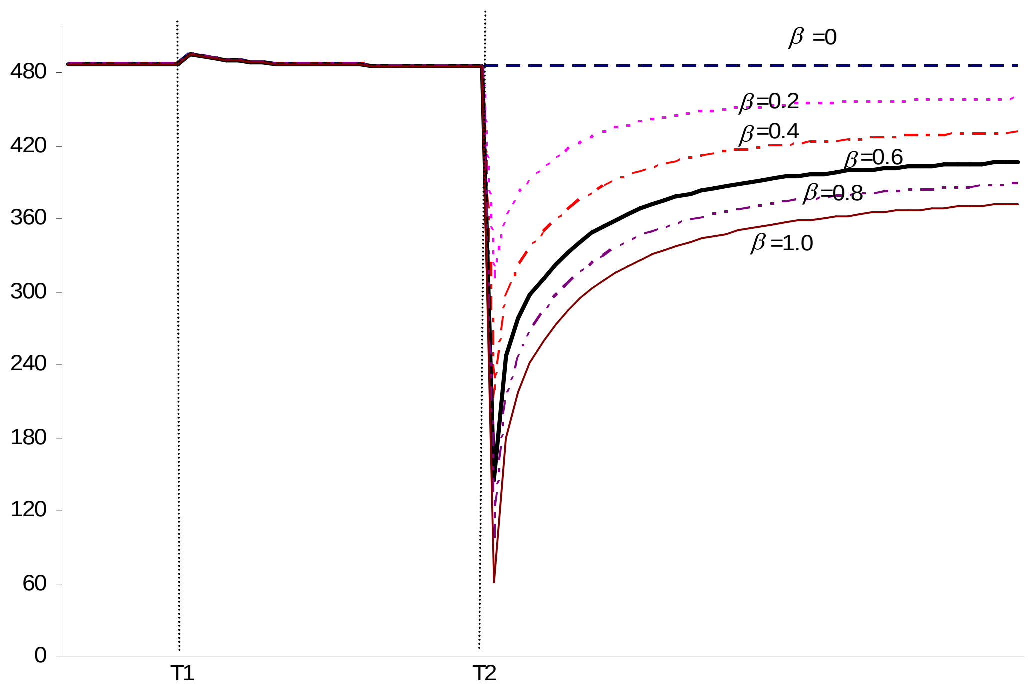


Figure 7: Impact of changes in the β parameter on the GDP of Euroland

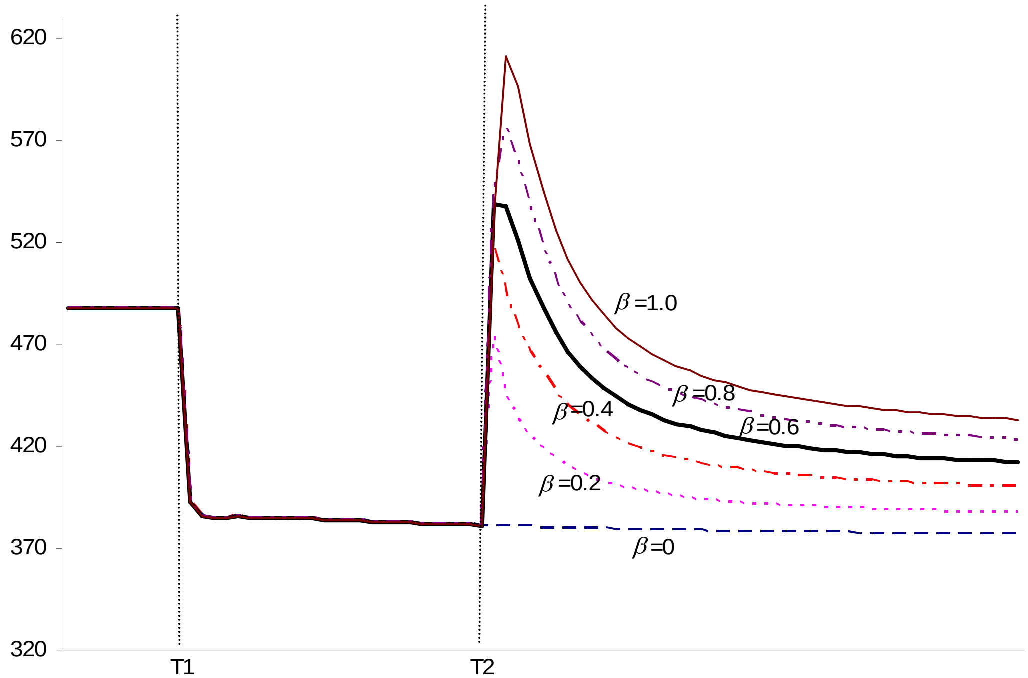


We look at five different values of the β parameter at time T_2: 0.4, 0.6, 0.8, and 1.0. For each value of the parameter β, we get a different composition of China's foreign reserves by currency – the dollar vs. the euro (e.g. 100% vs. 0% for β=0; 83.3% vs. 16.7% for β=0.2; 71.4% vs. 28.6% for β=0.4; 62.5% vs. 37.5% for β=0.6; 55.6% vs. 44.4% for β=0.8; and 50.0% vs. 50% for β=1.0). Here, diversification is such that the Chinese central bank keeps at least 50% of its reserves in US dollars. As in the previous section, we look at three variables: the exchange rate, the trade account, and GDP. We will focus on the impact on Euroland since Euroland will be worse off with the diversification of China's foreign reserves.

As shown in Figures 5, 6 and 7, the amplitude of one-step policy change in diversification has a clear impact on these three variables, especially in the short-run, but also in the long-run. This may indicate that the choice of the value of the β parameter is not innocuous. Indeed, the model remains stable even when disproportionate and unlikely changes are considered.

As pointed out above, without the diversification of China's reserves (β=0), external shocks only have a short-run impact on the Euroland's trade position and its GDP, and no permanent, long-run, effect. However, diversification has both short-run and long-run negative effects on the Euroland's economy. The larger the diversification, the larger the effects will be on Euroland. Also, as shown in Figure 8, if the β parameter is large enough, the trade balance position of the U.S. can move from deficit to surplus in the short run, while it returns back to a trade deficit in the long run.

Figure 8: Impacts of changes in the parameter β on the GDP of the U.S.



7. Gradual diversification

In the real world, a one-step change in the proportion of foreign exchange reserves held in dollars and in euros is likely to destabilize international financial markets and the world economy. As the illustrative numbers of Figure 7 show, the Euro would skyrocket following a large one-step diversification of Chinese foreign reserves, and it would have a catastrophic impact on the GDP of Euroland. In this section, we propose a more likely alternative closure. The Chinese central bank is assumed to set a target percentage composition of its foreign reserve holdings by currencies. China's central bank gradually sells its dollars and purchases euros, achieving its diversification target over a longer time period.[15]

As an alternative closure of the main model, we insert the following equations.

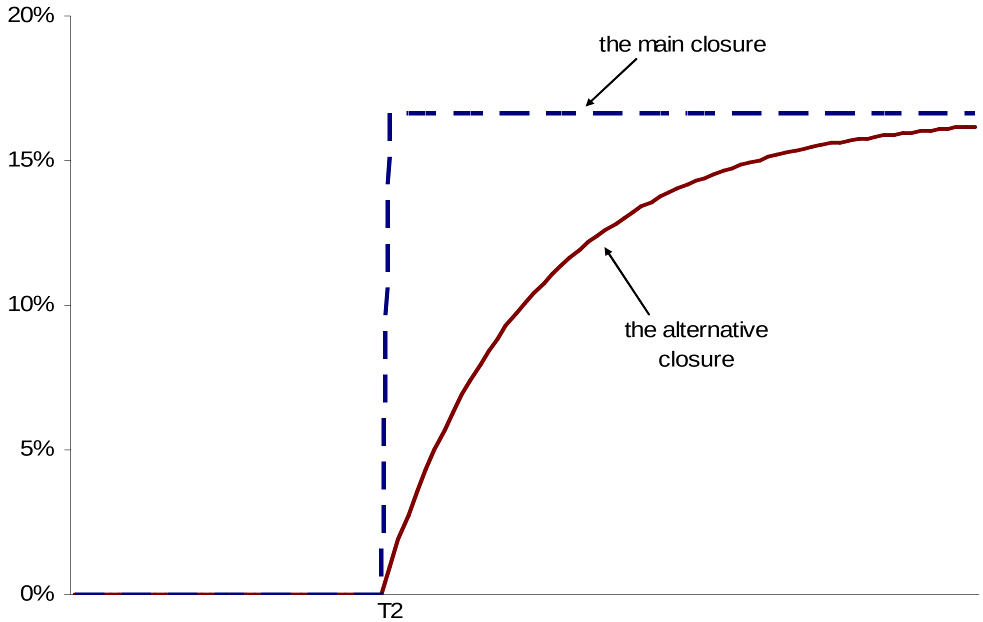
(73a) $Bcb^{d}_{3,2,t} = \beta_t \cdot Bcb^{d}_{3,1,t}$

[15] In fact, because the US trade balance cannot be rectified as long as the value of the renminbi remains pegged to the US dollar, dollar reserves keep rising through time, even though China's central bank acquires euros, as shown in Figure 2.

(73b) $\Delta\beta_t = \tau \cdot (\beta^T - \beta_{t-1})$	
(73b') $\beta_t = \beta_{t-1} + \tau \cdot (\beta^T - \beta_{t-1})$	$\beta \geq 0$

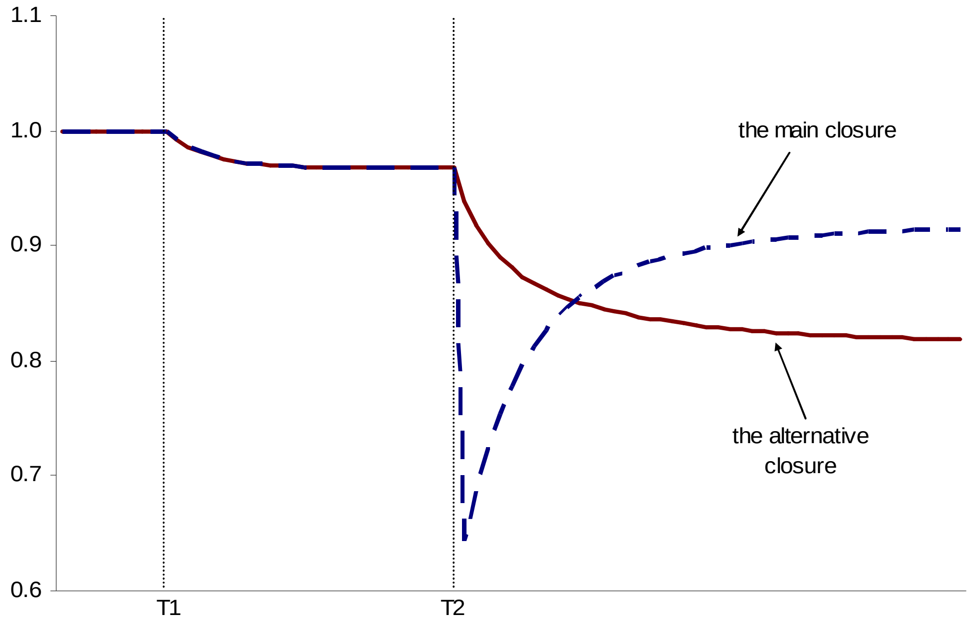
Here β^T is an exogenous variable that represents the target percentage composition of China's foreign reserves, and τ is a speed reaction parameter. The beta (β) parameter is no longer a parameter in the alternative closure of the model; it is instead an endogenous variable that reflects the actual composition of the foreign reserves (in contrast to the target). The new value of β_t is partially adjusted to the discrepancy between the target β^T and the previous beta (β_{t-1}). In other words, there is a partial adjustment mechanism, as shown below in Figure 9 below.

Figure 9: Diversification impact on the share of euros in Chinese foreign reserves, compared to that of the main model



The figure illustrates diversification when the long-run target share of the euro bills in the foreign reserve holdings of the Chinese central bank is 16.7% (and hence the share of dollar bills is 83.3%). This implies that $\beta^T = 0.2$. Once the target is set, at time T_2, the share of euro securities in Chinese foreign reserves gradually increases through time, approaching the target in the long-run, with the adjustment parameter being τ, with τ =0.05.

Figure 10: Diversification impact on the value of the dollar in terms of the euro, compared to that of the main model



Because the diversification of China's reserves is gradual and initially of a small amplitude, the overshooting effect vanishes, as shown in Figure 10. The euro appreciates steadily against the dollar, until a new (quasi) steady state is achieved, once the target level of diversification is attained. However, in the long run, the value of the euro in terms of dollars in this alternative closure is much higher than that of the main model. In other words, the long-run appreciation of the euro against the dollar and the RMB is much larger than was the case in the main closure, when diversification was a one-step affair.

Figure 11: Diversification impact on the trade position of Euroland, compared to that of the main closure

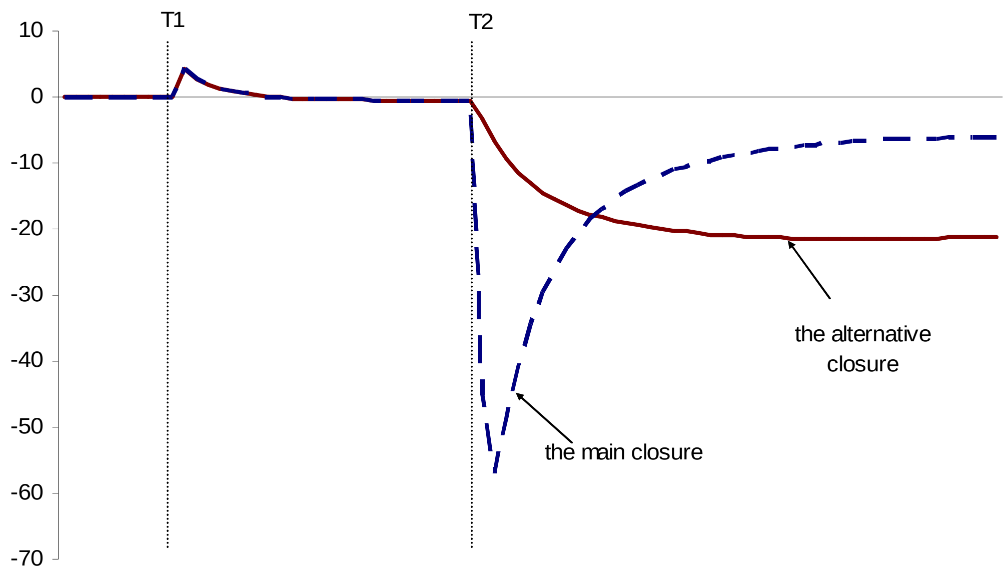
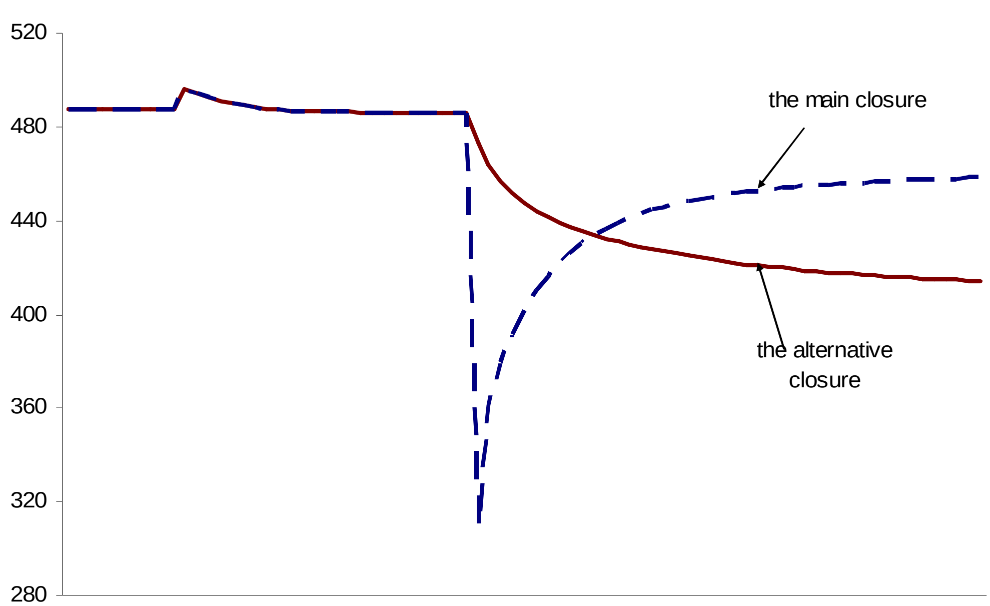


Figure 12: Diversification impact on the GDP of Euroland, compared to that of the main closure



Similar effects can be observed when one looks at the evolution of the other main variables. Compared to the main model, in the long run, the large appreciation of the euro against the dollar and the RMB leads to a bigger trade deficit in Euroland (Figure 11). Thus there is no surprise in observing that gradual reserve diversification generates a steady-state Euroland GDP which is even lower than what it was with one-step diversification, as shown in Figure 12. Meanwhile, through feedback effects, both China and the US economy show improved long-run trade accounts and higher GDP, relative to the one-step diversification main closure (see Figures 13 and 14 for the US economy).

Figure 13: Diversification impact on the trade position of the U.S., compared to that of the main closure

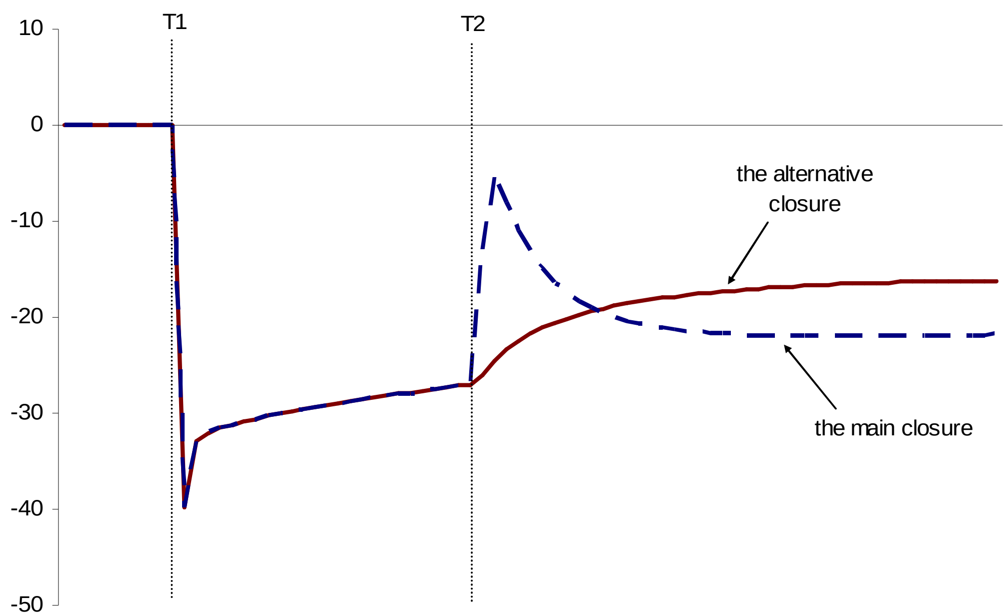
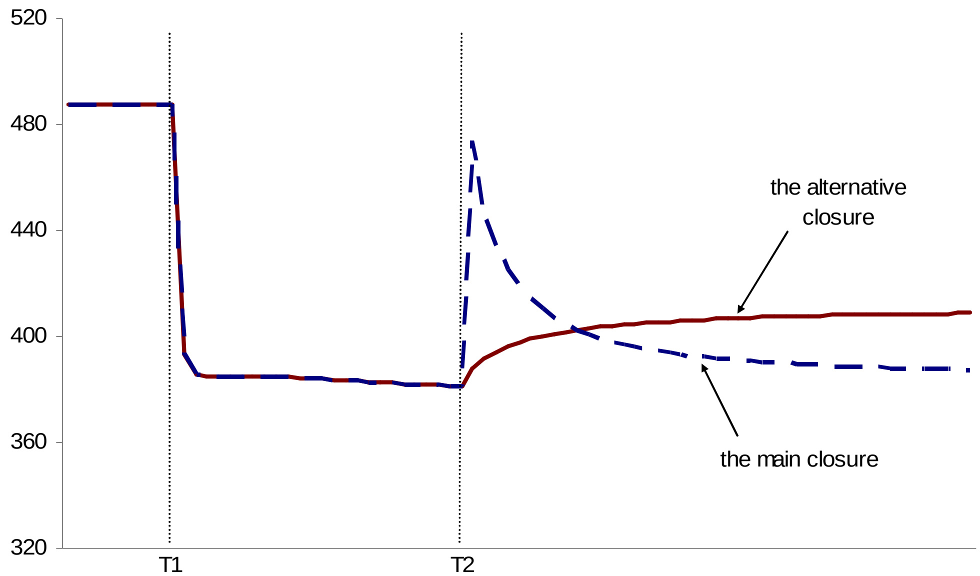


Figure 14: Diversification impact on the GDP of the U.S., compared to that of the main closure



Comparing the main model and its alternative closure, we find that in the long run most of the main endogenous variables do not convergence towards a unique equilibrium set. In other words, despite the fact that all parameters are the same in the main and alternative closures, including the proportion of Chinese foreign reserves being held in euros, the steady-state values of endogenous variables of the model are different in the two closures. How the central bank of China will achieve its target diversification rate has an impact on the steady state values of the model. In other words, the transition path towards the diversification target influences the long run equilibrium. Thus, the equilibrium levels of the key endogenous variables in our model also depend on the path chosen to achieve the target. It depends on the values taken by the adjustment parameters during the transition.

There is path dependence in this model, in contrast to what can be observed in most models, in particular in neoclassical models. Thus it can be said that the present model incorporates the concept of historical time, dear to post-Keynesian economists (Setterfield 1996). In this case, path dependency must be attributed to the different interest payment flows generated by the different series of asset stocks associated with the different transitional assumptions. Our simulation results provide an example of path dependence, that is, both the starting steady state and transitional reaction parameters to shocks can have significant long-run effects.

8. Conclusion

This paper has presented a three-country stock-flow consistent model, with one fixed exchange rate and two flexible exchange rates. The model is within the tradition of portfolio balance models with imperfect asset substitutability, inaugurated by Branson (1979), abandoned for about 15 years, and resuscitated by Godley (1999). The model has been applied to simulate the impact of changes in the foreign exchange policies being pursued by the central bank of China, more precisely the impact of the diversification of its foreign reserves, away from US dollars and towards euros.

A distinguishing feature of the paper, besides its stock-flow consistent approach, is that most variables are endogenous. This is notably the case of *GDP,* personal and disposable income, consumption, gross investment, fixed capital, imports, exports, the budget balance and government debts, trade and current account balances, the capital account balance, loans, deposits, advances, wealth and its allocation among the available assets, the exchange rate between the Dollar and the Euro, and the exchange rate between the RMB and the Euro. The amount of foreign reserves held by the Chinese central bank in dollar and euro assets are also an endogenous variable.

The model is an idealized version of the real world since we know that China moved onto a managed float exchange rate regime in July 2005. Since then, the renmibi has appreciated by about 21 percent relative to the dollar, at the time of writing. Such an appreciation, as has been argued by several observers, would lead to a reduced US trade deficit and a higher US GDP in our model, while the impact on the Euro economy would be nearly nil. We thus decided to focus excusively on the more contentious impact of reserve diversification in this paper.

The simulation results show that with a one-step diversification of China's foreign reserves, the euro appreciates against the dollar and the RMB, with an overshooting effect on the exchange rate. China and the U.S. both benefit from the diversification, while the Euroland economy slows down. These findings are consistent with those achieved by Blanchard et. al (2005a, 2005b) and Dullien (2007) in their portfolio balance models.

Using parameter sensitivity analysis, we find, as one would expect, that the larger the percentage of diversification, the more significant the negative impact on the Euroland economy. Gradual diversification, as one would also expect, can eliminate the highly detrimental short-run effects on the Euroland economy. However, for a given target percentage of reserve diversification towards euros, the long-run value of the euro against the dollar and the RMB is higher in the case of gradual diversification than it is with a one-step diversification. As a result, the Euroland economy is worse off in the long run under the gradual diversification scenario, with a lower GDP and higher trade deficit.

An interesting feature of the model is that it generates path dependency. How the central bank of China will achieve its target diversification rate during the transition period has an impact on the steady state values of the model. In other words, the transition path towards the diversification target influences its long-run equilibrium. Thus, in our model, the past influences the future, as the long run equilibrium will depend on both the moment T_2 when diversification will be applied as well as the pace at which the diversification target will be achieved. By contrast, in the model of Blanchard et al. (2005a, 2005b), where the steady state equilibrium depends on the starting point (in other words it depends on the choice of T_2), the past still depends on the future as the economy is presumed to evolve along a saddle point path.

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Appendix 1

Parameter values for simulations

$\alpha_{i,1}=0.8$ $\alpha_{i,2}=0.05$

$\theta_i=0.266304$ *(tax rate)*

$\lambda_{i,00}=0.2963$ $\lambda_{i,10}=0.1111$

$\lambda_{i,20}=0.1111$ $\lambda_{i,30}=0.1111$

$\lambda_{i,40}=0.3704$

$\lambda_{i,11}=0.6$ $\lambda_{i,12}=-0.2$

$\lambda_{i,13}=-0.2$ $\lambda_{i,14}=-0.2$

$\lambda_{i,21}=-0.2$ $\lambda_{i,22}=0.6$

$\lambda_{i,23}=-0.2$ $\lambda_{i,24}=-0.2$

$\lambda_{i,31}=-0.2$ $\lambda_{i,32}=-0.2$

$\lambda_{i,33}=0.6$ $\lambda_{i,34}=-0.2$

$\delta_i=0.1$ $\gamma_i=0.09$

$\kappa_i=2$

$\zeta_{i,1}=2.05$ $\zeta_{i,2}=1$

$\mu_{i0}=\mu_{i3}=-0.996$

$\mu_{i2}=\mu_{i5}=1.0$

$\mu_{i1}=\mu_{i4}=0.2$

$\tau=0.05$

Where i=1,2,3.

Appendix 2 Stock-flow matrices

Table 1

	the U.S.A.					Euroland					China					
Items	House-holds	Firms	Banks	Govern-ment	Central Bank	House-holds	Firms	Banks	Govern-ment	Central Bank	House-holds	Firms	Banks	Govern-ment	Centra Bankl	Sum
Tangible K		K1					K2					K3				$\sum K$
Cash	Hh1				-Hs1	Hh2				-Hs2	Hh3				-Hs3	0
Deposit	M1		-M1			M2		-M2			M3		-M3			0
Bill1	Bh1,1		Bcmb1,1	-B1	Bcb1,1	Bh2,1				Bcb2,1	Bh3,1				Bcb3,1	0
Bill2	Bh1,2				Bcb1,2	Bh2,2		Bcmb2,2	$-B_2$	Bcb2,2	Bh3,2				Bcb3,2	0
Bill3	Bh1,3					Bh2,3					Bh3,3		Bcmb3,3	-B3	Bcb3,3	0
Loan		-L1	L1				-L2	L2				-L3	L3			0
Advance													0		A3	0
Balance	-V1			-Vg1	0	-V2			-Vg2	0	-V3			-Vg3	-Vcb3	$-\sum V$
SUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2

Items	The U.S.						Euroland						China			
	Households	Firms		Banks	Government	Central Bank	Households	Firms		Banks	Government	Central Bank	Households	Firms		Banks
		Current	Capital					Current	Capital					Current	Capital	
CONSUMPTION	-C1	+C1					-C2	+C2					-C3	+C3		
Government expenditure		+G1			-G1			+G2			-G2			+G3		
Investment		+I1	-I1					+I2	-I2					+I3	-I3	
Import		IM1,2						IM2,1						IM3,1		
		IM1,3						IM2,3						IM3,2		
Export		EX1,2						EX2,1						EX3,1		
		EX1,3						EX2,3						EX3,2		
GDP		[Y1]						[Y2]						[Y3]		
WAGES	+W1	-W1					+W2	-W2					+W3	-W3		
Depreciation		-DA1	+DA1					0	0					0	0	
TAX	-T1				+T1		-T2				+T2		-T3			
Interest Payment	+r1*Bh1,1			+r1*Bcmb1,1	-r1*B1	+r1*BCb1,1	+r1*Bh2,1*E1					+r1*BCb2,1*E	+r1*Bh3,1*E2			
	+r2*Bh1,2/E1					+r2*BCb1,2/E1	+r2*Bh2,2			+r2*Bcmb2,2	-r2*B2	+r2*Bcb2,2	+r2*Bh3,2*E3			
	+r3*Bh1,3/E2						+r3*Bh2,3/E3						+r3*Bh3,3			
		-r1*L1		+r1*L1				-r2*L2		+r2*L2				-r3*L3		+r3*L3
																0
	+r1*M1			-r1*M1			+r2*M2			-r2*M2			+r3*M3			-r3*M3
Central Bank profit					+Fb1	-Fb1					+Fb2	-Fb2				
Changes in																
Loan			+ΔL1	-ΔL1					+ΔL2	-ΔL2					+ΔL3	-ΔL3
Advance																+ΔA3
Bank Deposit	-ΔM1			+ΔM1			-ΔM2			+ΔM2			-ΔM3			+ΔM3
Cash	-ΔHh1					+ΔHs1	-ΔHh2					+ΔHs1	-ΔHh3			
Bill1	-ΔBh1,1			-ΔBcmb1,1	+ΔB1	-ΔBcb1,1	-ΔBh2,1*E1					-ΔBcb21*E1	-ΔBh3,1*E2			
Bill2	-ΔBh1,2/E1					-ΔBcb1,2/E1	-ΔBh2,2			-ΔBcmb2,2	+ΔB2	-ΔBcb22	-ΔBh3,2*E3			
Bill3	-ΔBh1,3/E2						-ΔBh2,3/E3						-ΔBh3,3			-ΔBcmb3,3
SUM	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0