Dollar Hegemony and China’s Economy

Kai Liu†

Abstract: this paper models the US dollar as a global currency and focuses on the spillover effects of the US Quantitative Easing (QE) on China’s economy. Exchange rate targeting and capital controls in the context of dollar hegemony are investigated. Given a positive US money supply shock, both the inflation and real GDP of China will be below their steady state levels in the medium term; while for the US there is no inflation pressure. And the spillover of liquidity effect exists. Given that the US dollar’s hegemony is not weakened, the regime with liberalized capital accounts and an exchange rate peg to the US dollar for China is best for Chinese households under the US money supply shock. However, when the US dollar is no longer the global reserve currency but instead a supranational reserve currency replaces it, then for China this regime is the worst kind of reform, no matter whether or not the dollar standard in international trade is maintained.

Key words: US dollar, global currency, capital control, exchange rate, business cycle

JEL classification codes: E32, E42, E51, F31, F41, F44

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1. Introduction

On September 13\textsuperscript{th} of 2012, the Federal Reserve decided to launch a new $40 billion per month and open-ended bond purchasing program, which is called QE3, in order to stimulate the US economy. On December 12\textsuperscript{th} of 2012, the Federal Reserve announced an increase in the amount of open-ended purchases from $40 billion to $85 billion per month. Like QE1 and QE2, this unconventional monetary policy triggered fierce debates not only inside the US but also worldwide. One reason why people care so much about QE is that the US dollar serves as both the US national currency and a “world currency”. In spite of the rise of the Euro, the US dollar is the only one that could be regarded as a global currency.

Research on QE at least follows two dimensions. One is of domestic concern, to discuss this kind of unconventional monetary policy under the situation when the nominal interest rate reaches its zero lower bound. The other is of international concern, to study the spillover effects of the US QE on other economies, especially on developing countries.

The main question this paper explores is how the US money supply affects China’s business cycles. This is a question about the nature of money, specifically about the nature of the US dollar as a global currency. There is a consensus in macroeconomics: money is not neutral at least in the short run. This statement should not be confined in the context of a closed economy. Monetary policies within one country could influence, at least in the short run, the economy of another country at least through international trade and global financial markets. The monetary policies of the US, as the provider of a world currency and the biggest economy of the world, are supposed to have strong externalities on other economies. Those who are against the US QEs believe that the externality of the US QE is significantly negative on other economies. For example, QE rounds by the Federal Reserve are criticized by BRIC countries (Brazil, Russia, India and China). They share the view that such actions amount to protectionism and competitive devaluation. As net exporters whose currencies are partially pegged to the US dollar, they protest that it causes their inflation to rise and penalizes their industry.

The US money supply could influence the global economy in several ways. First of all, it has an impact on the US macro economy through channels such as the aggregate price level within the US, and the demand and interest rate of the US government bonds if the newly created US dollar is used to buy them. Since the global economy is linked through international trade and international financial markets, the fluctuation of the US economy will naturally affect other economies. Secondly, oil and many other important commodities in global markets are priced by the US dollar. Therefore, a sudden increase of the US money supply means dollar’s depreciation to some degree, which will lead to the fluctuations of commodity prices denominated in the US dollar. Given the existence of exchange rate targeting for some countries, international trade and then the global economy will be further influenced. Third, changes in the dollar’s value and many countries’ net exports and current accounts, caused by the change in the US money supply, will alter these countries’
holdings of dollar assets, such as the US government bonds, as their foreign exchange reserves. This consequently will again have impacts on the US domestic economy and the global economy. One should bear in mind that the channels above about how the US money supply affects the world economy are just first-round effects. There exist second-round and even third-round effects, since different economies are interdependent and closely linked.

Although the US dollar plays such an important role in the global economy, the US monetary authority adjusts the US monetary policies,\(^1\) such as the US money supply, only according to its national economic and financial conditions prevailing in the United States, not in the whole world. Schulmeister (2000) discusses the double role of the US dollar as both national currency and world currency and the relevant conflict between the need for stable monetary conditions for the world economy as a whole and the national monetary need inside the US. He argues that the most important events in postwar economic development ranging from the oil price shocks in the 1970s to the financial crises in Latin America in the 1980s and in East Asia in the late 1990s could be related to the US dollar’s double role. This kind of conflict generates some new questions for China’s economy: does an increase in the US money supply harm or benefit China’s economy? Does this kind of externality depend or not on the special institutional arrangements of China, such as exchange rate targeting and strict capital controls? Will this kind of externality be attenuated when China’ GDP share in the world becomes larger and larger? What is the scenario if the US dollar was not a world currency?

The conventional models on either a theoretical level or an empirical level cannot provide a suitable framework to explore the above questions. As Dees et al. (2010) criticize, the existing open-economy DSGE literature has tended to use either models for two economies of comparable size, such as the euro area and the US (as in de Walque et al., 2005), or small open-economy models where the rest of the world is treated as exogenous and there is no interactions between them. Given the questions this paper is concerned with, we need a multi-country framework in which China has different institutional arrangements from both the US and the rest of the world, the US dollar plays special roles of a world currency and is different from other economies’ currencies, and also the interactions across economies should be allowed. On an empirical level, global VAR (GVAR) models can be employed to examine the international transmission of shocks, with global linkages incorporated. However, it has proved difficult to use such reduced multi-country VARs to examine the effects of structural shocks with clear economic interpretation, since the model itself is not micro-founded. The way the GVAR literature deals with the global linkages is also skeptical. Specifically, using trading weights to weight foreign financial variables such as interest rate is problematic, because international finance behaves in a quite different manner from that for international trade. Therefore, in this paper I will

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\(^1\) For the spillover effects of other US monetary policy shocks such as nominal interest rate shock on other economies there are at least three strands of literature. One is to use small open economy DSGE models, such as Uribe and Yue (2006) and Chang et al. (2013); the second is to use GVAR models, such as Pesaran, Schuermann and Smith (2009); and the last is to use other econometric tools, for example, structural VAR, such as Mackowiak (2007).
develop a multi-country New Keynesian DSGE model in which the interactions among different economies of different sizes are sufficiently taken into account, the US dollar is modeled as a global currency, and different institutional arrangements for different economies will also be considered.

There are some researches empirically examining the international impact of the US money supply on some specific country, even though they are not global discussions. Farrell (1980) examines the international impact of the US money supply on the economy of Mexico and advises the Mexico’s policymakers to keep an eye on the course of the US money supply. Bailey (1989) studies the effects of weekly U.S money supply releases on the Canada’s financial markets and finds that Canadian stock index, bond prices and short-term interest rate change with surprises in the announced level of U.S. M1.

Another kind of literature focuses on the effects of the US money supply announcements or QE on the financial markets inside and beyond the United States. They usually use high-frequency intraday data. Bailey (1990) examines the responses of equity values across Pacific Rim countries to the US M1 announcement surprises and finds that the stock market’s response to the US M1 is better explained by the country’s degree of financial integration than real economic integration (through international trade) with the United States. Neely (2010) evaluates the effect of large-scale asset purchases (LSAP) on international long-term bond yields and exchange rates, and gets the result that the LSAP announcements substantially reduces international long-term bond rates and the spot value of the dollar.

This paper builds a multi-country New Keynesian global DSGE model with a world currency. In the benchmark model, three asymmetric economies have different institutional arrangements and interact with each other. The US dollar serves as a world currency and the US national currency as well, and China’s economy is featured with Chinese characteristics such as capital controls, compulsory exchange settlement and sales, and an exchange rate peg. The global DGSE model finds the following results: when a positive US money supply shock hits the global economy, the nominal interest rate of China will be lowered (the spillover of liquidity effect); in the medium term both China’s real output and its inflation rate are below the steady state levels; and both the terms of trade and nominal net exports for China will be pushed up on impact, but be below their steady state levels in the medium term. Several kinds of sensitivity analysis are implemented, and the above results are robust. Cost-push effects and relative price effects are employed to discuss the transmission mechanism. Welfare calculations for the benchmark model show that a positive 10% US money supply shock will result in a positive 1.25% welfare gain (as a fraction of the steady state consumption) for Chinese households, a positive 0.06% welfare gain for the US, but a 0.21% welfare loss for the rest of the world.

I also examine the relationship between the persistence of a US money supply shock and its influence on China’s economy. The more persistent the US money supply shock is, the larger the responses of China’s aggregate variables would be. It is also found that: the response of China’s economy to the US money supply shock will not become smaller when the share of China’s GDP in the global economy becomes
larger (even when it is the double of the US GDP), as long as the US dollar remains as the world currency and there is no reform to China’s institutional arrangements.

Counterfactual analyses are implemented in two ways: to reform China’s institutional arrangements or to weaken the global roles of the US dollar. For China’s liberalization reform, three cases are considered: a partial lifting of capital controls with maintenance of the exchange rate peg, allowing the exchange rate of Renminbi to float while keeping the capital account closed, and the full liberalizing reform. For weakening the US dollar’s global roles, I assume the dollar pricing in international trade is replaced by producer currency pricing (PCP), or assume there is another international bond to replace the US bonds as the global reserve asset. Given that the US dollar’s hegemony is not weakened, the regime with liberalized capital accounts and an exchange rate pegged to the US dollar for China is best for Chinese households under the US money supply shock. However, when the US dollar is no longer the global reserve currency but instead a supranational reserve currency replaces it, then for China this regime is the worst kind of reform, no matter whether or not the dollar standard in international trade is maintained. For China, to maintain the status quo (nominal exchange rate targeting and capital controls) cannot always achieve the first best, but can guarantee a second best under the US money supply shock. When the US dollar serves only as the domestic currency for the US, then for China a floating exchange rate regime or a regime with Renminbi pegged to the supranational currency can make China’s economy nearly unaffected by the US money supply shock, no matter whether or not its capital account is opened.

The recent global financial and economic crisis has generated a renewed interest in the implications of capital controls and exchange rate pegs, especially for emerging countries. Since it is not clear that financial integration can reduce macroeconomic fluctuations, under certain conditions capital controls or a fixed exchange rate regime may be preferred by policy makers. Farhi and Werning (2012) argue that capital controls can alleviate the influence of excess international capital movements triggered by risk premium shocks. Our paper could provide some insight for Chinese policy makers for their consideration of capital control policies as well as exchange rate reforms, particularly when the effects of the US money supply shock should not be ignored.

The rest of this paper is arranged as follows: Section 2 provides some stylized facts, based on which some assumptions will be made for the benchmark model of this paper; in Section 3 I build the benchmark model; Section 4 and 5 are the calibration and impulse response analysis of the benchmark model; in Section 6 and 7 I implement some counterfactual analyses and do the welfare comparison; finally I conclude.

2. Some stylized facts

Before the building of the theoretical model, I need to clarify some stylized facts, which will justify some assumptions of the benchmark model and can give some hints about our final results as well.
Krugman (1984) lists and explains the six roles of the US dollar as an international currency in detail: medium of exchange, unit of account and store of value for both private sector and central banks. Goldberg (2010) suggests that in spite of the emergence of the Euro, changes in the dollar’s value, and the fact that the financial market crisis has posed a significant challenge to the dollar’s long-standing position in world markets, the US dollar has retained its standing in key roles, according to an empirical study of the dollar across critical areas of international trade and finance. Galati and Wooldridge (2006) tell a similar story.

A. The US dollar is the central invoicing currency for international trade.

The New Open Economy Macroeconomics (NOEM) literature after Obstfeld and Rogoff (1995) usually assumes that the prices of traded goods are rigid in the currency of producers: firms set export prices in domestic currency, letting the foreign price of their product vary with the exchange rate. This hypothesis is called producer currency pricing (PCP), under which exchange rate pass-through on import prices is complete. However, the PCP assumption is questioned by another strand of the literature, such as Betts and Devereux (2000), taking a different view that firms preset prices in domestic currency for the domestic market and in foreign currency for the market of export destination. This hypothesis is called local currency pricing (LCP), under which exchange rate pass-through is zero for a firm not re-optimizing its price.

<table>
<thead>
<tr>
<th>Country</th>
<th>Observation year</th>
<th>US dollar share in export invoicing</th>
<th>US dollar share in import invoicing</th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>2003</td>
<td>99.8%</td>
<td>92.8%</td>
</tr>
<tr>
<td>Japan</td>
<td>2001</td>
<td>52.4%</td>
<td>70.7%</td>
</tr>
<tr>
<td>Korea</td>
<td>2001</td>
<td>84.9%</td>
<td>82.2%</td>
</tr>
<tr>
<td>Australia</td>
<td>2007</td>
<td>74.3%</td>
<td>52.0%</td>
</tr>
<tr>
<td>UK</td>
<td>2002</td>
<td>26.0%</td>
<td>37.0%</td>
</tr>
</tbody>
</table>

Source: Devereux et al. (2010).

But in reality the dollar pricing is widely used. Goldberg and Tille (2008) show that: the dollar is overwhelmingly used for invoicing both export and import prices for the US economy and other economies. Table 1 presents some data regarding the US dollar invoicing in overall trade flows for selected countries. Another empirical finding of international trade is that exports of primary commodities, including oil, are substantially priced in the US dollar. Devereux et al. (2010) point out: among 81 raw material price series published by the UNCTAD, only 5 are not dollar denominated; in the construction of the Rogers International Commodities Index, only 5 out of 35 commodity contracts comprising the index are not denominated in the US dollar, and the weighting of non-dollar denominated commodity in the index is only 2.02%. Devereux et al. (2010) build a model and show that a dollar standard in international trade is the equilibrium of firms’ choices, given some reasonable assumptions.
Goldberg and Tille (2009) use a simple center-periphery model to show that the US dollar’s global role as the dominant international trade invoicing currency magnifies the exposure of periphery countries to the US monetary policy shock, even when their trade flows with the US are limited.

B. The US dollar plays a prominent role in the portfolios of foreign exchange reserve accounts.

Figure 1 depicts the currency composition of official foreign exchange reserves from 1999 when the euro was created. The US dollar and the euro together make up above 85% of official foreign exchange reserves globally, while the former is always above 60% and more than double of the latter. Due to the euro crisis in 2009, the share of the euro reserves declined from 27.7% to 23.7% in 2013. Meanwhile, the share of the US dollar reserves was quite stable.

![Figure 1. Currency composition of official foreign exchange reserves (in percent)](image)
(Data source: IMF Statistics Department COFER database and International Financial Statistics\(^2\))

Besides the above two stylize facts, the dollar is a leading transaction currency in the foreign exchange markets as well. With about 86% share of foreign exchange transaction volume—more than twice the share of the euro—the US dollar continues to dominate these markets (Goldberg, 2010).

Generally speaking, the US dollar has still been playing a central and dominant role in international trade and finance as both a store of value and a medium of exchange, and no other currencies rival it. The US dollar is the only currency that can be viewed as a global currency in the world economy. Therefore, in the following global DSGE model, the US dollar plays two key roles as the global currency: the only invoicing currency for international trade and the only foreign exchange reserve currency.

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C. Foreign exchange reserves are now the major component of the total assets on the balance sheet of China’s central bank.

Figure 2 shows the foreign exchange reserves as a share of total assets for the People’s Bank of China (PBOC). Before 2003 this share was below 50%, but after 2009, the share of foreign reserves was stably around 80%. Due to continuous large trade surplus, strict capital controls and compulsory exchange settlement and sales, the expansion of the PBOC’s balance sheet is mainly achieved by absorbing foreign capital inflows and accumulating foreign exchange reserves, primarily dollar reserves. Although the capital control for China is not as strict as before, and after 2008 China has abandoned the system of compulsory exchange settlement and sales, in reality Chinese households are still not completely free to buy foreign assets and they also are not willing to do so currently because of the significant difference between home and foreign interest rates.

![Figure 2. Foreign reserves as a share of total assets for PBOC](Data source: People’s Bank of China. The value for 2013 is based on the data up to August.)

Therefore, in the benchmark model below, I assume for China that there are strict capital controls and compulsory exchange settlement and sales, Chinese households are prohibited from holding foreign assets, and firms are required to swap their foreign-currency revenues (if there are any) with the central bank for domestic currency. Thus if there is a positive current account for China, the money supply of Chinese currency will be passively expanded. And given the stylized facts A and B above, the PBOC is assumed to use all the absorbed US dollars to buy the US government bonds. In other papers such as Chang et al. (2013), a concept “sterilization” is discussed, which means that a subset of the central bank’s purchase of foreign assets can be financed by selling domestic bonds and then does not result in an expansion of domestic money supply. Bacchetta et al. (2013) study, in a semi-open economy where the central bank has access to international capital markets but the private sector does not, the optimal policy of the central bank when they can choose
the levels of both international reserves and domestic public debt. Considering the reality of China, especially the huge share of foreign reserves in the PBOC’s balance sheet, I do not take into account the central bank’s sterilization activity in the benchmark model.

D. In the post-crisis period the expansion of the US monetary base is almost entirely achieved by the Federal Reserve’ buying of the US Federal government’s debt.

Figure 3 depicts the evolving paths of the US monetary base and the US Federal debt held by the Federal Reserve.

![Figure 3. US monetary base and Federal debt held by Federal Reserve (billion $)](Data source: Federal Reserve Bank of St. Louis)

There was a jump for the US monetary base in the third quarter of 2008. After that, the US monetary base expanded from 1693 billion dollars to 3218 billion (a total 1525 billion increase), while the US Federal debt held by the Federal Reserve increased from 476 billion to 1937 billion (a total 1461 billion increase). So nearly the entire expansion of the US monetary base is achieved by the Federal Reserve’ QE operations. To reflect this kind of money creation feature of the US and also to simplify the model, in the benchmark model I assume that a US money supply shock is accompanied by an equal amount of change to the Federal Reserve’ holdings of the US government bonds.

3. Benchmark model

Three economies are under consideration: China, US and ROW (rest of the world), among which China is viewed as the home country. The US dollar serves as a global currency with two roles: there is a dollar standard in international trade and the US dollar is the only currency for foreign exchange reserve. The linkages through
international trade and international finance will be endogenized. First of all, Table 2 below lists the institutional arrangements for each economy in our benchmark model.

<table>
<thead>
<tr>
<th>Economy</th>
<th>Exchange rate regime</th>
<th>Capital control</th>
<th>Exchange settlement and sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>Pegging dollar</td>
<td>Yes</td>
<td>Compulsory</td>
</tr>
<tr>
<td>US</td>
<td>Global currency</td>
<td>No</td>
<td>Not compulsory</td>
</tr>
<tr>
<td>ROW</td>
<td>Floating</td>
<td>No</td>
<td>Not compulsory</td>
</tr>
</tbody>
</table>

3.1. China’s economy

3.1.1. Households

There is a continuum of infinitely-living households. A representative household seeks to maximize his life time utility:

\[ U_0 = E_0 \sum_{t=0}^{\infty} \beta^t \left[ \ln C_t - \phi_1 \cdot \frac{(L_t)^{1+\eta}}{1+\eta} + \phi_2 \cdot \ln \left( \frac{M_t}{P_t} \right) \right] \]

where \( E \) is the expectation operator, \( \beta \) is the utility discount factor, \( \phi_1 \) and \( \phi_2 \) are the utility weights for labor supply \( L_t \) and real money balance \( M_t/P_t \), \( P_t \) is the aggregate price level of final goods, and real consumption is \( C_t \).

The representative household can invest in two assets: real capital \( K_t \) which is used as a production factor with real rental rate \( r_t \) and domestic government bond \( B_t \) with nominal interest rate \( R_t \). Since there are capital controls, Chinese households are not allowed to hold foreign assets in the benchmark model. Due to the monopolistic power of the intermediate-goods firms of the economy, nominal profit \( D_t \) is generated and then distributed to households. The government collects nominal lump-sum tax \( T_t \) from households. Therefore, the budget constraint for the representative household is:

\[ P_t \cdot C_t + P_t \cdot K_{t+1} + B_{t+1} + T_t + M_t \leq (1 - \delta + r_t) \cdot P_t \cdot K_t + W_t \cdot L_t + (1 + R_{t-1}) \cdot B_t + D_t + M_{t-1} \]  

where \( \delta \) is the capital depreciation rate, and \( W_t \) is the nominal wage rate.

3.1.2. Final good producers and price indices

Final good producers first produce home good \( Y_{H,t} \) by combining a continuum of home-made intermediate goods \( Y_{H,t}(i) \), and foreign good \( Y_{F,t} \) by combining a continuum of imported foreign intermediate goods \( Y_{f,t}(i) \) (\( j = US \) or \( ROW \)); and then combine home good and foreign good to produce the final good \( Y_t \), which can be used for households’ consumption, capital investment and government’s expenditure.

The final good producers are perfectly competitive. The technologies of producing home and foreign good, and then final good are all CES technologies:
\[ Y_{H,t} = \left[ \int_0^1 Y_{H,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} \, di \right]^{\frac{\varepsilon}{\varepsilon-1}} \]  

(2)

\[ Y_{F,t} = \left[ (1 - \rho_2)^{\frac{1}{\xi}} \cdot Y_{ROW,t}^{\frac{\xi-1}{\xi}} + \rho_2^{\frac{1}{\xi}} \cdot Y_{US,t}^{\frac{\xi-1}{\xi}} \right]^{\frac{\xi}{\xi-1}} \]  

(3)

\[ Y_{US,t} = \left[ \int_0^1 Y_{US,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} \, di \right]^{\frac{\varepsilon}{\varepsilon-1}} \]  

(4)

\[ Y_{ROW,t} = \left[ \int_0^1 Y_{ROW,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} \, di \right]^{\frac{\varepsilon}{\varepsilon-1}} \]  

(5)

\[ Y_t = \left[ (1 - \rho_1)^{\frac{1}{\omega}} \cdot Y_{H,t}^{\frac{\omega-1}{\omega}} + \rho_1^{\frac{1}{\omega}} \cdot Y_{F,t}^{\frac{\omega-1}{\omega}} \right]^{\frac{\omega}{\omega-1}} \]  

(6)

where \( i \) represents the brand of intermediate goods, \( j (= US \text{ or } \text{ROW}) \) is the country index, \( Y_{j,t} \) is the foreign goods bundle from country \( j \), \( \varepsilon \) denotes the elasticity of substitution between the differentiated intermediate goods within one single country, \( \xi \) measures the substitutability between goods produced in two foreign countries, \( \omega \) represents the elasticity of substitution between domestic and foreign goods, \( \rho_1 \) refers to the share of domestic aggregate demand allocated to foreign goods and is thus a natural index of openness of the Chinese economy, and \( \rho_2 \) indicates the import share from US.

**Table 3. Price system of the benchmark model**

<table>
<thead>
<tr>
<th>Economy</th>
<th>Domestically sold goods</th>
<th>Export goods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intermediate bundle</td>
<td>Intermediate bundle</td>
</tr>
<tr>
<td>China</td>
<td>( P_{H,t}(i) )</td>
<td>( P_{H,t}^E(i) )</td>
</tr>
<tr>
<td>US</td>
<td>( P_{US,t}^S(i) )</td>
<td>( P_{US,t}^E(i) )</td>
</tr>
<tr>
<td>ROW</td>
<td>( P_{ROW,t}^R(i) )</td>
<td>( P_{ROW,t}^E(i) )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Invoicing currency</th>
<th>Invoicing currency</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>Renminbi</td>
<td>Dollar</td>
</tr>
<tr>
<td>US</td>
<td>Dollar</td>
<td>Dollar</td>
</tr>
<tr>
<td>ROW</td>
<td>Ro</td>
<td>Dollar</td>
</tr>
</tbody>
</table>

Then given the price levels of goods (described in Table 3), the cost minimization problem of the representative final good producer yields the following demand functions:

\[ Y_{H,t}(i) = \left( \frac{P_{H,t}(i)}{P_{H,t}} \right)^{-\frac{\varepsilon}{\varepsilon-1}} \cdot Y_{H,t} \]  

(7)

\[ Y_{US,t}(i) = \left( \frac{P_{US,t}^E(i)}{P_{US,t}^E} \right)^{-\frac{\varepsilon}{\varepsilon-1}} \cdot Y_{US,t} \]  

(8)

\[ Y_{ROW,t}(i) = \left( \frac{P_{ROW,t}^E(i)}{P_{ROW,t}^E} \right)^{-\frac{\varepsilon}{\varepsilon-1}} \cdot Y_{ROW,t} \]  

(9)

\[ Y_{US,t} = \rho_2 \cdot \left( \frac{P_{US,t}^E}{P_{US,t}} \right)^{-\frac{\xi}{\xi-1}} \cdot Y_{F,t} \]  

(10)
\[ Y_{ROW_t} = (1 - \rho_2) \cdot \left( \frac{P_{ROW_t}^E}{P_{F,t}^g} \right)^{-\xi} \cdot Y_{F,t} \] (11)

\[ Y_{H,t} = (1 - \rho_1) \cdot \left( \frac{P_{H,t}^E}{P_t} \right)^{-\omega} \cdot Y_t \] (12)

\[ Y_{F,t} = \rho_1 \cdot \left( \frac{P_{F,t}^E \cdot EX_t}{P_t} \right)^{-\omega} \cdot Y_t \] (13)

where \( P_{F,t}^g \) is the aggregate price of foreign goods for China, denominated in US dollar; and \( EX_t \) is the exchange rate of RMB.

Since the final good producers are perfectly competitive and there is no profit for them, we can easily derive the following price index formulas:

\[ P_{H,t} = \left[ \int_0^1 P_{H,t}(i)^{1-\varepsilon} di \right]^{\frac{1}{1-\varepsilon}} \] (14)

\[ P_{US,t}^E = \left[ \int_0^1 P_{US,t}^E(i)^{1-\varepsilon} di \right]^{\frac{1}{1-\varepsilon}} \] (15)

\[ P_{ROW,t}^E = \left[ \int_0^1 P_{ROW,t}^E(i)^{1-\varepsilon} di \right]^{\frac{1}{1-\varepsilon}} \] (16)

\[ P_{F,t}^g = \left[ (1 - \rho_2) \cdot P_{ROW,t}^E \cdot \xi + \rho_2 \cdot P_{US,t}^E \cdot \xi \right]^{\frac{1}{1-\xi}} \] (17)

\[ P_t = \left[ (1 - \rho_1) \cdot P_{H,t}^E \cdot \omega + \rho_1 \cdot (P_{F,t}^g \cdot EX_t)^{1-\omega} \right]^{\frac{1}{1-\omega}} \] (18)

In this paper it is assumed that three elasticities of substitution, \( \varepsilon, \xi, \) and \( \omega \), are the same across economies. Therefore, similarly we have the following expression:

\[ P_{H,t}^g = \left[ \int_0^1 P_{H,t}^E(i)^{1-\varepsilon} di \right]^{\frac{1}{1-\varepsilon}} \]

Then the terms of trade for China’s economy can be defined as below:

\[ TOT_t = \frac{P_{F,t}^g}{P_{H,t}^E} \] (19)

### 3.1.3. Intermediate-goods firms and prices setting

Intermediate goods market is monopolistically competitive. Firm \( i \) produces a differentiated intermediate good \( i \) with a Cobb-Douglas production function:

\[ Y_t(i) = a_t \cdot K_t(i)^{1-\alpha} \cdot [L_t(i)]^\alpha \]

where a temporary productivity shock \( a_t \) follows the following stochastic process:

\[ \ln a_t = \rho \ln a_{t-1} + v_t^a \sim N(0, \sigma^2_a) \]

Intermediate-goods firms need to set prices. The price of domestically sold goods is denominated in Renminbi, while the export price is set in US dollar. As the same logic for PCP explained in Corsetti et al. (2011), firms will optimally choose identical prices for both their ROW and US markets, since demand elasticities for intermediate goods are assumed to be constant and symmetric across countries in this paper, which is \( \varepsilon \). This is why in our benchmark model the same exported good from one country to different destinations have only one price. Following Calvo (1983), each
intermediate-goods firm may re-optimize its nominal prices, for both domestically
sold and export, only with probability $1 - \theta$ in any given period.

The price-resetting firm sets prices $(P_{H,t}^S$ and $P_{H,t}^E)^3$ to maximize the current
market value of the profits generated while that price remains effective:

$$
\max_{\{P_{H,t}^S, P_{H,t}^E\}} \sum_{k=0}^{\infty} \theta^k \cdot \mathbb{E}_t \left\{ F_{t,t+k} \cdot \left[ P_{H,t}^S \cdot Y_{t+k\mid t}^D + P_{H,t}^E \cdot E_{t+k\mid t}^F - \Phi_{t+k}(Y_{t+k\mid t}) \right] \right\}
$$

subject to the sequence of demand constraints:

$$
\begin{align*}
Y_{t+k\mid t} &= Y_{t+k\mid t}^D + Y_{t+k\mid t}^F \\
Y_{t+k\mid t}^D &= \left[ \frac{P_{H,t}^S}{P_{H,t+k}^S} \right]^{-\epsilon} \cdot Y_{t+k}^D \\
Y_{t+k\mid t}^F &= \left[ \frac{P_{H,t}^E}{P_{H,t+k}^E} \right]^{-\epsilon} \cdot Y_{t+k}^F
\end{align*}
$$

where $F_{t,t+k}$ is the discount factor for nominal payoffs; $\Phi_{t+k}$ is the nominal cost
function; $Y_{t+k\mid t}$ denotes output in period $t + k$ for a firm that last freely reset its
price in period $t$, which equals domestic demand $Y_{t+k\mid t}^D$ plus foreign demand $Y_{t+k\mid t}^F$;
and $Y_{t+k}^D$ and $Y_{t+k}^F$ are respectively the total domestic and foreign demand for
made-in-China goods.

The discount factor for nominal payoffs, $F_{t,t+k}$, can be defined as follows:

$$
F_{t,t+k} \triangleq \frac{1}{1 + R_t} = \prod_{i=0}^{k-1} F_{t+i,t+i+1} = \prod_{i=0}^{k-1} \frac{1}{1 + R_{t+i}}
$$

In the zero-growth and zero-inflation steady state, $E_{t+k\mid t} = E_{t+k \mid t} = EX_t = EX$,
$P_{H,t}^S = P_{H,t}$, $P_{H,t}^E = P_{H,t}$, and LOOP holds as well: $P_{H,t}^S = P_{H,t}^E \cdot E_{t+k \mid t}$. At the steady
state the relative prices of foreign goods, $P_{H,t}^E \cdot E_{t+k \mid t} / P_{H,t}^S = \tau_t^{US}$ and
$P_{H,t}^E \cdot E_{t+k \mid t} / P_{H,t}^S = \tau_t^{ROW}$, will be constant numbers, $\tau_t^{US}$ and $\tau_t^{ROW}$ respectively. Then the price
setting problem will yield the following result:

$$
\begin{align*}
\ln P_{H,t}^S - \ln P_{H,t-1} &= \beta \cdot \theta \cdot \mathbb{E}_t \left( \ln P_{H,t+1}^S - \ln P_{H,t} \right) + \\
(1 - \beta \cdot \theta) \cdot (\bar{mc}_t + \ln P_t - \ln P_{H,t}) + \Pi_{H,t} \\
\ln P_{H,t}^E - \ln P_{H,t-1} &= \beta \cdot \theta \cdot \mathbb{E}_t \left( \ln P_{H,t+1}^E - \ln P_{H,t} \right) + \\
(1 - \beta \cdot \theta) \cdot (\bar{mc}_t + \ln P_t - \ln E_{t+k} - \ln P_{H,t}^E) + \Pi_{H,t}^E
\end{align*}
$$

(20)

where $\bar{mc}_t = \ln(mc_t) - \ln(mc)$ is the log deviation of real marginal cost from its
steady state value $mc$, and $mc = (\epsilon - 1)/\epsilon$; $\Pi_{H,t} \triangleq \ln P_{H,t} - \ln P_{H,t-1}$ and
$\Pi_{H,t}^E \triangleq \ln P_{H,t}^E - \ln P_{H,t-1}$ are respectively the home-made goods’ inflation rates for
domestic price and export price.

And around the steady state, equations (18) and (19) together can imply that:

$$
\ln P_t = \ln P_{H,t} + \phi \cdot (\text{tot}_t + x_t)
$$

(21)

where $\phi \triangleq 1 - \frac{1 - \rho_1}{(1 - \rho_1 + \rho_1(TOT)\tau^{TOT})^{1-\omega}}$; $\text{tot}_t \triangleq \ln(TOT_t/TOT)$ and $x_t \triangleq \ln(P_{H,t}^E \cdot E_{t+k} / \text{tot}_t)$

---

3 As in the literature of Calvo pricing, all firms resetting prices will choose identical prices, namely $P_{H,t}^S(i) \equiv P_{H,t}^S$ and
$P_{H,t}^E(i) \equiv P_{H,t}^E$.

4 In equation (21) and hereafter for any log-linearized equation, a constant term is omitted.
\( P_{H,t} \) can be called terms of trade gap and LOOP gap respectively, which are the log deviations from their corresponding steady state values.

### 3.1.4. Dollar pricing, PCP, LCP and open-economy NKPC

In a two-country model, dollar pricing is equivalent to that PCP is assumed for one country and LCP for the other. In the three-country model of this paper, for US it is always PCP, for ROW it can be viewed as a partial LCP, and for China it is essentially PCP under the fixed exchange rate regime and a partial LCP under the flexible exchange rate regime. To unify the analysis, I begin with the most general context.

Equation (21), together with equation (20), will give the following open-economy New-Keynesian Phillips curve (NKPC):

\[
P_{H,t} = \beta \cdot E_t (P_{H,t+1}) + \frac{(1-\theta)(1-\beta-\theta)}{\theta} \cdot \{m\bar{c}_t - \phi \cdot (t\bar{t}_t + x_t)\}
\]  

(22)

Similarly, we can have another NKPC for export price:

\[
P_{H,t}^E = \beta \cdot E_t (P_{H,t+1}^E) + \frac{(1-\theta)(1-\beta-\theta)}{\theta} \cdot \{m\bar{c}_t - x_t + \phi \cdot (t\bar{t}_t + x_t)\}
\]

(23)

For the benchmark setting with China’s fixed exchange rate regime, the pricing mechanism of China’s firms is in fact PCP. Under PCP, firms will optimally choose identical prices for both their domestic and export markets, and the LOOP will hold independently of barriers to markets integration. Therefore, \( x_t \equiv 0 \), and one NKPC, equation (23), should be replaced by the following LOOP condition:

\[ P_{H,t}^E \cdot EX = P_{H,t} \]

When China adopts a flexible exchange rate regime, equation (23) applies.

### 3.1.5. Equilibrium and aggregation

Government bond (or debt) \( B_t \) evolves according to:

\[ B_{t+1} = (1 + R_{t-1}) \cdot B_t + G_t - T_t \]

where \( G_t \) is nominal government spending. For labor market and capital market, we have the following market clearing conditions:

\[ L_t = \int_0^1 L_t(i) \, di \]

\[ K_{t+1} = \int_0^1 K_t(i) \, di = (1 - \delta) \cdot K_t + I_t \]

Real GDP of China is defined as:

\[ GDP_t \equiv \left[ \int_0^1 Y_t(i) \cdot \frac{\epsilon - 1}{\epsilon} \, di \right]^{\frac{\epsilon}{\epsilon - 1}} \]

And we also have the following aggregate demand equation:

\[ Y_t = C_t + I_t + G_t/P_t \]

The market clearing condition for each intermediate good is:

\[ Y_t(i) = Y_{H,t}(i) + Y_{H,t}^{US}(i) + Y_{H,t}^{ROW}(i) \]

(24)

where \( Y_{H,t}(i) \) is the demand of home-made intermediate good \( i \) from country \( j \). According to equation (7)-(13) and their counterparts for US and ROW economies,
equation (24) is equivalent to the following:

\[
\ln GDP_t = \frac{(1 - \rho_1)\tau^{\omega \cdot Y}}{\text{GDP}} \cdot \left[ \ln Y_t + \omega \cdot \varphi \cdot (\text{tot}_t + x_t) \right] \\
+ \frac{\rho_2^US \cdot \rho_1^US \cdot \tau^{\omega \cdot Y \cdot US}}{\text{GDP}} \cdot \left[ \ln Y_t^{US} - \xi \cdot (1 - \tau_5) \cdot \left( \ln P_{H,t}^E - \ln P_{ROW,t}^E \right) \right] \\
- \omega \cdot \left( 1 - \varphi^{US} \right) \cdot (\text{tot}^{US}_t + x_t^{US}) \\
+ \frac{\rho_2^{ROW} \cdot \rho_1^{ROW} \cdot \tau^{\omega \cdot Y \cdot ROW}}{\text{GDP}} \cdot \left[ \ln Y_t^{ROW} - \xi \cdot (1 - \tau_6) \cdot \left( \ln P_{H,t}^E - \ln P_{US,t}^E \right) \right] \\
- \omega \cdot \left( 1 - \varphi^{ROW} \right) \cdot (\text{tot}^{ROW}_t + x_t^{ROW})
\] (25)

where \( \rho_j^1 \) and \( \rho_j^2 \), and \( Y^j_t \) are respectively the degree of openness parameters and aggregate demand of country \( j (= \text{US or ROW}) \); \( EXR_t \) is the exchange rate for the currency \( RO \) (US dollar to \( RO \)); variables without subscript \( t \) mean steady state values; \( \text{tot}^j_t \) and \( x^j_t \) are respectively the terms of trade gap and LOOP gap for country \( j \); \( \varphi^{US} \) and \( \varphi^{ROW} \) are defined similarly to \( \varphi \); constants \( \tau_1, \tau_2, \tau_3, \tau_4, \tau_5, \) and \( \tau_6 \) are determined by steady state price ratios \( (\tau^{US} \) and \( \tau^{ROW} \)) and given below:

\[
\tau_1 \triangleq \left[ \rho_2^{US} + (1 - \rho_2^{US}) \cdot \left( \tau^{ROW} \right)^{1-\xi} \right]^{\frac{1}{1-\xi}} \\
\tau_2 \triangleq \left[ \rho_1^{US} + (1 - \rho_1^{US}) \cdot (\text{TOT}^{US})^{-1-\omega} \right]^{\frac{1}{1-\omega}} \\
\tau_3 \triangleq \left[ \rho_2^{ROW} + (1 - \rho_2^{ROW}) \cdot \left( \tau^{US} \right)^{1-\xi} \right]^{\frac{1}{1-\xi}} \\
\tau_4 \triangleq \left[ \rho_1^{ROW} + (1 - \rho_1^{ROW}) \cdot (\text{TOT}^{ROW})^{-1-\omega} \right]^{\frac{1}{1-\omega}} \\
\tau_5 \triangleq \rho_2^{US} / \rho_2^{US} \cdot \left[ \rho_2^{US} + (1 - \rho_2^{US}) \cdot \left( \tau^{ROW} \right)^{1-\xi} \right] \\
\tau_6 \triangleq \rho_2^{ROW} / \rho_2^{ROW} \cdot \left[ \rho_2^{ROW} + (1 - \rho_2^{ROW}) \cdot \left( \tau^{US} \right)^{1-\xi} \right]
\]

### 3.1.6. The external sector, current account and Central Bank’s balance sheet

As China’s capital account is closed, the private sector is not allowed to hold foreign assets. Instead, exporters swap their US dollar proceeds for domestic currency (RMB), and importers swap Renminbi for US dollar, with the Central Bank (PBOC) at par market values. If there is a trade surplus, then Central Bank will increase the supply of Renminbi, and use the net inflow of US dollar to buy more US government bonds. Then for the US economy, money supply is not changed, while the demand for its government bond is increased.

Nominal net export of China, \( NNX_t \), is denominated in US dollar and defined as:

\[
NNX_t \triangleq p_{H,t}^E \cdot \left( Y_{H,t}^{US} + Y_{H,t}^{ROW} \right) - p_{F,t}^E \cdot Y_{F,t}
\]

Then GDP deflator, \( Def_t \), can be defined as:

\[
Def_t \triangleq (P_t \cdot Y_t + NNX_t \cdot EX_t) / GDP_t
\]

The nominal profit coming from monopolistic competition is:

\[
D_t = Def_t \cdot GDP_t - W_t \cdot L_t - P_t \cdot K_t \cdot \tau_t
\]

Combining the above equation with the budget constraint of the representative household, equation (1), we can get the national account identity as follows:

\[
Def_t \cdot GDP_t = P_t \cdot C_t + P_t \cdot I_t + G_t + (M_t - M_{t-1})
\]

As we will see in equation (29), nominal money growth, \( M_t - M_{t-1} \), is actually equal
to the nominal net export denominated in Renminbi.

Given the relationships between aggregate demand of one economy and its components, nominal net export of China $NNX_t$ then can be expressed as below:

$$NNX_t = \frac{p_{F,t}^E}{p_{F,t}^E} \cdot \left[ \rho_2^U \cdot \frac{p_{H,t}^E}{p_{F,t}^E} \cdot \rho_1^U \cdot \frac{p_{US,F,t}^E}{p_{US,t}^E} - \rho_1^U \cdot \frac{p_{US,F,t}^E}{p_{US,t}^E} \cdot y_t^U + \rho_2^R \cdot \frac{p_{F,t}^E}{p_{F,t}^E} \cdot \rho_1^R \cdot \frac{p_{ROW,t}^E}{p_{ROW,t}^E} \cdot y_t^R \right]$$

where $p_{F,t}^E, p_{F,t}^j, \text{ and } y_t^j$ are respectively foreign good price, aggregate price, and aggregate demand of country $j (= \text{US or ROW}); \rho_1^j$ and $\rho_2^j$ are the country $j$’s degree of openness parameters; and $EXR_t$ is the exchange rate for the currency $RO$ (US dollar to $RO$). So the steady state value of nominal net export, $NNX$, is:

$$NNX = \frac{p_{F,t}^E}{p_{F,t}^E} \cdot \left[ \rho_2^U \cdot \frac{p_{US,F,t}^E}{p_{US,t}^E} \cdot \tau_1 \cdot \tau_2^\omega \cdot y_t^U - \rho_1^U \cdot \frac{p_{US,F,t}^E}{p_{US,t}^E} \cdot \tau_1 \cdot \tau_2^\omega \cdot y_t^R - \rho_1^R \cdot \frac{p_{ROW,t}^E}{p_{ROW,t}^E} \cdot \tau_1 \cdot \tau_2^\omega \cdot y_t^R \right]$$

(26)

The (nominal) current account surplus ($CA_t$) equals the trade surplus plus the net interest income received from holdings of US government bonds. Since the amount of foreign capital inflows equals the current account surplus, and Central Bank buys up any net inflow of the US dollar from the private sector using Renminbi (the so-called non-sterilized foreign-exchange reserve intervention) and then exchanges US dollar for US government bond;\(^3\) we have the following:

$$CA_t \triangleq NNX_t = R_{t-1}^U \cdot B_{H,t}^{US}$$

$$B_{H,t+1}^{US} = CA_t + B_{H,t}^{US}$$

$$M_t^S - M_{t-1}^S = EX_t \cdot \left[ B_{HCB,t+1}^U -(1 + R_{t-1}^U) \cdot B_{HCB,t}^U \right]$$

(27)

(29)

where $B_{H,t}^{US}$ denotes China’s foreign reserve, which here equals the Central Bank’s holdings of US government bond at the period $t$, $B_{HCB,t}^{US}$; $R_{t-1}^U$ is the interest rate of US government bond; and $M_t^S$ is the money supply of Renminbi.

3.2. The economies of US and rest of the world (ROW)

While many ingredients of the model economies of US and ROW are similar to China’s, there are some structural differences. Differences in structural parameters such as the degree of openness and Calvo price stickiness are also allowed.

The open-economy NKPCs of country $j (= \text{US or ROW})$ are:

$$\Pi_{j,t}^F = \beta_j \cdot \mathbb{E}_t (\Pi_{j,t+1}^F) + \frac{(1 - \theta_j) \cdot (1 - \beta_j \cdot \theta_j)}{\theta_j} \cdot \left\{ m_{ct}^j + \phi_j \cdot (tot_t^j + x_t^j) \right\}$$

$$\Pi_{j,t}^E = \beta_j \cdot \mathbb{E}_t (\Pi_{j,t+1}^E) + \frac{(1 - \theta_j) \cdot (1 - \beta_j \cdot \theta_j)}{\theta_j} \cdot \left\{ m_{ct}^j - x_t^j + \phi_j \cdot (tot_t^j + x_t^j) \right\}$$

(30)

\(^3\) In a later section, a Taylor-type interest rate rule will also be examined. In reality the central bank of China uses other policy instruments such as loan quota and bank’s reserve rate control. To follow the main-stream literature and also to make the model tractable and solvable, these monetary policy instruments are ignored in this paper.
where variables and parameters with superscript (or subscript) \( j \) denote the corresponding variables and parameters for country \( j \) which are defined in the similar way to those for China’s economy. For the US equation (30) will degenerate to the LOOP condition: \( P_{US,t}^s = P_{US,t}^s \), since the logic of PCP holds here.

The households of ROW are allowed to buy US bonds. To capture home bias in the household’s portfolio choice, domestic bonds and US bonds are imperfect substitutes.\(^6\) It is costly to adjust the share of domestic bonds in the household’s portfolio away from the steady-state allocation, which is assumed to be the first best for the household. Therefore, the budget constraint for the representative household of ROW is as follows, as the counterpart of equation (1):

\[
P_t^{ROW} \cdot C_t^{ROW} + P_t^{ROW} \cdot K_t^{ROW} + T_t^{ROW} + M_t^{ROW} + (B_{t+1}^{ROW} + EXR_t \cdot B_{RP,t+1}^{US}) \left[ 1 + \frac{\Omega_t^{ROW}}{2} \left( \frac{P_t^{ROW} B_{t+1}^{ROW}}{B_{t+1}^{ROW} + EXR_t \cdot B_{RP,t+1}^{US}} - \psi_t^{ROW} \right)^2 \right] \leq (1 - \delta_t^{ROW} + r_t^{ROW}) \cdot P_t^{ROW} \cdot K_t^{ROW} + W_t^{ROW} \cdot L_t^{ROW} + (1 + R_t^{ROW}) \cdot B_t^{ROW} + (1 + R_t^{US}) \cdot EXR_t \cdot B_{RP,t}^{US} + D_t^{ROW} + M_t^{ROW}
\]

where variables and parameters with superscript \( ROW \) denote the corresponding variables and parameters for country \( ROW \), which are defined in the similar way to those for China’s economy; \( B_{RP,t}^{US} \) is the private holdings of US government bonds for country \( ROW \); \( \Omega_t^{ROW} \) is a parameter measuring the size of the portfolio adjustment cost; the household’s portfolio share of domestic bonds is denoted by \( \psi_t^{ROW} \equiv B_{t+1}^{ROW} / (B_{t+1}^{ROW} + EXR_t \cdot B_{RP,t+1}^{US}) \); and \( \psi_t^{ROW} \) is the steady-state portfolio share of domestic bonds held by ROW households.

The utility maximization gives the following modified UIP condition:

\[
R_t^{ROW} = R_t^{US} + \mathbb{E}_t(\ln EXR_{t+1} - \ln EXR_t) + \Omega_t^{ROW} \cdot \psi_t^{ROW} \cdot \bar{\psi}_t^{ROW}
\]  

(31)

where \( \bar{\psi}_t^{ROW} \) is the percent deviation of the portfolio share from its steady-state level, and according to the definition of \( \psi_t^{ROW} \) the following equation holds:

\[
\bar{\psi}_t^{ROW} = (1 - \psi_t^{ROW})(B_{t+1}^{ROW} - \bar{EXR}_t) - \psi_t^{ROW} \cdot \frac{\text{Def}_t^{ROW} \cdot \text{GDP}_t^{ROW}}{B_t^{ROW}} \cdot B_{RP,t+1}^{US}
\]

where \( B_{RP,t+1}^{US} \) is the deviation of the following ratio from its steady-state value:

\[
(\text{EXR} \cdot B_{RP,t+1}^{US}) / (\text{Def}_t^{ROW} \cdot \text{GDP}_t^{ROW})
\]

The modified UIP condition, equation (31), tells that the spread on ROW bonds versus US bonds depends not only on the expected depreciation of ROW currency, but also on the changes in the portfolio share. Since the adjustment of portfolio share is costly, the household should be compensated with a higher relative interest rate to be willing to hold more domestic bonds. Therefore, the interest rate differential \((R_t^{ROW} - R_t^{US})\) is positively related with portfolio share deviation.

For ROW the US bonds are held by both the central bank and the households, and the sum of private and public holdings equals this economy’s foreign reserves:

\[
B_{ROW,t}^{US} = B_{RP,t}^{US} + B_{RCB,t}^{US}
\]

---

\(^6\) Imperfect asset mobility is introduced into open-economy DSGE models also for the reason to avoid an indetermination of the net foreign asset holdings at the steady state and instability of the dynamic system in absence of perfect international risk-sharing (Schmitt-Grohé and Uribe, 2003).
where $B_{RCB,t}^{US}$ is the ROW central bank’s holdings of US bonds. And the relationships among the foreign reserves, balance sheet of the central bank and net export for ROW are given by the following:

$$B_{ROW,t+1}^{US} = NNX_{t}^{ROW} + (1 + R_{t-1}^{US}) \cdot B_{ROW,t}^{US}$$

$$M_{t}^{ROW,S} - M_{t-1}^{ROW,S} = EX_{t} \cdot [B_{RCB,t+1}^{US} - (1 + R_{t-1}^{US}) \cdot B_{RCB,t}^{US}]$$

where $M_{t}^{ROW,S}$ is the money supply of the economy ROW.

Because US dollar serves as the global reserve currency, it is assumed that for US households there is a complete home bias of government bonds and they will not buy the bonds from ROW. So the budget constraint for the representative household of US is similar to China’s. When there is a trade surplus for China and ROW, the US dollar flowing outside US will finally flow back into the US economy and the money supply of US dollar within the US economy keeps unchanged. However, the demand of US bonds will be affected. When there is a trade deficit for US, the foreign demand of US bonds will increase: US consumes more than its production, while other economies save in the form of buying US bonds. We have the following identities:

$$B_{t}^{US} = B_{H,t}^{US} + B_{ROW,t}^{US} + B_{US,t}^{US}$$

$$B_{US,t}^{US} = B_{US,t}^{US} + B_{US,t}^{US}$$

where $B_{t}^{US}$ is the aggregate demand of US bonds, which consists of three parts: demand from China, from ROW and US domestic demand ($B_{US,t}^{US}$, which equals US private demand $B_{US,t}^{US}$ plus US central bank’s demand $B_{US,t}^{US}$). So the balance sheet of US Federal Reserve expands in the following way:

$$M_{t}^{US} - M_{t-1}^{US} = B_{US,t+1}^{US} - (1 + R_{t-1}^{US}) \cdot B_{US,t}^{US}$$

In the benchmark model, we assume the real money supply of US dollar is an AR(1) process and subject to a stochastic shock:

$$\ln(M_{t}^{US} / P_{t}^{US}) = \rho_{MU} \cdot \ln(M_{t-1}^{US} / P_{t-1}^{US}) +$$

$$(1 - \rho_{MU}) \cdot \ln(M_{t-1}^{US} / P_{t-1}^{US}) + \nu_{t}^{MU}, \nu_{t}^{MU} \sim N(0, \sigma_{M}^{2}) \quad (32)$$

where $M_{t}^{US}$ is the steady-state level of US money supply.

Given the budget constraints for all the three economies’ representative households and the aggregate demand equation for US bonds, we can derive an identity linking three economies’ nominal net exports:

$$NNX_{t} + NNX_{t}^{ROW} + NNX_{t}^{US} = 0$$

### 3.3. Fiscal policies

We define the debt-GDP ratio $b_{t}$, government expenditure-GDP ratio $g_{t}$, and fiscal revenue-GDP ratio as follows:

$$b_{t} = B_{t} / (Def_{t} \cdot GDP_{t})$$

$$g_{t} = G_{t} / (Def_{t} \cdot GDP_{t})$$

$$fr_{t} = T_{t} / (Def_{t} \cdot GDP_{t})$$
Then $g_t$ is assumed to follow an $AR(1)$ process:

$$\ln(g_t) = (1 - \rho_G) \cdot \ln(g) + \rho_G \cdot \ln(g_{t-1}) + v^G_t, v^G_t \sim N(0, \sigma^2_G)$$

The fiscal revenue reacts to, with one-period lag, the deviation of debt-GDP ratio from its target $b$:

$$f_r/t \cdot f_r = (b_{t-1}/b)^{\varepsilon T}$$

where $f_r$ is the steady-state level of fiscal revenue-GDP ratio.

3.4. Monetary policies, exchange rates determination and model stability

Monetary policies are related to both the determination of exchange rates and the saddle path stability of the global model. The existence and uniqueness of a stable path of a dynamic model is a holistic phenomenon, depending on the interaction of all agents’ behaviors. In a closed economy, the Taylor principle usually makes the model satisfy the Blanchard-Kahn conditions, which guarantee the stability and determinacy of the dynamic system. In an open economy, interest rate rule also plays a role in determining the exchange rate of currencies through such as uncovered interest rate parity. In some circumstance, a money supply rule can be an alternative to the interest rate rule. In this paper, three asymmetric economies with different monetary institutional arrangements and different degrees of openness are interacting. So the situation would be more complicated.

3.4.1. Monetary policies and exchange rates determination

Since we have a special interest of US money supply shock’s effect on China’s economy, the monetary policy for US is a money supply rule, described by equation (32). The US monetary authority can influence the nominal interest rate of US bonds through the money supply of US dollar.

For China, fixed exchange rate regime is assumed for the benchmark setting. And the money supply of Renminbi passively expands or shrinks due to China’s trade surplus or deficit, since there are capital controls and exchange settlement and sales are compulsory. Equations (27) to (29) depict this mechanism. Given the money supply of Renminbi, the Euler equation with respect to money demand determines the nominal interest rate for China, holding other variables unchanged. For example, when there is a trade surplus for China, the money supply will increase and nominal interest rate of China will decrease. This is a monetary expansion policy, although it is “passive”. And a lower interest rate will stimulate Chinese households to consume more and Chinese firms to invest more, which will consequently increase China’s aggregate demand and import. Then net export of China will decrease and the trade has a tendency to be balanced.

In an upcoming section a floating exchange rate regime or an opened capital account for China will be considered. If the capital account is opened and Chinese households are allowed to freely buy US bonds, a modified UIP condition will play a role in the determination of Renminbi’s exchange rate. If China adopts a flexible exchange rate regime (while the capital control is maintained), the exchange rate of
Renminbi will be determined by the market clearing condition of China’s GDP, equation (25); since the exchange rate of Renminbi reflects the relative price between Chinese goods and foreign goods, and it can influence the domestic demand of China’s GDP. When there is a trade surplus for China, Renminbi tends to appreciate, relative to the US dollar; and simultaneously the money supply of Renminbi will increase due to the compulsory exchange settlement and sales. Given the money demand function and a Taylor-type interest rate rule which is to replace the fixed exchange rate condition, an expanded money supply will push up the aggregate price level for China. So Renminbi will also “depreciate” relative to domestic goods. The appreciation of Renminbi relative to the US dollar and its “depreciation” relative to domestic goods will unambiguously make China’s import increase, which will then lead to the closure of China’s trade gap.

For ROW, a Taylor-type interest rate rule is assumed. In a stylized two-country NOEM model with perfect assets substitution, the exchange rate is determined by the equilibrium risk-sharing condition, or equivalently the normal UIP condition, given the monetary policies in the two countries. In our three-country model with imperfect assets substitution here, the modified UIP condition, equation (31), links the interest rate differential, exchange rate and the private holdings of foreign bonds. Therefore, given the monetary policies of all the countries, this modified UIP condition and market clearing conditions for US bonds determine the exchange rate of Ro and ROW private holdings of US bonds together.

3.4.2. Monetary policies and model stability

Monetary policies are related to the saddle path stability as well. Not as in a closed economy, the Taylor principle for the monetary policy is not necessarily a sufficient condition any more for the existence and uniqueness of a stable path for an open economy. In a two-country model of Carton (2011), the dynamic system is unstable if the net foreign asset position is absent in monetary policy.

Given the fixed exchange rate regime and compulsory exchange settlement and sales for China and a money supply rule described by equation (32) for US, a Taylor-type interest rate rule for ROW is assumed. In spite of imperfect asset mobility, which prevents a unit root related to the net foreign asset position for ROW, the accumulation of official reserves of China to maintain the fixed exchange rate of Renminbi may lead to a dynamic of China’s net foreign asset holdings without mean-reverting forces. To satisfy the Blanchard-Kahn conditions for a large-scale open-economy DSGE model, there may be more than one way to achieve this; because the existence and uniqueness of a stable path is a holistic phenomenon, depending on the interaction of all agents’ behaviors in all the three economies and the concrete values of structural parameters as well. For example, it may work to let the monetary policy of some countries react to their net foreign asset positions, as in Carton (2011). In this paper, since the monetary policies of the US and China are the focus, I adopt a simple way to achieve the saddle-path stability of the global model for the calibrations to come in this paper: to choose the form of the ROW monetary policy.
To be specific, the ROW monetary policy rule is a forward-looking rule as below:

\[ R_t^{ROW} = R^{ROW}_t + \varphi_1^R \cdot \sum_{j=1}^{4} \mathbb{E}_t \left( \Pi_{t+j}^{ROW} \right)/4 + \varphi_2^R \cdot \sum_{j=1}^{4} \mathbb{E}_t (GAP_t^{ROW})/4 + v_R^{ROW,t} \]

where \( R^{ROW}_t \) is the steady-state level of nominal interest rate for ROW, and \( \Pi_t^{ROW} \) and \( GAP_t^{ROW} \) are the inflation gap and real GDP gap of ROW respectively.

### 3.5. Steady state of the global economy

In this paper zero GDP growth and zero inflation are assumed at the steady state. In fact, it could be assumed alternatively that at the steady state the growth rates of real GDP of all the three economies are positive and the same, or the growth rates of the aggregate price levels of all the three economies are positive and the same. In these alternative circumstances, the cyclical representation of the model around the steady state and thus the main results of this paper would keep unchanged.

If one wants to build a model closer to the reality that during the past decades the growth rate of China’s GDP has been much higher than that of the US GDP, he could also assume that at the steady state the growth rate of China’s GDP is positive and larger than that of the US GDP. But the problem is: at this kind of steady state the relative size of the US economy compared to China’s economy would converge to zero, which is neither realistic nor easy to deal with in the model. Therefore, zero GDP growth and zero inflation are assumed for all the three economies at the steady state in this paper, to simplify the analysis and also consistent with many papers of open-economy literature. At the steady state of zero GDP growth for all the economies in the world, if it is assumed, to reflect a reality, that China holds a large amount of foreign reserve in terms of the US dollar at the steady state, then it could imply that at the steady state China should import a lot from other economies, which contradicts another reality. So the long run global trade imbalances must be linked with the long run growth imbalances in the world. I leave these for future studies, but ignore them in this paper. The main aim of this paper is to explore the effects of the dollar hegemony on China’s economy and policy choices at business-cycle frequencies. And the fact that China accumulates a large amount of foreign reserves has been shown in Figure 2 and justifies the assumption in this paper that China has strict capital controls and compulsory exchange settlement and sales.

It is also assumed that at the steady state the foreign asset holdings for China and ROW are zero, which implies complete asset home bias (\( \varphi^{ROW}_R = 1 \)) at the steady state and results in a balanced global trade at the steady state as well. In a coming part of sensitivity analysis, this assumption will be relaxed, and then the global trade at the steady state would be unbalanced.

Since there is no real GDP growth at the steady state but in reality all the economies are growing (particularly, China is growing quite fast), great ratios for all the three economies at the steady state cannot be calibrated to match the data. I assume the government spending-GDP ratio is 20% for all the economies at the steady
state. Given the equilibrium conditions and the values of some parameters (such as the capital depreciation rate), the steady-state investment-GDP ratio for each economy and many other aggregate variables’ steady-state values can be calculated.

Two relative prices at the steady state, $\tau_{ROW}$ and $\tau_{US}$, are important, and they determine many coefficients of the log-linearized representation of the benchmark model. Given the steady-state values for any two economies’ net nominal export, equation (26) and its analogue for ROW (or US) provide an equation group to solve $\tau_{ROW}$ and $\tau_{US}$.

4. Calibration

The parameters of the cyclical global DSGE model\(^7\) fall into three categories: Category 1-basic structural parameters such as preference parameters, and some other parameters, which need be exogenously provided; Category 2-steady state values of aggregate variables, which are set to match the data; and Category 3-other parameters which are determined by the above two categories, given the steady state equilibrium conditions. Parameter values are specified on a quarterly model.

Category 1 parameters for the three economies are listed in Table 4 in the appendix. As in many New Keynesian DSGE models, $\varepsilon$ is calibrated to be 11, leading to a 10% steady-state markup over marginal cost. For $\xi$, Collard and Dellas (2002) suggest a value between one and two, so we use 1.5. For $\omega$, micro data typically indicates a value in the range of 5 to 10 (Funke et al., 2010); and Obstfeld and Rogoff (2000) have shown that such high elasticity can explain an observed large home bias in trade. So we set it to be 6. The inverse of Frisch elasticity of labor supply, $\eta$, is set to be 1.0 for all the three economies. In terms of labor share in production function, for China it is set to be 0.5, as in Chen et al. (2012) and indicating a relatively low output elasticity of labor in China\(^8\); and for US and ROW, we use a standard calibration, 0.67. The Calvo parameter is set to be 0.75 for China implying an average adjustment of prices every year and consistent with Chen et al. (2012), and to be 0.5 for US and ROW as normal. We set the depreciation rate of capital to a value of 5% for China\(^9\) and 2.5% for the other two economies. The AR(1) persistence parameters are all set to be 0.7. The parameters of monetary policy rule for ROW are set to be 1.5 and 0.2, consistent with the literature. In terms of the elasticity in the tax rule, it is set to be 0.2 for each economy.

We set a baseline value for $\rho_1$ of 0.3 and for $\rho_2$ of 0.247, indicating that: when the prices of home good and foreign good are the same, import of China is 30%\(^10\) of its total demand; and when the prices of imported goods from US and ROW are the same, China’s import share from them is proportional to their GDP size. For US and ROW, the specification is as follows: $\rho_1^{US} = 0.265, \rho_2^{US} = 0.147; \rho_1^{ROW} = 0.113, \rho_2^{ROW} = 0.344$. The rationality of this specification is explained in Appendix A.1.

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\(^7\) The cyclical DSGE representation of the benchmark model is available in the online appendix of this paper.

\(^8\) He et al. (2007) and Mehrotra et al. (2011) use an even smaller value, 0.4.

\(^9\) This high depreciation rate is in line with the economic reality of China, as explained in He et al. (2005).

\(^10\) According to the 2011 data from the National Bureau of Statistics of China, imported goods (service excluded) are about 24% of GDP.
Two parameters ($\psi_{\text{ROW}}$ and $\Omega_{\text{ROW}}$) in the modified UIP condition are calibrated as follows. The steady-state portfolio share of domestic bonds held by ROW households $\psi_{\text{ROW}}$ is set to be 1.0, meaning that there are zero foreign asset holdings at the steady state, This guarantees a balanced global trade at the steady state for our model. The portfolio adjustment cost parameter $\Omega_{\text{ROW}}$ is set to be 0.22, in line with Chang et al. (2013) which estimate this parameter from a panel data set of 22 countries with a sample period from 2001 to 2011.\footnote{I have also studied the benchmark model when $\tau_{\text{ROW}}$ is set to be 0.15 or 0.25, and the results for the benchmark model in this paper do no change at all.}

Category 2 parameters for the three economies are listed in Table 5 in the appendix. The nominal GDP of China denominated in US dollar in 2012 is normalized to be unit. According to the IMF data, in 2012 the GDP of US and ROW are respectively 1.91 times and 5.81 times of China’s. In terms of steady-state nominal interest rate, for all the three economies it is set to be 4% annually, and thus the quarterly rate is 1%. For government debt-GDP ratios, we refer to the IMF report \textit{Fiscal Monitor} (IMF, 2013) and use the 2012 data. For US, it is 106.5%. For China, it is 22.8%, but sub-national debt is not included. So we use a higher value, 40%, for China. Then given the world average ratio 81.1% and world’s GDP distribution, we can calculate that for ROW the debt-GDP ratio is about 79.8%. Since our model is a quarterly one, all these ratios are amplified by 4 times. The steady-state exchange rate of Renminbi is set to be 6.3, the average value for the year 2012. For ROW currency, Ro, its steady-state exchange rate is set to be 1 for simplicity.

In Table 5 the ratio of money stock to nominal GDP in the steady state is set to match the M0-GDP ratio data in 2012. For China this ratio is 10.5%, for US it is 6.7%, and for ROW we take a value of 15%.\footnote{The M0-GDP ratios for the Euro area, Japan, UK and India in 2012 are respectively 9.1%, 16.8%, 16.9% and 13.2%.} Finally we amplify these ratios by 4 times in accord with our quarterly model. Here we use M0 as the index of US money supply for two reasons: first, in our model there is capital accumulation and capital stock is owned by the households as saving, so in the model money as another kind of asset to the households is better to denote currency rather than more broadly defined moneys which include households’ savings; and secondly, in our model money is totally supplied by the central banks as their liabilities, so M0 rather than M1 or M2 is a better indicator. In a coming section, M1-GDP ratios will be explored as well.

Category 3 parameters for the three economies are listed in Table 6 in the appendix. In the steady state, we can easily get that: $NNX = 0$, and $NNX_{\text{ROW}} + NNX_{\text{US}} = 0$. Given the assumption of complete steady-state asset home bias ($\psi_{\text{ROW}} = 1$), we can get that $NNX_{\text{ROW}} = 0$. Then equation (26) and its analogue for ROW (or US) provide an equation group to solve $\tau_{\text{ROW}}$ and $\tau_{\text{US}}$, both of which are 1. This implies that balanced global trade leads to equal global prices.

5. **Impulse responses and welfare implication**

5.1. US money supply shock and China’s economic fluctuation
Now we do the impulse response analysis to see how US money supply shock will affect China’s macro economy through global linkages. Figure 4 depicts the reactions of China’s aggregate variables to a one-percent US money supply shock. On impact China’s inflation will increase by 0.003%, while China’s GDP will increase as well, by about 0.002%. Both of these increases are very small. If we look at the time series of US money supply, its HP-filter cycle has a standard error of about 10%. So even when there is a positive one standard-error (S.E.) shock to US money supply, on impact China’s real GDP and inflation rate will still be slightly influenced. But one quarter later, both China’s inflation rate and GDP level will be pulled down, and one year later inflation gap and output gap are respectively about -0.007% and -0.024%.

![Figure 4](image)

**Figure 4.** Impulse responses of China’s aggregate variables (cycles) to a one-percent US money supply shock (in percent)

Generally speaking, the US money supply shock has a tiny influence on China’s inflation rate, but has a certain negative effect on China’s real output in the medium term although the immediate effect is slightly positive. A positive one S.E. shock to US money supply results in that China’s GDP will be 0.24% below its steady state level one year after the shock. The responses are moderately persistent, and three years later both the inflation gap and output gap diminish to zero.

The complex responses of China’s inflation and output here indicate a complicated transmission mechanism. US money supply shock will first affect US economy, and then affect China through international trade and global financial market. This is just a first-round effect. Unlike many other open-economy models which take the rest of world as exogenous and passive, in our interacting multi-country model there are infinite rounds’ feedbacks among China, US and ROW.

Figure 4 also shows the impulse responses of terms of trade, real exchange rate of Renminbi, nominal net export, real marginal cost and other variables of China to a one-percent US money supply shock. Figure 10 and 11 in the appendix show the aggregate variables’ reactions to this US money supply for US and ROW.
To explain the transmission mechanism, first of all a “cost-push” story can be told as follows: when the US money supply increases, the US dollar is likely to depreciate, and then oil and many other commodities which are priced in the US dollar are going to have higher prices. Since the exchange rate of RMB to the US dollar is quite stable, the import prices of oil and other commodities for China will go up. Consequently, a kind of cost-push inflation is generated, and real output will decrease as well, according to the textbook AS-AD analysis.

Overall, for the benchmark model here the cost-push story almost holds at the very beginning when this US money supply shock hits the global economy. The real exchange rates for both Renminbi and Ro (in fact also for the nominal exchange rate of Ro) appreciate on impact, indicating the depreciation of US dollar. In fact, the export price of ROW goods will increase on impact, while the export goods’ prices of China and US do not change much at the beginning. The increase of the export price of ROW goods can be largely understood as the price increase of oil and other international commodities. Since ROW is the biggest economy and exporter in the world, the increase of its export price (denominated by US dollar) will generate cost-push pressure for both China and US, given that China adopts a fixed exchange rate regime and US dollar is US domestic currency. This partly explains why both the inflation rate and real marginal cost for both China and US will increase at the very beginning when this US money supply shock hits the global economy.

It is worth providing an explanation to the fact that the export price of ROW goods will increase on impact, while the export goods’ prices of China and US do not change much at the beginning. This can be understood by examining the different NKPC curves for different economies. For China with a fixed exchange rate regime in the benchmark model, the NKPC for export, equation (23), will degenerate to the LOOP condition and the LOOP gap $x_t \equiv 0$. Therefore, other things equal, the other NKPC (equation (22)) indicates that the price of home good in the domestic market will not be affected much at the beginning when the US money supply shock hits the global economy. Thus the export price of China will not change much either due to the LOOP condition. The situation for the US is similar, since the US dollar is the national currency of the US and its NKPC for export price degenerates to the LOOP condition as well. But for the ROW, the story is different, because the LOOP condition does not hold for it and equation (30) is the ROW NKPC for export. Given the appreciation of Ro and the fact that $0 < \phi^{ROW} < 1$, other things equal, the export price of the ROW goods will increase at the beginning.

Nevertheless, the cost-push story is not the full story here, because usually higher marginal cost generated by higher import price indicates lower GDP level, but for our model here China’s GDP will increase slightly at the very beginning. Thus, at least we can and should tell another story: the story of relative price effect. US money supply shock can, through the price channel, influence China’s GDP as well. Changes in relative prices of international trade will alter relative demands for China’s products. Since the export price of ROW goods will increase much, while the export goods’ prices of China and US do not change much at the beginning when US money supply shock hits the global economy, this will definitely lead to an increase of the terms of
trade for both China and US, but lower down the terms of trade for ROW, which is shown by Figure 4, 10 and 11. Higher terms of trade together with the holding of LOOP for China imply that Chinese goods are becoming relatively cheaper, keeping other things equal. This kind of relative price effect will increase the world demand for China’s GDP, which partly explains the immediately positive response of China’s output gap to a positive US money supply shock. In our benchmark model here, this relative price effect on China’s GDP seems to overwhelm the cost-push effect at the very beginning, but afterwards cost-push effect dominates. Lowered GDP in the medium run also explains disinflation of China to a certain degree.

The transmission mechanism of the influence of US money supply shock on China’s macro economy can be very complicated and the channels identified by us above are just part of it. There are many other possible channels. For example, the aggregate demands of all the economies will be affected by US money supply shock, and this will then affect China’s output gap as well.

Intuitively, as in a standard closed economy model, an increase of US money supply will lead to a lower level of US nominal interest rate, which is usually called liquidity effect and indeed holds in our global framework here. Partly due to the relatively cheaper price of Chinese goods (or higher terms of trade), the nominal net export for China (denominated in US dollar) increases at the beginning, which then leads to an increase of China’s foreign asset (US bonds) holdings. Consequently, the money supply of China passively expands as well because of capital controls and the compulsory exchange settlement and sales in China. Then the nominal interest rate in China decreases as well due to the expansion of domestic money supply. Additionally, the expansion of China’s money supply also contributes to a positive inflation for China in the short run. The nominal net export of US will also increase at the beginning, partly because that the US export goods become cheaper, relative to the ROW export goods. Since both US and China achieve trade surplus, naturally ROW will have a trade deficit, which then results in fewer holdings of its foreign assets (US bonds). In terms of the ROW private holdings of US bonds, the appreciation of Ro relative to US dollar has a positive effect on it due to a wealth effect in some sense, but a lower interest rate of US bonds has a negative effect. The model indicates a positive overall effect on the ROW private holdings of US bonds (not shown in Figure 11). Given fewer national holding of US bonds for ROW, the central bank of ROW will unambiguously hold fewer US bonds. This implies a shrinking money supply of ROW and then a possible higher nominal interest rate for ROW. The response of ROW nominal interest rate could also be explained by its Taylor rule, given the responses of ROW output gap and inflation gap shown in Figure 11. To conclude, at early stages after a positive US money supply shock hits the global economy, both China and US will have a trade surplus while for ROW there is a trade deficit; there is a domestic liquidity effect in US (lower nominal interest rate) and this liquidity effect spills over to China, but for ROW there is an opposite effect (higher domestic interest.

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13 In reality, due to the financial market distortions of China, as described by Song et al. (2011) and Peng et al. (2014), this international liquidity effect of US QE and its influence on China’s economy may be affected, and the corresponding transmission mechanism may be more complicated.
rate); the holdings of US bonds for China will increase, while for ROW they will decrease.

The above analysis mainly discusses the responses of global economy at the beginning periods after a positive US money supply shock hits the world economy. Cost-push effects and relative price effects are employed to explain the dynamics of the impulse responses of China’s real GDP and inflation in the medium term. The responses of some other variables in the medium term can be much more sophisticated than just converging to the steady state, since it is a large-scale multi-country model and different transmission channels are interacting with each other.

5.2. The persistence of US money supply shock

It is meaningful to examine the relationship between the persistence parameter of US money supply shock, \( \rho_{MU} \), and the reactions of China’s aggregate variables. This relationship can be revealed by Figure 12 in the appendix. Generally speaking, the more persistent US money supply shock is, the larger the responses of China’s aggregate variables would be; while the qualitative results above remain unchanged.

5.3. The share of China’s GDP in the world and US money supply shock

Will the response of China to US money supply shock be smaller when the share of China’s GDP in the global economy becomes larger and larger? The answer is no, shown by Figure 13 in the appendix.

When China’s GDP at the steady state is doubled or quadrupled and the levels of US GDP and ROW GDP at the steady state keep unchanged, a positive US money supply shock will result in slightly larger responses for China’s aggregate variables. Considering the definition of cycles in this paper, the absolute response of China’s economy is in fact larger than the benchmark setting. Therefore, the response of China to US money supply shock will not become smaller when the share of China’s GDP in the global economy becomes larger, as long as the US dollar remains as the world currency and there is no reform to China’s institutional arrangements.

5.4. Sensitivity analysis

Five alternative re-calibrations are considered to see whether the results above about the response of China’s economy to US money supply shock are robust or not. For Case 1, M1 data rather than M0 is used to calibrate the steady-state money supply-GDP ratios. In Case 2, the assumption of zero holdings of foreign assets at the steady state for ROW is relaxed, and thus the global trade at the steady state is unbalanced. I take the value of 0.8 to re-calibrate the bond home bias for ROW, following Coeurdacier and Rey (2011) and Aviat and Coeurdacier (2007). Case 3

\[14\] When the world’s GDP distribution changes, some parameters (such as degree-of-openness parameters) should be re-calibrated according to the formula in Appendix A.1.
resets the annual nominal interest rates to be 1% for US and ROW at the steady state, to reflect the reality of 2012. Case 4 considers a smaller Frisch elasticity of labor supply, 1/3, as in Galí and Monacelli (2005). So the parameter \( \eta \) is set to be 3. Another even bigger value \( \eta = 10 \), as in Chang et al. (2013), is examined as well, and the result is nearly as the same as when \( \eta = 3 \). Case 5 changes the elasticity of substitution between domestic and foreign goods, \( \omega \), to be a rather smaller number, 1.5, in line with Chang et al. (2013) and others.

Overall, the following qualitative results are robust according to the sensitivity analysis: when a positive US money supply shock hits the global economy, the nominal interest rate of China will be lowered down (the spillover of liquidity effect); in the medium term both China’s real output and its inflation rate are below the steady state levels; and both the terms of trade and nominal net export for China will be pushed up on impact, but be below the steady state levels in the medium term.

5.5. Welfare implication of the benchmark model

We can calculate the welfare gain (or loss) of Chinese households due to US money supply shock. We first need to derive the welfare loss function. In Chang et al. (2013), they use the following loss function:

\[
W = -\frac{1}{2} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[ \lambda_H \cdot (\bar{H}_t)^2 + \lambda_{GAP} \cdot (GAP_t)^2 + \lambda_R \cdot (\bar{R}_t)^2 + \lambda_B \cdot (\bar{B}^{US}_{Ht})^2 \right]
\]

They argue that “the quadratic terms involving inflation, output, and the nominal interest rate in the loss function are standard in the optimal monetary policy literature. They can be derived from second-order approximations to the representative household’s utility function [e.g., Woodford (2003)]. The interest rate smoothing term appears in the policy objective in the presence of transaction frictions, such as money in the utility function.” And they also add a quadratic term for foreign-asset holdings arbitrarily, which is not strictly derivable. In fact, their argument about the quadratic terms involving inflation, output and the nominal interest rate is problematic as well, and not applicable for our model’s welfare evaluation.

Edge (2003) extends the utility-based welfare criterion developed by Rotemberg and Woodford (1997) and Woodford (2003) to a model with endogenous capital accumulation, just as in this paper. Edge (2003) proves that: although a criterion can be specified such that welfare losses depend solely on quadratic functions (including cross-product terms) of the model’s variables (including capital stock and investment), an important difference from the traditional criterion is that the composition of output directly affects welfare in the endogenous-capital model. This endogenous-capital model is a closed-economy one and does not have real money balance in the utility function either. If we consider these two aspects, the welfare criterion would have a more complicated form and cannot be guaranteed to be a quadratic form.

Therefore, in this paper I do not seek to derive a quadratic form welfare criterion. Instead, we can use a straightforward way to evaluate welfare. A second-order approximation to the consumer’s welfare losses can be written and expressed as a
fraction of the steady state consumption as below (the derivation of the welfare loss function is given by Appendix A.2):

\[ W_L = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[ \hat{C}_t - \phi_1 \cdot \hat{L}_t + \phi_2 \cdot (\hat{M}_t - \hat{P}_t) \right] \]

When there is a shock to US money supply, we can get the impulse response functions for all the cyclical components of China’s economy in the above equation. Since in the end all these impulse responses will converge to zero, we take their values in the first 40 periods (10 years) to calculate an approximated welfare loss as follows:

\[ W_L \approx \mathbb{E}_0 \sum_{t=0}^{40} \beta^t \left[ \hat{C}_t - \phi_1 \cdot \hat{L}_t + \phi_2 \cdot (\hat{M}_t - \hat{P}_t) \right] \]

where the utility weights \( \phi_1 \) and \( \phi_2 \) are calibrated to be 1.56 and 0.01 respectively, in order to match the steady state conditions and benchmark calibration of the model.

Welfare calculation shows that: a positive 10% of US money supply shock will result in a positive 1.25% welfare gain for China, a positive 0.06% welfare gain for US, but a 0.21% welfare loss for the rest of the world. This implies that a positive US money supply shock increases the welfare of US domestic households, although the welfare gain is not very big; and it generates a positive externality for Chinese households but a negative one for ROW. This positive 1.25% welfare gain for China can be decomposed into three parts: -0.15%, +1.08% and +0.32%, which are respectively the contributions from fluctuations of consumption, labor input and real money balance. Accompanied with a decline of China’s GDP in the medium term after the shock, the consumption level of Chinese households is lowered down slightly as well. But the welfare loss from this part is very small, only -0.15% (as a fraction of the steady state consumption). The major contribution of the welfare gain for China comes from the decrease of labor input (or leisure increase). In other words, under US money supply shock, Chinese households work fewer hours without consumption being much affected, and thus achieve some welfare gain.

The different welfare implications between China and the ROW under the US money supply shock reveal, to a certain degree, the necessity of capital controls and exchange rate pegs under some circumstances, such as when the US QE as a global shock hits the global economy. This result is intuitive, because a closed capital market together with an exchange rate peg can protect the home country from global turbulences in global financial and exchange rate markets.

6. **China’s liberalization reforms**

Perfect capital mobility and a flexible exchange rate usually can improve market efficiency and improve social welfare for an open economy, especially in the context with no big market failures. However, these also make the economy widely exposed to the international shocks. After 2007-2008 global financial crisis, some economists suggest to re-examine the financial liberalizing policies in developing countries. This paper mainly explores the impact of US money supply shock on China’s economy, so I want to examine whether or not this kind of impact will be exaggerated when the
Chinese economy were becoming more liberalized. Welfare analysis based on this may lead to constructive policy suggestions for China’s liberalizing reform.

In this section I evaluate the dynamics of China’s economic responses to the same US money supply shock when some kind of liberalization of China’s economy has taken place. I consider three alternative liberalization reforms for China: (1) a partial lifting of capital controls with maintenance of the exchange rate peg, (2) allowing the exchange rate of RMB to float while keeping the capital account closed, and (3) a full reform which is the combination of the above two partial reforms.

In the introduction of this paper, I explain why I need to develop a multi-country DSGE model in which the interactions among different economies are sufficiently taken into account, and abandon the conventional small-open economy models or two-country models. However, the price is that it is difficult to fully uncover the transmission mechanism of shocks, which has been shown in the analysis above. Therefore, in the counterfactual analyses of this and the following section, I mainly show the results deviating from the benchmark scenario and compare the welfare, but do not struggle painfully to uncover every transmission channels of shocks.

6.1. Opening the capital account

In this circumstance, the Chinese households are assumed to be allowed to hold US government bonds as an imperfect substitute for domestic bonds, like the households of ROW; while the households of US and ROW would not buy any Chinese bonds. The budget constraint, equation (1), is now replaced by the following:

\[
P_t \cdot C_t + P_t \cdot K_{t+1} + T_t + M_t + (B_{t+1} + EX_t \cdot B_{US,H^P,t+1}) \left[ 1 + \frac{\Omega}{2} \left( \frac{B_{t+1}}{B_{t+1} + EX_t \cdot B_{US,H^P,t+1}^t} - \psi \right) \right]^2 \leq (1 - \delta + r_t) \cdot P_t \cdot K_t
\]

\[+ W_t \cdot L_t + (1 + R_{t-1}) \cdot B_t + (1 + R_{t-1}^{US}) \cdot EX_t \cdot B_{US,H^P,t}^t + D_t + M_{t-1}\]

where \(\psi\) is the steady-state portfolio share of domestic bonds and is calibrated to be 1.0 (the same as the setting for ROW), in order to indicate a zero steady-state holdings of US bonds for China and thus a balanced global trade at the steady state.

Then we can get a modified UIP condition between China and US as follows:

\[R_t = R_t^{US} + \hat{\psi}_t (lnEX_{t+1} - lnEX_t) + \Omega \cdot \psi \cdot \hat{\psi}_t\]

\[\hat{\psi}_t = (1 - \psi)(B_{t+1}^t - EX_t) - \psi \cdot \frac{Def.GDP}{B_{US,H^P,t}} \cdot B_{US,H^P,t+1}^t\]

Since the fixed exchange rate regime is maintained, the above condition is reduced to:

\[R_t = R_t^{US} - \Omega \cdot \frac{Def.GDP}{B_{US,H^P,t}} \cdot B_{US,H^P,t+1}^t\]

And we also have another equilibrium condition for the Chinese economy as below:

\[B_{US,H^P,t}^t = B_{US,H^P,t}^{US} + B_{US,HB,t}^{US}\]

Figure 5 depicts the impulse responses of China’s major aggregate variables to US money supply shock in this circumstance. Compared to the benchmark case, the response of China’s economy is nearly the same. This is reasonable because of the
strong home-bond bias and the existence of portfolio adjustment cost. Chinese households have no big incentive to deviate much from the steady-state zero holdings of foreign assets.

Figure 5. Impulse responses of China’s aggregate variables (cycles) to a one-percent US money supply shock under alternative regimes for China (in percent)

Nevertheless, by opening the capital account, China can achieve some flexibility and then some welfare gains under US money supply shock, although the welfare gain is quite small. Table 7 in the appendix provides the welfare gain (or loss) (as a fraction of the steady-state consumption) of Chinese households when a one-percent US money supply shock hits the global economy, under the benchmark and all alternative counterfactual settings. The counterfactual analysis is implemented in two ways: one is to reform China’s monetary institutional arrangements, which is analyzed in this section; and the other way is to weaken the global roles of US dollar, which is the task of Section 7. Table 8 and 9 show the welfare results for US and ROW respectively.

6.2. Floating the exchange rate of Renminbi

We turn to an alternative policy reform for China when the exchange rate peg is removed but capital controls are maintained. Compared to the benchmark case, the exchange rate of Renminbi now is allowed to float freely rather than being fixed at its steady-state level. The monetary policy to stabilize China’s economy now is a Taylor-type interest rate rule as follows:\textsuperscript{15}

\[ R_t = R + \varphi_1 \cdot T_t + \varphi_2 \cdot GAP_t + \nu_t R \]

In this circumstance, the price setting for Chinese firms is no longer equivalent to PCP, and the LOOP condition does not hold any more. Instead, the open-economy NKPC with respect to the Chinese export goods’ price, which is equation (23), now applies.

For China, the GMM estimation of Mehrrotra \textit{et al.} (2011) suggests 1.34 and 0 for the two Taylor rule parameters. The value 1.34 indicates that monetary policy in

\textsuperscript{15} Persistence can be added into the Taylor rule, but the results are nearly the same.
China fulfills the Taylor principle, which is in line with the empirical observation that China’s inflation rate has been remarkably low since the mid-1990s. But the value 0 seems to underestimate the interest rate response to the output gap for China. We set $\phi_2$ to be a little larger value, 0.15.

Figure 5 also gives the impulse responses of China’s inflation and output to US money supply shock in this counterfactual situation. Compared to the benchmark regime, the effect on the inflation rate is totally opposite: negative responses in the short run but positive responses in the medium run; the response of China’s real GDP is similar but the immediate effect is quite large. Since the exchange rate of Renminbi is flexible, on impact Renminbi appreciates (not shown in Figure 5), like the response of Ro. The larger positive response of real GDP on impact can be explained as follows: an appreciating Renminbi will attenuate the cost-push effect which will lower down China’s real GDP, so the overall effect would be larger given that at the beginning the relative price effect dominates the cost-push effect. The appreciation of Renminbi has a wealth effect as well: the international goods priced by US dollar is now becoming relatively cheaper, so the import of China will relatively increase, resulting in a smaller trade surplus in the beginning compared to the benchmark model. The negative responses of inflation in the short run could be partly explained by the price stickiness and the failure of LOOP here due to a floating Renminbi: given the price stickiness, the LOOP gap $x_t \triangleq \ln(P^e_{H,t} \cdot EX_t/P_{H,t})$ will be negative because of the appreciation of Renminbi, so in the short run the inflation rate gap for the home-made goods price will be negative (given not very big values for marginal cost gap and terms of trade gap), explained by equation (22); and because nearly 70% of the final goods are made of home-made goods, the aggregate-price inflation is likely to be negative as well.

By floating the exchange rate of Renminbi while maintaining capital controls, China will have some welfare losses under US money supply shock now. Table 7 in the appendix shows that: a 10% US money supply shock will result in 0.5% welfare loss for Chinese households. The welfare loss mainly comes from the disutility generated by the net increase of labor supply, while in fact the welfare effect from consumption is slightly positive.

6.3. Liberalizing the capital account and floating the exchange rate

Finally, a full reform is considered, when both the capital account is opened and the exchange rate of Renminbi is allowed to float. The impulse responses of China’s aggregate variables are similar to the situation when only the exchange rate of Renminbi is floating. This is not surprising since opening the capital account has no big influence, as explained before. The only big difference is that the short-run response of nominal interest rate of China is slightly positive now, rather than negative. This can be illustrated straightforwardly by the Taylor interest rate rule, given the short-run responses of China’s output gap and inflation gap. The welfare result for Chinese households is still negative, but improved a little compared to the case with floating exchange rate of Renminbi but capital controls.
7. A weakened US dollar in the global economy

In the benchmark model, US dollar serves as the unique global currency with two key roles: the only invoicing currency in the international trade and the only foreign reserve currency. Due to the rise of Euro and rapid economic growth and stronger global influence of emerging countries during the past decades, dollar standard in the international trade and international finance is being challenged, although US dollar is still the only currency that can be viewed as a global currency if there is one.

In this section we evaluate the dynamics of China’s economic responses to the same US money supply shock when some of the US dollar’s global roles have been weakened. Three counterfactual cases are considered: (1) there is no dollar standard in the international trade and the dollar pricing is replaced by PCP, (2) US dollar is no longer the global reserve currency, and (3) US dollar serves as neither the only invoicing currency in the international trade nor the global reserve currency, and it is only the domestic currency for US. Would US money supply shock have smaller impacts on China’s economy, given a weakened US dollar in the world economy? The counterfactual analysis in this section can also help us understand better about what happens in reality, because the assumption of US dollar’s global roles in this paper deviates from the reality in some sense, and the real response of China’s economy to US money supply shock should lie somewhere between the results from the benchmark model and the following counterfactual analysis.

7.1. Removing dollar pricing in international trade

First we remove the dollar standard in international trade, and consider an alternative pricing mechanism: producer currency pricing (PCP). Under PCP the LOOP condition holds for all the three economies:

\[ P_{H,t}^E \cdot EX_t = P_{H,t} \]
\[ P_{ROW,t}^E \cdot EXR_t = p_{ROW,t}^R \]
\[ P_{US,t}^E = p_{US,t}^R \]

In this circumstance there is another exchange rate of the ROW currency in price of Renminbi, \( EXRR_t \), and the non-arbitrage condition is assumed to be satisfied: \( EXRR_t = EX_t / EXR_t \). So for notational convenience we can still denote all the export prices by US dollar prices, and this will not affect the model result.

Under PCP we also consider four alternative monetary regimes for China: the benchmark one when the capital accounts are closed and the exchange rate of Renminbi is fixed, opening the capital account only, floating the exchange rate only and the full liberalizing reform.

Figure 6 provides the impulse responses of China’s aggregate variables to the same US money supply shock under these four settings. First of all, compared to the benchmark model result under the dollar pricing, the response of China’s economy with no reform or only opening the capital account under PCP is nearly the same, except that the initial response of the real GDP is negative now rather than slightly
positive. Secondly, under PCP, a reform with a floating Renminbi but closed capital account will make China’s economy almost unaffected by US money supply shock. Finally, under PCP, the response of China’s economy with a fully liberalizing reform is quite different from that with no reform, especially for nominal net export, terms of trade and real GDP.

**Figure 6.** Impulse responses of China’s aggregate variables (cycles) to a one-percent US money supply shock under different regimes for China when the dollar pricing in the international trade is replaced by PCP (in percent).

Welfare comparison shows that: under PCP the welfare of Chinese households will be always improved compared to the dollar pricing setting, no matter what kind of regime China adopts; and still the regime with no capital controls but fixed exchange rate is best for China, while the regime with capital controls but floating exchange rate is worst, under US money supply shock. Under PCP, there is welfare loss for US households when there is no reform for China. However, a floating Renminbi can always make US households achieve some welfare gains.

### 7.2. Eliminating the role of US dollar as the global reserve currency

In this part the dollar standard in the international trade is maintained and US dollar is still the only invoicing currency, but it is assumed that US dollar is no longer the global reserve currency. For this counterfactual circumstance, we consider two alternative settings: (1) there is a kind of international bond with zero net supply, but this bond is still denominated in US dollar, (2) there is a kind of international bond with zero net supply, and this bond is denominated in a supranational reserve currency, which is a combination of three currencies (US dollar, Renminbi and Ro), weighted by the corresponding country’s GDP share in the world.

#### 7.2.1. An international bond denominated in US dollar
In this case a kind of international bond denominated in US dollar, $B_t^{int}$, is the only internationally traded asset, to replace US government bond in the benchmark model. Its nominal interest rate is $R_t^{int}$ and its net supply is zero in every period. There are capital controls for China, but not for US and ROW, and both the households and the central bank of US or ROW can buy this kind of international bond. Now not only for China and ROW but also for US the expansion of money supply is backed by the increase of the international bond holdings.

The nominal interest rate of the international bond is determined by the global financial market, and the following two modified UIP conditions link this rate with the nominal interest rates of US and ROW:

$$R_t^{ROW} = R_t^{int} + \mathbb{E}_t(\ln EX_{t+1} - \ln EX_t) + \Omega^{ROW} \cdot \psi_t^{ROW} \cdot \bar{\psi}_t^{ROW}$$

$$R_t^{US} = R_t^{int} + \Omega^{US} \cdot \psi_t^{US} \cdot \bar{\psi}_t^{US}$$

where $\psi_t^{ROW}$ and $\psi_t^{US}$ are the households’ portfolio share of domestic bonds for ROW and US, and $\bar{\psi}_t^{ROW}$ and $\bar{\psi}_t^{US}$ are the percent deviations of $\psi_t^{ROW}$ and $\psi_t^{US}$ from their steady-state values. Here for the modified UIP condition linking the nominal interest rates of US bond and the international bond, there is no term for exchange rate, because the international bond is still denominated in US dollar here, which is the same for US bond.

Under this counterfactual setting we consider four alternative monetary regimes for China as well: the regime when the capital accounts are closed and the exchange rate of Renminbi is fixed (no reform), opening the capital account only, floating the exchange rate only and the full liberalizing reform.

Figure 7 shows the results in this circumstance. If we compare Figure 7 with Figure 5, we can find that they are almost the same. So if there is an international bond to replace US government bond, as the global reserve asset, but the international bond is still denominated in US dollar, the response of China’s economy to US money supply
shock will be similar to the case as if the US bond were still the only global reserve asset. The welfare implication for China is also nearly the same, as shown in Table 7. However, as we will see, when this international bond is denominated not in US dollar but in a supranational reserve currency, the result would be quite different.

7.2.2. An international bond denominated in a supranational reserve currency

In this case, to eliminate US bond’s role in the international financial market as in the benchmark model, still there is a kind of international bond, $B_t^{int}$, which is the only internationally traded asset and has zero net supply. The difference from the above case is that this bond is denominated in a supranational reserve currency, which is created as a combination of three currencies, weighted by the corresponding country’s GDP share in the world. Simply it can be expressed as below:

\[ \text{Int} = \omega_1 \cdot \text{RMB} + \omega_2 \cdot \text{Ro} + (1 - \omega_1 - \omega_2) \cdot \text{USD} \]

where \( \text{Int} \) is this supranational reserve currency, and \( \text{RMB} \), \( \text{USD} \) and \( \text{Ro} \) denote respectively RMB, US dollar and the ROW currency. \( \omega_1 \) and \( \omega_2 \), are respectively the GDP shares of China and ROW in the world at the steady state.

Therefore, the supranational currency \( \text{Int} \) now does not only have its own nominal interest rate, but also has its exchange rates relative to US dollar, Renminbi and Ro. Suppose the exchange rates of \( \text{Int} \) to Renminbi, Ro and US dollar, under the indirect quotation, are \( \text{IntEX}_t \), \( \text{IntEXR}_t \) and \( \text{IntEXU}_t \) respectively. Then these three exchange rates can be in fact explained by two exchange rates of US dollar (under the indirect quotation as well), \( \text{EX}_t \) and \( \text{EXR}_t \), as below:

\[ \text{IntEX}_t = \omega_1 \cdot \frac{\text{EX}_t}{\text{EXR}_t} + (1 - \omega_1 - \omega_2) \cdot \text{EX}_t \]
\[ \text{IntEXR}_t = \omega_1 \cdot \frac{\text{EXR}_t}{\text{EX}_t} + \omega_2 + (1 - \omega_1 - \omega_2) \cdot \text{EXR}_t \]
\[ \text{IntEXU}_t = \omega_1 \cdot \frac{1}{\text{EX}_t} + \omega_2 \cdot \frac{1}{\text{EXR}_t} + (1 - \omega_1 - \omega_2) \]

The modified UIP conditions should be changed accordingly as follows:

\[ R_t^{ROW} = R_t^{int} + \mathbb{E}_t(\ln(\text{IntEXR}_{t+1}) - \ln(\text{IntEXR}_t)) + \Omega^{ROW} \cdot \psi^{ROW} \cdot \psi_t^{ROW} \]
\[ R_t^{US} = R_t^{int} + \mathbb{E}_t(\ln(\text{IntEXU}_{t+1}) - \ln(\text{IntEXU}_t)) + \Omega^{US} \cdot \psi^{US} \cdot \psi_t^{US} \]

Under this counterfactual setting we again consider four alternative monetary regimes for China: no reform, opening the capital account only, floating the exchange rate only and the full reform. As shown in Figure 8, except for the regime opening the capital account only, for all other three regimes, the response of China’s economy to US money supply shock is similar to the case as if the US bond were still the only global reserve asset. But for the regime opening the capital account only, the responses of China’s aggregate variables are totally opposite to the regime with no reform and the magnitude becomes much larger. This kind of larger fluctuation generates a big welfare loss for China: a 10% US money supply shock will result in 3.85% welfare loss for Chinese households. And in this scenario no reform is the best reform for China, under US money supply shock.
Figure 8. Impulse responses of China’s aggregate variables (cycles) to a one-percent US money supply shock under different regimes for China when an international bond denominated in a supranational reserve currency replaces US bond as the global foreign exchange reserves (in percent).

7.3. When US dollar serves as the US domestic currency only

In this part the dollar standard in the international trade is removed and replaced by PCP, and US dollar is no longer the global reserve currency. In other words, US dollar now serves as the US domestic currency only. We focus on the situation when there is an international bond denominated in a supranational reserve currency.

Figure 9. Impulse responses of China’s aggregate variables (cycles) to a one-percent US money supply shock under different regimes for China when the dollar pricing in international trade is replaced by PCP and an international bond denominated in a supranational reserve currency replaces US bond as the global foreign exchange reserves (in percent). (Note: the case “Peg Supranational Currency” means that the capital account of China is opened but the exchange rate of Renminbi to this supranational reserve currency, rather than to US dollar, is fixed)
Figure 9 shows the impulse responses of China’s aggregate variables to the same US money supply shock under four alternative regimes for China. First of all, with no reform China’s economy would have similar response to the situation when US dollar is the world currency, and this makes the best welfare gain for Chinese households. Secondly, with the regime opening the capital account only but keeping the exchange rate of Renminbi pegging the US dollar, China’s economy would be much more fluctuating, and thus Chinese households would have quite a big welfare loss, as shown in Table 7. Third, to let the exchange rate of Renminbi to float, China’s economy will nearly not be influenced by US money supply shock at all, no matter whether capital controls are lifted or not.

Since US dollar now is no longer the world currency, why should Renminbi peg US dollar? I also examine the circumstance that the capital account of China is opened but Renminbi pegs the supranational reserve currency, rather than US dollar. The corresponding result is shown in Figure 9 as well. Now with the regime opening the capital account only, China’s economy would not fluctuate largely any more. Therefore, when US dollar serves only as the US domestic currency, pegging US dollar but opening capital account would generate a large welfare loss for China due to big economic fluctuations; but when pegging the supranational reserve currency rather than US dollar, China’s economy would nearly not be affected any more.

8. Concluding remarks

In this paper, the US dollar is modeled as a world currency in a New Keynesian global DSGE framework within which three asymmetric economies are interacting with each other and the so called “rest of the world” is not exogenously or passively given; and focus on the effects of US money supply shock upon China’s macro economy.

The global DGSE model finds the following results: when a positive US money supply shock hits the global economy, the nominal interest rate of China will be lowered down (the spillover of liquidity effect); in the medium term both China’s real output and its inflation rate are below the steady state levels; and both the terms of trade and nominal net export for China will be pushed up on impact, but be below their steady state levels in the medium term. Several kinds of sensitivity analysis are implemented, and the above results are quite robust. Cost-push effect and relative price effect are employed to discuss the transmission mechanism. A positive 10% US money supply shock will result in a positive 1.25% welfare gain (as a fraction of the steady state consumption) for Chinese households, a positive 0.06% welfare gain for US, but a 0.21% welfare loss for the rest of the world.

The more persistent the US money supply shock is, the larger the responses of China’s aggregate variables would be. The response of China’s economy to US money supply shock will not become smaller when the share of China’s GDP in the global economy becomes larger.

Counterfactual analyses are implemented in two ways: to reform China’s institutional arrangements, or to weaken the global roles of US dollar. Given that US
dollar’s hegemony is not weakened, the regime with liberalized capital accounts and a fixed exchange rate for China is best for the Chinese households under the US money supply shock, while the regime with a floating exchange rate and capital controls is the worst. However, when US dollar is no longer the global reserve currency but instead a supranational reserve currency replaces it, then for China the regime with liberalized capital accounts and an exchange rate peg to US dollar now is the worst kind of reform, no matter whether or not the dollar standard in the international trade is maintained. For China, to maintain the status quo (nominal exchange rate targeting and capital controls) cannot always achieve the first best, but can guarantee a second best under the US money supply shock. When US dollar serves only as the domestic currency for US, then for China a floating exchange rate regime or a peg to the supranational currency can make China’s economy nearly unaffected by the US money supply shock, no matter whether or not its capital account is opened.

The results of this paper can help us better understand US dollar as a world currency and the effect of US QE on China’s economy, and then can provide some meaningful information for China’s policy makers. Considering only US money supply shock, a fully liberalizing reform with capital controls removed and the exchange rate of Renminbi floating is not the best reform for China. This result is different from Chang et al. (2013) who consider only the US interest rate shock in a small-open economy framework. Besides US money supply shock and US interest rate shock, many other external shocks and risks that are influential to China’s economy, should be considered as well to evaluate the potential reforms to China’s institutional arrangements. I leave this for future studies.

The framework and analysis of this paper could be extended by several means. First of all, the so called “sterilization activity” could be introduced by allowing the central bank of China to hold a certain amount of domestic bonds. Then the purchases of foreign assets can be financed by selling domestic bonds, which does not result in an expansion but instead leads to a structural reallocation of the central bank’s balance sheet. Secondly, one can introduce the zero lower bond of nominal interest rate for US, and examine the spillover effects of US money supply shock when there is a liquidity trap in US. Third, a natural extension can be achieved by incorporating financial frictions into the model and making it more complex and realistic. Last but not least, optimal monetary policy making and possible policy coordination between US and China could be considered.
References


Appendices

Appendix A: Supplementary algebra

Appendix A.1: specification of degree-of-openness parameters

China’s GDP can be normalized to be unit. Assume the GDP of US and ROW are respectively $x$ and $y$. Then the economy of US and ROW can be viewed as consisting of $x$ and $y$ unit economies like China, and the global economy has $(1 + x + y)$ unit economies. Consider the situation when the prices of all kinds of goods are the same. Assume the import of each unit economy is $\rho_1$ times its aggregate demand (which is equal to its GDP, since the trade is balanced here), and it equally comes from the rest $(x + y)$ unit economies. So the import of any unit economy from another different unit economy is $\rho_1/(x + y)$. Ignoring the intra-national trade of US and ROW, we can get the following table for each economy’s import components:

<table>
<thead>
<tr>
<th>Import from</th>
<th>China</th>
<th>US</th>
<th>ROW</th>
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</thead>
<tbody>
<tr>
<td>China</td>
<td>0</td>
<td>$\rho_1 \cdot x/(x + y)$</td>
<td>$\rho_1 \cdot y/(x + y)$</td>
</tr>
<tr>
<td>US</td>
<td>$\rho_1 \cdot x/(x + y)$</td>
<td>0</td>
<td>$\rho_1 \cdot x \cdot y/(x + y)$</td>
</tr>
<tr>
<td>ROW</td>
<td>$\rho_1 \cdot y/(x + y)$</td>
<td>$\rho_1 \cdot x \cdot y/(x + y)$</td>
<td>0</td>
</tr>
</tbody>
</table>

Using this table, we can calculate $\rho_2$ and the parameters ($\rho_1^U$ and $\rho_2^U$) for US and ROW easily:

$$
\rho_2 = x/(x + y)
$$

$$
\rho_1^U = \rho_1 \cdot (1 + y)/(x + y), \rho_2^U = 1/(1 + y)
$$

$$
\rho_1^{ROW} = \rho_1 \cdot (1 + x)/(x + y), \rho_2^{ROW} = 1/(1 + x)
$$

In fact, the international trade here is a simple gravity model.
Appendix A.2: derivation of the welfare loss function

This appendix derives a second-order approximation to the China’s representative household’s utility when the economy remains in a neighborhood of the steady state.

The following second-order approximation of relative deviations in terms of log deviations is frequently used:

$$\frac{Z_t - Z}{Z} \approx Z_t + \frac{1}{2}(Z_t)^2$$

where $\bar{Z}_t = \log(Z_t) - \log(Z)$ is the log deviation from steady state for a generic variable $Z_t$. The period $t$ utility of the China’s representative household, $u_t$, is given below:

$$u_t = \ln C_t - \phi_1 \cdot \left(\frac{L_t}{L}\right)^{1+\eta} + \phi_2 \cdot \ln(M_t/P_t)$$

The Second-order Taylor expansion of $u_t$ around a steady state $(C, L, M, P)$ yields:

$$u_t - u \approx C_t/C - \phi_1 L_t/L + \phi_2 \cdot \left(\frac{M_t - M}{M} - \frac{P_t - P}{P}\right)$$

$$+ \frac{1}{2} \left\{ -\left(\frac{C_t - C}{C}\right)^2 + \phi_1 \cdot \left(\frac{L_t - L}{L}\right)^2 - \phi_2 \cdot \left(\frac{M_t - M}{M}\right)^2 + \phi_2 \cdot \left(\frac{P_t - P}{P}\right)^2 \right\}$$

In terms of log deviations,

$$u_t - u \approx \hat{C}_t - \phi_1 \cdot \hat{L}_t + \phi_2 \cdot (\hat{M}_t - \hat{P}_t)$$

Then a second-order approximation to the consumer’s welfare losses can be written and expressed as a fraction of the steady state consumption as:

$$WL = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{u_t - u}{u_C \cdot C}\right) = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t (u_t - u)$$

$$= \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[ \hat{C}_t - \phi_1 \cdot \hat{L}_t + \phi_2 \cdot (\hat{M}_t - \hat{P}_t) \right]$$
Appendix B: supplementary tables

Table 4. Parameter calibration: Category 1

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<th>US value</th>
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<td>0.7</td>
</tr>
</tbody>
</table>

Table 5. Parameter calibration: Category 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>China value</th>
<th>ROW value</th>
<th>US value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Def} \cdot \text{GDP}/\text{EX}$</td>
<td>1</td>
<td>$\text{Def}^{\text{ROW} \cdot GD_{\text{ROW}}}/\text{EXR}$ 5.81</td>
<td>$\text{Def}^{\text{US} \cdot GD_{\text{US}}}$ 1.91</td>
</tr>
<tr>
<td>$R$</td>
<td>0.01</td>
<td>$R_{\text{ROW}}$ 0.01</td>
<td>$R_{\text{US}}$ 0.01</td>
</tr>
<tr>
<td>$M/(\text{Def} \cdot \text{GDP})$</td>
<td>10.5%*4</td>
<td>$M_{\text{ROW}}/(\text{Def}^{\text{ROW} \cdot GD_{\text{ROW}}})$ 15%*4</td>
<td>$M_{\text{US}}/(\text{Def}^{\text{US} \cdot GD_{\text{US}}})$ 6.7%*4</td>
</tr>
<tr>
<td>$B/(\text{Def} \cdot \text{GDP})$</td>
<td>40%*4</td>
<td>$B_{\text{ROW}}/(\text{Def}^{\text{ROW} \cdot GD_{\text{ROW}}})$ 79.8%*4</td>
<td>$B_{\text{US}}/(\text{Def}^{\text{US} \cdot GD_{\text{US}}})$ 106.5%*4</td>
</tr>
<tr>
<td>$\text{EX}$</td>
<td>6.3</td>
<td>$\text{EXR}$ 1</td>
<td></td>
</tr>
</tbody>
</table>
Table 6. Parameter calibration: Category 3

<table>
<thead>
<tr>
<th>Parameter</th>
<th>China</th>
<th>ROW</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.99</td>
<td>$\beta^\text{ROW}$</td>
<td>0.99</td>
</tr>
<tr>
<td>$r$</td>
<td>0.06</td>
<td>$r^\text{ROW}$</td>
<td>0.035</td>
</tr>
<tr>
<td>$\tau$</td>
<td>1</td>
<td>$\tau^\text{ROW}$</td>
<td>1</td>
</tr>
<tr>
<td>$\phi$</td>
<td>0.3</td>
<td>$\phi^\text{ROW}$</td>
<td>0.113</td>
</tr>
<tr>
<td>$p$</td>
<td>1</td>
<td>$p^\text{ROW}$</td>
<td>0.1587</td>
</tr>
<tr>
<td>$\tau_7$</td>
<td>0.2474</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>$\tau_6$</td>
<td>0.3436</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>$P \cdot (\text{Def} \cdot \text{GDP})$</td>
<td>37.88%</td>
<td>$P^\text{ROW} \cdot (\text{Def}^\text{ROW} \cdot \text{GDP}^\text{ROW})$</td>
<td>21.43%</td>
</tr>
<tr>
<td>$Y$</td>
<td>6.3</td>
<td>$Y^\text{ROW}$</td>
<td>36.603</td>
</tr>
<tr>
<td>$B^\text{US}_R$</td>
<td>0</td>
<td>$B^\text{US}_\text{ROW}$</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 7. Welfare gain (or loss) for China under alternative counterfactual settings

<table>
<thead>
<tr>
<th>Regime of China's economy</th>
<th>US dollar’s global roles (R1 &amp; R2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Benchmark (R1 + R2)</td>
</tr>
<tr>
<td></td>
<td>Case 1</td>
</tr>
<tr>
<td>Benchmark</td>
<td>+ 0.125</td>
</tr>
<tr>
<td>Capital controls lifted</td>
<td>+ 0.126</td>
</tr>
<tr>
<td>Exchange rate peg removed</td>
<td>- 0.049</td>
</tr>
<tr>
<td>Full reform</td>
<td>- 0.042</td>
</tr>
</tbody>
</table>

Notes: 1. Welfare gain (or loss) is measured as a fraction of the steady-state consumption under a one-percent US money supply shock; 2. All numbers are in percent; 3. $R1$ and $R2$ respectively denote the two roles of US dollar as the world currency, the only invoicing currency in the international trade and the only global reserve currency; 4. $Case 1$ and $Case 2$ denote two alternative situations that the international bond is denominated either in US dollar or in a supranational reserve currency. These notes are also applicable to Table 8 and 9 below.
### Table 8. Welfare gain (or loss) for US under alternative counterfactual settings

<table>
<thead>
<tr>
<th>Regime of China’s economy</th>
<th>US dollar’s global roles (R1 &amp; R2)</th>
<th>Benchmark (R1 + R2)</th>
<th>No R1</th>
<th>No R2</th>
<th>No R1 and No R2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Case 1</td>
<td>Case 2</td>
<td>Case 1</td>
<td>Case 2</td>
</tr>
<tr>
<td>Benchmark</td>
<td>+ 0.006</td>
<td>- 0.009</td>
<td>+ 0.006</td>
<td>+ 0.005</td>
<td>- 0.010</td>
</tr>
<tr>
<td>Capital controls lifted</td>
<td>+ 0.006</td>
<td>- 0.008</td>
<td>+ 0.004</td>
<td>+ 0.098</td>
<td>- 0.018</td>
</tr>
<tr>
<td>Exchange rate peg removed</td>
<td>+ 0.003</td>
<td>+ 0.015</td>
<td>- 0.002</td>
<td>- 0.002</td>
<td>+ 0.016</td>
</tr>
<tr>
<td>Full reform</td>
<td>+ 0.000</td>
<td>+ 0.096</td>
<td>- 0.003</td>
<td>- 0.007</td>
<td>+ 0.001</td>
</tr>
</tbody>
</table>

### Table 9. Welfare gain (or loss) for ROW under alternative counterfactual settings

<table>
<thead>
<tr>
<th>Regime of China’s economy</th>
<th>US dollar’s global roles (R1 &amp; R2)</th>
<th>Benchmark (R1 + R2)</th>
<th>No R1</th>
<th>No R2</th>
<th>No R1 and No R2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Case 1</td>
<td>Case 2</td>
<td>Case 1</td>
<td>Case 2</td>
</tr>
<tr>
<td>Benchmark</td>
<td>- 0.021</td>
<td>- 0.017</td>
<td>-0.030</td>
<td>- 0.034</td>
<td>- 0.027</td>
</tr>
<tr>
<td>Capital controls lifted</td>
<td>- 0.020</td>
<td>- 0.017</td>
<td>-0.038</td>
<td>+ 0.459</td>
<td>- 0.040</td>
</tr>
<tr>
<td>Exchange rate peg removed</td>
<td>- 0.035</td>
<td>+ 0.001</td>
<td>-0.111</td>
<td>- 0.110</td>
<td>+ 0.013</td>
</tr>
<tr>
<td>Full reform</td>
<td>- 0.041</td>
<td>+ 0.058</td>
<td>-0.088</td>
<td>- 0.101</td>
<td>- 0.010</td>
</tr>
</tbody>
</table>
Appendix C: supplementary figures

Figure 10. Impulse responses of US aggregate variables (cycles) to a one-percent US money supply shock (in percent).

Figure 11. Impulse responses of ROW aggregate variables (cycles) to a one-percent US money supply shock (in percent)
Figure 12. Impulse responses of China’s aggregate variables (cycles) to a one-percent US money supply shock under different settings for the persistence parameter of the shock: Benchmark $\rho_{MU} = 0.7$, Case 1 $\rho_{MU} = 0.5$, and Case 2 $\rho_{MU} = 0.9$ (in percent).

Figure 13. Impulse responses of China’s aggregate variables (cycles) to a one-percent US money supply shock under different settings for the size of China’s economy in the world at the steady state: for Case 1 China’s real GDP is doubled, while US GDP and ROW GDP keep the same as in the benchmark model setting; and for Case 2 China’s real GD is quadrupled (in percent).