Sources of Fluctuations of the China-US Bilateral Real Exchange Rate: Evidence from a Structural VAR Model

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This paper examines the sources of fluctuations of the China-US bilateral real exchange rate using monthly data over 1994-2010. We develop a structural VAR model using a mixture of short run and long run restrictions and study the impacts of various structural shocks. We find that, among the factors examined, US aggregate demand and aggregate supply shocks have no statistically significant impact on the bilateral real exchange rate. It is China's aggregate supply shock and exchange rate shock that explain the fluctuations the most. It is also documented that exchange rate shock plays little role in explaining the variations in each country's output or price, suggesting that exchange rate may not be the solution to the imbalances between the two economies. These results shed light on policymaking in both countries.

INTRODUCTION

In July 2005, the Chinese government made announcements regarding changes in its exchange rate policy. First, it appreciated the Renminbi (RMB) by 2.1% against the U.S. dollar. Second, the RMB would move from a managed dollar peg to a managed float with its exchange rate referenced to a basket of currencies. And third, it was moving towards more flexibility.[1] Since then, the RMB has appreciated by about 35% relative to the US dollar, from RMB827.65 to RMB614.5 per 100 US dollar. This move has marked an end to China's long-standing *de facto* peg to the US dollar since 1994 and a beginning towards more flexibility.

Study of China's exchange rate policy is burgeoning in recent years, fueled mainly by concerns of the accumulating trade deficits of the US with China and the alleged manipulation of the RMB by the Chinese authority. Attempts to understand China's exchange rate policy have followed along three lines. One is the estimation of real equilibrium exchange rate and the investigation of whether and to what extent the RMB has been undervalued. The second addresses the appropriateness of greater flexibility in China's exchange rate regime. The third studies sources of shocks in the RMB real exchange rate a la Clarida and Gali (1994).

Along the first line, researchers have provided disagreeing evidence on whether RMB is undervalued. Coudert and Couharde (2007) use the behavioral equilibrium exchange rate (BEER) approach and the fundamental equilibrium exchange rate (FEER) approach and calculate real effective exchange rate that are consistent with sustainable current account. They find a lack of Balassa (1964) effect in China that the real exchange rate did not appreciate with a rapid growth in the tradable sector. Their results lend support to an undervaluation of the real exchange rate (RER) between 2002 and 2005 in effective terms and even more against the US dollar. Goldstein (2006), Goldstein and Lardy (2006), and Lardy (2005) support with caution a RMB undervaluation in real, trade-weighted terms by 20% to 35%, using various "underlying balance" approaches. Kim and Goh (2005) estimate the RMB equilibrium real exchange rate for the period 1978-2002 and find that RMB is not significantly undervalued during the last few years of the sample. Wang, Hui, and Soofi (2007) find no consistent undervaluation in the RMB real exchange rate using the BEER approach for the period of 1980-2004. Chinn, Cheung, and Fujii (2007) center on a discussion on the difficulty of measuring "the equilibrium real exchange rate" and quantify the uncertainty in measuring the level of real equilibrium exchange rate from economic theory and empirics. They find that RMB appeared to be undervalued, but not with statistical significance.

Along the second line, there is as heated a debate on whether China should consider more flexibility in its exchange rate. McKinnon (2005, 2006, and 2007) and Xu (2000) call for more stability in the Renminbi exchange rate (relative to the dollar). McKinnon (2007) argues that in the long run, exchange rate stabilization against the dollar is needed by China to prevent the unduly low interest rate and the deflationary trap experienced by Japan in the 1990s. It is also needed for further financial integration in East Asia, which already appears to be close to an "optimum currency area" with the U.S. He further argues that trade imbalances should be addressed by other policy alternatives. On the other hand, stronger voices are heard calling for flexibility in China's exchange rate. Among them are Eichengreen (2005, 2007), Roberts and Tyers (2003), Roubini (2007), and others. Drawing lessons from the 1997-1998 financial crisis, Eichengreen (2005, 2007) argues that a more flexible exchange rate is in China's interest and should precede further opening of the capital account, to reduce currency market speculations and market participants all lining up on one side of the market. Roubini (2007) believes that a more flexible exchange rate will enable the government to use independent monetary policy to address the overheated economy. Consistent appreciation in the nominal exchange rate will prevent a costly increase in inflation resulting from the real exchange rate appreciation driven by rapid economic growth. Roberts and Tyers (2003) assess different exchange rate regimes for China by examining the implications of domestic and external shocks in an elemental comparative static macroeconomic model with differing degree of capital mobility. They find that more flexibility would be in China's interest and that the benefit increases with increases in capital mobility.

Along the third line, researchers examine the sources of macroeconomic shocks in China's real exchange rate by various vector autoregression models. Wang (2005) pioneers a three-variable structural VAR model, consisting of relative output, relative price level, and real effective exchange rate and recovers relative supply shock, relative real demand shock, and nominal shock using annual data from 1985-2003. He finds that real demand shocks are the most important source of fluctuations in China's real exchange rate. Supply shocks are found to be as important as nominal shocks in contributing to real exchange rate variations in China. Huang and Guo (2007) extend the analysis by incorporating oil shocks and investigate the importance of oil price shocks on the variations of China's real exchange rate, in addition to supply shocks, demand shocks, and nominal (monetary) shocks, for the period of 1990-2005. They find that real demand shocks have a dominant role in explaining real exchange rate changes in China. Oil shock appears to have minimal and perverse effects on the real exchange rate, that is, an increase in oil price leads to an appreciation of China's real exchange rate in the long run. They attribute this perverse effect of oil shock to China's less dependence on imported oil and heavy energy price regulation. Zhang and Wan (2007) build a four-variable structural VAR model to study the sources of fluctuations of China's trade balance for 1985-2000. They extend previous studies by distinguishing foreign supply shock from domestic supply shock. They find that domestic supply shocks and nominal shocks dominate in explaining the fluctuations in real exchange rate.

This paper attempts to examine the sources of fluctuations in the US-China bilateral real exchange rate. In particular, we are investigating what factors explain more of the variations: Chinese shocks or US shocks, supply shocks or demand shocks; and to what extent real exchange rate shocks can explain fluctuations in each country's output and price level. Knowledge of these dynamics will help us understand some fundamental issues related to China's exchange rate policy and some of the trade disputes between the U.S. and China.

To achieve this goal, we develop a six-variable structural VAR model, consisting of oil price, US industrial production, US consumer price, China's industrial production, China consumer price, and CPI-deflated US-China bilateral real exchange rate, using monthly data for 1994-2010. Our model estimation reveals the short run dynamics and long run equilibrium of the variables in response to six structural shocks: oil-induced supply shock, US aggregate supply shock, US aggregate demand shock, China aggregate supply shock, China aggregate demand shock, and exchange rate (nominal) shock.

This paper contributes to the literature in the following ways. First, we integrate China and the US, two large economies, in one structural VAR model and examine the interactions between them. Second, we use a mixture of short run and long run restrictions to identify the structural shocks. By doing so, our model complies with the basic macroeconomic theory while remaining the maximum freedom from unnecessary restrictions and thus is able to reveal the dynamics in the data. Third, incorporating the US directly in the model is important in that the results help reveal whether China and the US are subject more to symmetric or asymmetric shocks. Under the optimum currency area theory, symmetry of macroeconomic shocks is a necessary condition for countries to peg their currencies (Mundell, 1961; McKinnon, 1963). The results may shed light on whether China's move toward RMB flexibility can be justified economically.

The preview of the estimation results is as follows. For the sources of fluctuations in the China-US bilateral real exchange rate, we find that US shocks have no statistically significant impact on the bilateral real exchange rate. It is China's aggregate supply shock and exchange rate shock that explain the fluctuations the most. For how the exchange rate shock affects the real sector of each economy – industrial output and consumer price, we find that exchange rate shock plays little role in explaining the variations in these variables, suggesting that exchange rate may not be the solution to the trade imbalances between the two economies and policy makers may need to resort to other solutions.

The rest of the paper is organized as follows. Section 2 presents the empirical model. Section 3 discusses the empirical results. And section 4 concludes.

EMPIRICAL MODEL

Structural VAR modeling of China's economy is relatively new, led by Wang (2005), Huang and Guo (2007), and Zhang and Wan (2007), to name a few, who specifically study sources of fluctuations in China's real exchange rates. This new practice benefits from the burgeoning literature in empirical modeling of open economy macroeconomics pioneered by Blanchard and Quah (1989) and Clarida and Gali (1994), and the further opening of China's economy during the recent phase of its economic reform. As discussed in Wang (2005) and Heytens and Zebregs (2003), the open economy setting is becoming more applicable to China, especially since the 1990s, when most prices were liberalized and production plans were abolished or diluted in as early as the 1980s. Even capital account has grown sufficiently porous, as discussed in Eichengreen (2007) and Cheung, Chinn and Fujii (2007), making the open economy setting more appropriate for China.

Assume that the economy can be described by the following structural VAR model:

$$A_0 X_t = \sum_{i=1}^{n} A(i) X_{t-i} + \varepsilon_t \tag{1}$$

where $X_t = (\Delta poil, \Delta USIP, \Delta USCPI, \Delta CNIP, \Delta CNCPI, \Delta RER)$ is the vector of the six endogenous variables, consisting of the first differences of oil price, $\Delta poil$; US industrial production, $\Delta USIP$; US consumer price, $\Delta USCPI$; China Industrial production, $\Delta CNIP$; China consumer price $\Delta CNCPI$; and bilateral CPI-based China-US real exchange rate, ΔRER. All variables are in logarithms and first differenced. A_0 and $A(i)'s$, i = 1, 2, … n, are 6x6 matrices capturing the contemporaneous and lagged interactions among the variables, respectively. $\varepsilon_t = (\varepsilon^{os}, \varepsilon^{s}_{US}, \varepsilon^{d}_{US}, \varepsilon^{s}_{CN}, \varepsilon^{d}_{CN}, \varepsilon^{er})$ is the vector of the six structural shocks, namely, oil supply shock, US aggregate supply shock, US aggregate demand shock, China aggregate supply shock, China aggregate demand shock, and exchange rate shock, respectively. The ε_t's are i.i.d and $Var(\varepsilon_t) = I$. Rearranging (1) yields:

$$X_t = A_0^{-1} \sum_{i=1}^{n} A(i) X_{t-i} + A_0^{-1} \varepsilon_t \tag{2}$$

Rewriting (2), we obtain the reduced-form model:

$$X_t = \sum_{i=1}^{n} B(i) X_{t-i} + u_t \tag{3}$$

where $B(i) = A_0^{-1} A(i)$, $u_t = A_0^{-1} \varepsilon_t = C\varepsilon_t$, and $C = A_0^{-1}$. $u_t = C\varepsilon_t$ is the vector of the reduced-form residuals, where C captures the contemporaneous reactions of the variables to the structural innovations. Rewrite (3) to express X_t in terms of the structural innovations, we get

$$X_t = \left[I - \sum_{i=1}^{n} B(i) L^i \right]^{-1} C\varepsilon_t \tag{4}$$

Let $D(L) = \left[I - \sum_{i=1}^{n} B(i) L^i \right]^{-1}$. We can then extend the structural model into the following form:

$$\begin{bmatrix} \Delta oilp \\ \Delta USIP \\ \Delta USCPI \\ \Delta CNIP \\ \Delta CNCPI \\ \Delta RER \end{bmatrix} = D(L)C \begin{bmatrix} \varepsilon^{os} \\ \varepsilon_{US}^{s} \\ \varepsilon_{US}^{d} \\ \varepsilon_{CN}^{s} \\ \varepsilon_{CN}^{d} \\ \varepsilon^{er} \end{bmatrix} \tag{5}$$

where $D(L)C =$

$$\begin{bmatrix} D_{11}(L) & D_{12}(L) & D_{13}(L) & D_{14}(L) & D_{15}(L) & D_{16}(L) \\ D_{21}(L) & D_{22}(L) & D_{23}(L) & D_{24}(L) & D_{25}(L) & D_{26}(L) \\ D_{31}(L) & D_{32}(L) & D_{33}(L) & D_{34}(L) & D_{35}(L) & D_{36}(L) \\ D_{41}(L) & D_{42}(L) & D_{43}(L) & D_{44}(L) & D_{45}(L) & D_{46}(L) \\ D_{51}(L) & D_{52}(L) & D_{53}(L) & D_{54}(L) & D_{55}(L) & D_{56}(L) \\ D_{61}(L) & D_{62}(L) & D_{63}(L) & D_{64}(L) & D_{65}(L) & D_{66}(L) \end{bmatrix} \begin{bmatrix} c_{11} & c_{12} & c_{13} & c_{14} & c_{15} & c_{16} \\ c_{21} & c_{22} & c_{23} & c_{24} & c_{25} & c_{26} \\ c_{31} & c_{32} & c_{33} & c_{34} & c_{35} & c_{36} \\ c_{41} & c_{42} & c_{43} & c_{44} & c_{45} & c_{46} \\ c_{51} & c_{52} & c_{53} & c_{54} & c_{55} & c_{56} \\ c_{61} & c_{62} & c_{63} & c_{64} & c_{65} & c_{66} \end{bmatrix}$$

The structural shocks, $\varepsilon_t's$, are not identified. We can recover them from the estimated coefficients of the reduced-form model in (3) by solving for matrix *C*. There are 36 unknown elements in *C*, requiring 36 equations. $Var(u_t) = \Sigma$ can be obtained from estimating the reduced-form model (3). $Var(u_t) = Var(C\varepsilon_t) = CC^{-1} = \Sigma$ gives us 21 equations. The remaining 15 restrictions are a mixture of long run and short run assumptions, imposed as follows.

Let $G(1) = \begin{bmatrix} G_{11}(1) & G_{12}(1) & G_{13}(1) & G_{14}(1) & G_{15}(1) & G_{16}(1) \\ G_{21}(1) & G_{22}(1) & G_{23}(1) & G_{24}(1) & G_{25}(1) & G_{26}(1) \\ G_{31}(1) & G_{32}(1) & G_{33}(1) & G_{34}(1) & G_{35}(1) & G_{36}(1) \\ G_{41}(1) & G_{42}(1) & G_{43}(1) & G_{44}(1) & G_{45}(1) & G_{46}(1) \\ G_{51}(1) & G_{52}(1) & G_{53}(1) & G_{54}(1) & G_{55}(1) & G_{56}(1) \\ G_{61}(1) & G_{62}(1) & G_{63}(1) & G_{64}(1) & G_{65}(1) & G_{66}(1) \end{bmatrix} = D(1)C$ captures the long run responses of the endogenous variables to the structural innovations.

Long Run Restrictions

Following Blanchard and Quah (1989), Clarida and Gali (1994), aggregate demand shocks and nominal shocks have no long run effects on the level of real output, which is determined only by supply side factors, such as technology change and oil-induced supply shocks. Hence, we assume that US real output is not affected by US aggregate demand shocks, China's aggregate demand shocks, and exchange rate shocks in the long run, that is, $G_{23}(1) = G_{25}(1) = G_{26}(1) = 0$. In a similar fashion, we assume that Chinese real output is not affected by US aggregate demand shock, domestic aggregate demand shock, and the exchange rate shock, that is, $G_{43}(1) = G_{45}(1) = G_{46}(1) = 0$. These assumptions provide the following six long run restrictions (6.1) through (6.6):

$$D_{21}(1)c_{13} + D_{22}(1)c_{23} + D_{23}(1)c_{33} + D_{24}(1)c_{43} + D_{25}(1)c_{53} + D_{26}(1)c_{63} = 0 \tag{6.1}$$

$$D_{21}(1)c_{15} + D_{22}(1)c_{25} + D_{23}(1)c_{35} + D_{24}(1)c_{45} + D_{25}(1)c_{55} + D_{26}(1)c_{65} = 0 \tag{6.2}$$

$$D_{21}(1)c_{16} + D_{22}(1)c_{26} + D_{23}(1)c_{36} + D_{24}(1)c_{46} + D_{25}(1)c_{56} + D_{26}(1)c_{66} = 0 \tag{6.3}$$

$$D_{41}(1)c_{13} + D_{42}(1)c_{23} + D_{43}(1)c_{33} + D_{44}(1)c_{43} + D_{45}(1)c_{53} + D_{46}(1)c_{63} = 0 \tag{6.4}$$

$$D_{41}(1)c_{15} + D_{42}(1)c_{25} + D_{43}(1)c_{35} + D_{44}(1)c_{45} + D_{45}(1)c_{55} + D_{46}(1)c_{65} = 0 \tag{6.5}$$

$$D_{41}(1)c_{16} + D_{42}(1)c_{26} + D_{43}(1)c_{36} + D_{44}(1)c_{46} + D_{45}(1)c_{56} + D_{46}(1)c_{66} = 0 \tag{6.6}$$

Short Run Restrictions

It is a common practice in the literature that the world oil price is determined exogenously by oil exporting countries, indicating that external shocks do not affect the oil price contemporaneously, at least within a month, so $c_{12} = c_{13} = c_{14} = c_{15} = c_{16} = 0$ (See Kim and Roubini, 2000). Huang and Guo (2007) model oil price as being completely exogenous even in the long run. We deem this assumption too strong. We believe that oil price, set mainly by oil exporting countries, does respond to supply and demand shocks in the world economies in the long run. We would rather leave it to the data.

On the US side, we assume that US real output does not contemporaneously respond to China's aggregate supply shock, but may do so through the real exchange rate, that is, $c_{24} = 0$. We assume contemporaneous price stickiness in the US relative to China's aggregate demand shock, $c_{35} = 0$, at least within a month. We believe that the transmission from China's aggregate demand shock to the US consumer price is mainly through the exchange rate channel. Evidence suggests that there are not only low exchange rate pass-through from China to the US, as in Marazzi and Sheets (2007), but also slow pass-through from the exchange rate to consumer prices in general, as in Goldberg and Knetter (1997). Following Kim (2003) and Kim and Roubini (2000), price is assumed not to respond to exchange rate shock contemporaneously, thus, $c_{36} = 0$.

On China's side, price stickiness implies that $c_{56} = 0$ (see Mehrotra, 2007). We did not restrict the Chinese output from responding to US aggregate supply and aggregate demand shocks contemporaneously due to China's heavy reliance on the US as its export market, requiring China to respond promptly to shocks in the US, even within a month.

To summarize our six long run restrictions and nine short run restrictions, the expanded form of $G(L)$ is defined as follows:

$$\begin{bmatrix} G_{11}(1) & G_{12}(1) & G_{13}(1) & G_{14}(1) & G_{15}(1) & G_{16}(1) \\ G_{21}(1) & G_{22}(1) & 0 & G_{24}(1) & 0 & 0 \\ G_{31}(1) & G_{32}(1) & G_{33}(1) & G_{34}(1) & G_{35}(1) & G_{36}(1) \\ G_{41}(1) & G_{42}(1) & 0 & G_{44}(1) & 0 & 0 \\ G_{51}(1) & G_{52}(1) & G_{53}(1) & G_{54}(1) & G_{55}(1) & G_{56}(1) \\ G_{61}(1) & G_{62}(1) & G_{63}(1) & G_{64}(1) & G_{65}(1) & G_{66}(1) \end{bmatrix} = D(L) \begin{bmatrix} c_{11} & 0 & 0 & 0 & 0 & 0 \\ c_{21} & c_{22} & c_{23} & 0 & c_{25} & c_{26} \\ c_{31} & c_{32} & c_{33} & c_{34} & 0 & 0 \\ c_{41} & c_{42} & c_{43} & c_{44} & c_{45} & c_{46} \\ c_{51} & c_{52} & c_{53} & c_{54} & c_{55} & 0 \\ c_{61} & c_{62} & c_{63} & c_{64} & c_{65} & c_{66} \end{bmatrix}$$

EMPIRICAL RESULTS

Data and Preliminary Analysis

The data are monthly from 1994:1 to 2010:12. Oil price, US consumer price, US industrial production, nominal bilateral Renminbi/Dollar exchange rate (period averages) are from the *International Financial Statistics* of the IMF. China's industrial production and consumer price are from the *IFS* and China's *Monthly Economic Indicators* and other reports of the National Bureau of Statistics of China. The bilateral real exchange rate (RER) is constructed as the nominal bilateral exchange rate (NER) of Renminbi per USD adjusted by the relative prices of the two economies. That is, RER = NER x (USCPI/CNCPI). The resulting time series is then normalized using 2005 as the base year. Constructed as such, an increase in RER implies a real depreciation in the Renminbi and a real appreciation in the US dollar. All six variables are indexed (2005=100), seasonally adjusted, and in logarithmic form.

Before proceeding with the VAR estimation, we test for unit root and cointegration in our data. For stationarity, we use the Dickey-Fuller test, the Phillips-Perron test, and the KPSS test. For cointegration, we use the Johansen and Juselius (1990) maximum likelihood procedure. All our variables are clear of the unit root and cointegration tests at the first difference.[2]

Impulse Responses

Given our system being stationary at first differences and non-cointegrated, we estimate the VAR model assuming 6 lag[3]. Figure 1 presents the estimated impulse responses.

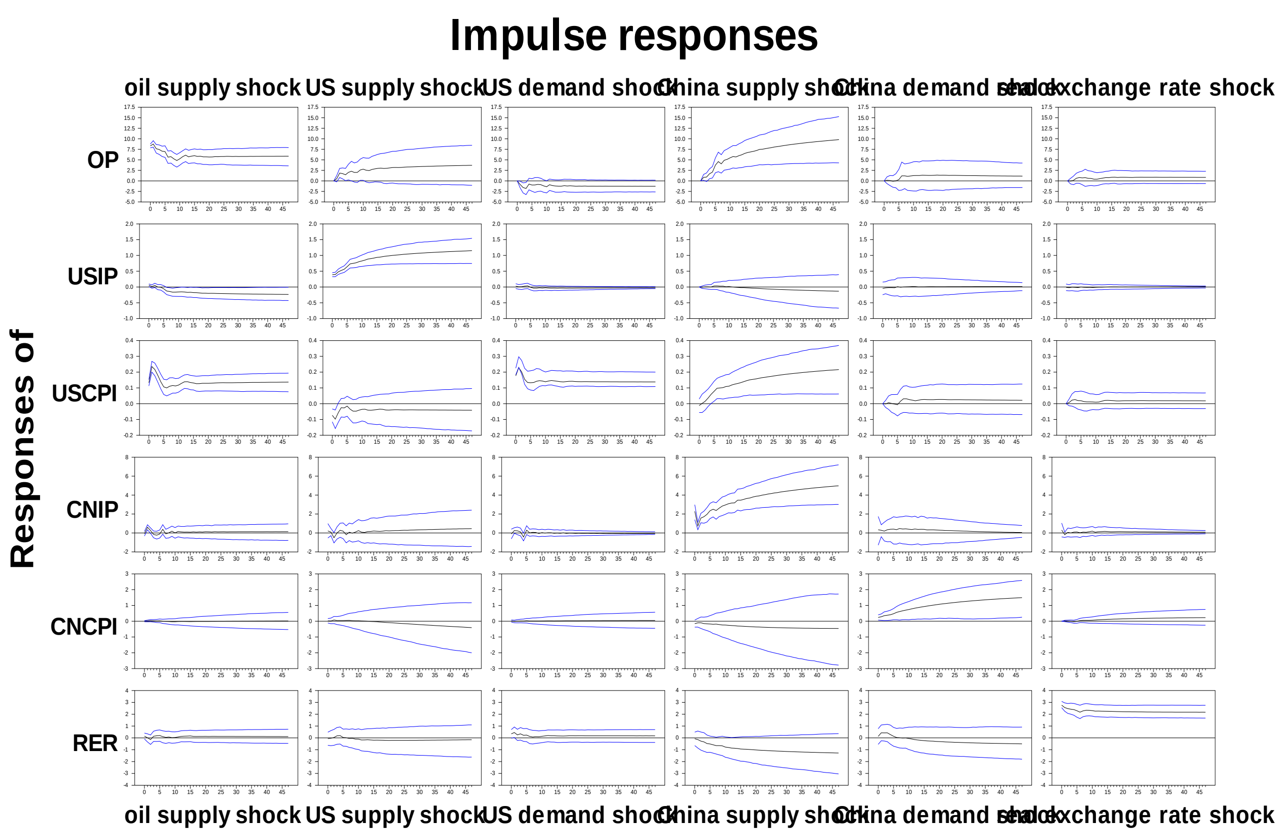
We first look at the impulse responses of the bilateral real exchange rate to the various structural shocks.

A positive shock in the oil price leads to a permanent depreciation in the real exchange rate for China. A possible explanation for this result is that as China relies on imported oil, its terms of trade worsen with increases in the oil price. Though insignificant, our result did not show the perverse effect found in Huang and Guo (2007), who identified a permanent appreciation for real RMB in response to an oil price shock.

A positive aggregate supply shock in the US leads to a permanent real exchange rate depreciation for the US (appreciation for China). This is in conformity with the theory that a positive supply shock will lead to a fall in the relative price of home output and hence a permanent depreciation in the real exchange rate of home currency (US dollar). A positive aggregate demand shock in the US tends to appreciate the real dollar (depreciate the real RMB) permanently. In consistency with the theory, a permanent demand shock increases the relative price of home output, hence appreciates home currency's real exchange rate (the US dollar).

A positive aggregate supply shock in China leads to a statistically significant appreciation in the real exchange rate for China. Unlike what is found with the US supply shock, this seemingly perverse response could be explained by the Balassa-Samuelson effect. According to Balassa (1964) and Samuelson (1964), countries under rapid economic growth will experience appreciation in their real exchange rate as a result of the distortion in purchasing power parity resulting from the international differences in relative productivity between the tradable goods sector (mainly manufacturing and agricultural goods) and the non-tradable goods sector (mainly service)[5]. In the past decades, China has maintained two-digit economic growth, and its productivity rapidly caught up with other industrial countries, in the tradable good sector. The industrial production used as China's output is more in line with the tradable good sector of China. Similar to what is found with the U.S. demand shock, a positive aggregate demand shock in China leads to a real exchange rate appreciation for China. These results are consistent with the theory, indicating that the model is well justified.

FIGURE 1[3]



Next, we look at how country level outputs and consumer prices respond to the exchange rate shock. Both China's and US industrial outputs do not seem to respond to the exchange rate shock. Both China's and US consumer prices increase slightly in response to a positive shock in the bilateral real exchange rate (an appreciation for the US), however, the results are not statistically significant. These findings indicate that changes in the exchange rate won't affect the real economy in either country, suggesting that changing the real exchange rate may not be an effective solution to address the trade imbalances between the two countries.

Variance Decompositions

Table 1 presents the forecast error variance decompositions, which are used to examine the relative importance of different shocks in explaining the fluctuations of the variables.

TABLE 1
FORECAST ERROR VARIANCE DECOMPOSITION

Variables	Time horizon	Forecast error variance decomposition explained by					
		ε^{os}	ε^{s}_{US}	ε^{d}_{US}	ε^{s}_{CN}	ε^{d}_{CN}	ε^{er}
$\Delta oilp$	1	100	0	0	0	0	0
	4	83.77	4.17	3.67	4.11	2.15	2.13
	12	65.31	7.12	6.79	9.79	6.45	4.54
	24	64.53	7.31	6.91	9.89	6.59	4.77
	48	63.81	7.57	7.17	9.96	6.65	4.85
$\Delta USIP$	1	1.79	73.65	2.98	0	15.69	5.89
	4	6.15	60.87	5.71	4.14	15.21	7.91
	12	9.54	56.32	6.46	4.63	14.76	8.29
	24	9.87	54.17	7.18	5.85	14.62	8.31
	48	9.91	53.93	7.07	6.75	14.15	8.19
$\Delta USCPI$	1	26.16	8.97	61.13	3.74	0	0
	4	28.75	10.76	52.31	4.17	2.01	1.99
	12	27.36	11.68	45.67	6.18	5.02	4.09
	24	26.79	11.97	43.83	6.98	5.89	4.54
	48	26.13	12.23	41.79	7.31	6.98	5.56
$\Delta CNIP$	1	1.03	9.79	3.11	58.75	18.65	8.67
	4	6.79	11.17	5.14	51.98	15.83	9.08
	12	9.81	12.01	10.77	43.67	14.38	9.35
	24	10.52	12.23	11.07	43.54	13.21	9.43
	48	10.57	13.89	12.03	42.61	11.76	9.14
$\Delta CNCPI$	1	1.18	10.09	3.54	37.65	47.54	0
	4	3.11	12.16	5.01	34.75	43.55	1.43
	12	3.56	13.54	5.37	32.86	40.8	3.87
	24	3.98	14.12	5.79	32.8	38.18	5.13
	48	4.23	15.67	6.21	30.65	37.98	5.26
ΔRER	1	0.97	4.32	3.16	2.76	6.67	82.11
	4	4.23	4.97	3.97	4.51	8.73	73.59
	12	5.19	7.12	5.84	5.82	10.61	65.41
	24	5.77	7.76	6.29	7.29	11.5	61.39
	48	6.01	8.03	6.89	8.15	11.77	59.15

Note: Estimation of the benchmark model is done with 6 lags assumed over the whole data period: 1994-2010.

It is shown that variations in the bilateral real exchange rate is mainly explained by exchange rate shocks, which account for around 80% in the short run and 60% in the long run. The next important factor is China's aggregate demand shock, which is around the teens and increases slightly over time. China's aggregate supply shock, US aggregate supply and demand shocks, and oil-induced supply shock each account for less than 10% of the total variation in the bilateral real exchange rate, with increases in the variance decompositions over time. These results are in line with the existing literature. Wang (2005) and Huang and Guo (2007) find that the magnitude of exchange rate shocks (defined as real demand shocks in their work) lies within the range of sixties to eighties percentage points. Other shocks, supply and nominal shocks explain a total of 20% to 40% of total variation in China's real exchange rate.

Combined with the impulse responses, we can conclude that US shocks, supply or demand, are not important in explaining the fluctuations in the bilateral real exchange rate. Neither does the oil shock. China's domestic shocks have a slightly higher weight in the fluctuations of the bilateral real exchange rate, especially China's demand shocks. However, the US-China bilateral real exchange rate remains largely unexplained by the country level macroeconomic shocks, as the exchange rate shock accounts for the dominant weight of 60% to 80% of the fluctuations.

These results are not surprising and suggest the following implications for policy making. First, the US and China are both large economies. Given the depth and breadth of each, they can stay quite insulated from each other's macroeconomic shocks and thus neither alone may exert a dominant influence on the bilateral real exchange rate. Any significant change in the bilateral real exchange rate may require considerable coordination between the two monetary authorities. Second, the bilateral real exchange rate is mainly explained by factors outside traditional macroeconomic scope, indicating that policy makers need to look beyond traditional monetary and fiscal policies to address any exchange rate concerns, one such area could be the financial markets (and foreign exchange markets).

Next, we look at the relative importance of the exchange rate shock as an explanatory factor of variations in the two countries' industrial outputs and consumer prices. Though the variance decompositions remain less than 10% for all four variables, the pattern seems interesting in that for both the industrial outputs, the weight of exchange rate shocks is higher than for the two consumer prices. For the consumer prices in both countries, exchange rate shock explains a range of 0 to 5.6% of the variations over time; while for the industrial outputs, it explains 6%-8% of the U.S. and 8%-9% of China's industrial outputs over time.

On one hand, these findings may be the result of the relatively low and delayed exchange rate pass-through to China's CPI as documented in existing research (Jin, 2011; Shu and Su, 2009). On the other hand, the relatively low variance decompositions of the exchange rate shock (under 10%) on industrial outputs may suggest that changing the exchange rate may not be an effective way to correct the trade imbalances. Policy makers may need to take a more holistic approach when addressing the imbalances between the two economies (Li and Xu, 2011; Mohammadi and Yue, 2012; Thorbecke and Smith, 2010; and Zhang, 2012).

CONCLUSION

This paper studies the China-US bilateral real exchange rate and the macroeconomic interactions between the U.S. and China in a structural VAR model. In particular, we are interested in the following two questions. 1) What explains the fluctuations in the bilateral real exchange rate? China's macroeconomic shocks or US macroeconomic shocks? Demand shocks or supply shocks? Does oil shock matter? And 2) Does the bilateral real exchange rate bear the solution to the trade imbalances between the US and China?

To answer these questions, we integrate oil price, US industrial production, US consumer price, China's industrial production, China's consumer price, and the US-China bilateral real exchange rate in a structural VAR model. Using a mixture of long run and short run restrictions, we identify six structural shocks and then study the impulse responses of our variables and the variance decompositions of the forecast error variances relative to these shocks. Our main findings are as the following.

Among the factors examined, US aggregate demand and aggregate supply shocks have no statistically significant impact on the bilateral real exchange rate. It is China's aggregate supply shock and exchange rate shock that explain the fluctuations the most. We also find evidence for the Balassa-Samuelson effect for China, that is, a positive aggregate supply shock in China leads to statistically significant appreciation in the bilateral real exchange rate for China. It is also documented that exchange rate shock plays little role in explaining the variations in each country's output or price level, suggesting that exchange rate may not be an effective solution to the trade imbalances between the two economies.

ENDNOTES

1. People's Bank of China announced that RMB would be allowed to move by $\pm 0.3\%$ relative to the dollar and $\pm 3\%$ relative to other non-dollar currencies in its basket on a daily basis; and the RMB exchange rate would be determined more by the market supply and demand. Lately, RMB's daily variation band relative to the dollar has been widened to $\pm 1\%$.
2. The results are not shown to save space and can be available upon request.
3. See Kim and Roubini (2000).
4. The dashed lines are the .16 and .84 fractiles calculated from Monte Carlo Integration with 1000 draws. Hence, the bands are one standard deviation bands.
5. During the development process, productivity tends to increase more quickly in the tradable goods sector than in the services sector. Given that the prices of tradable goods are set by international competition, an increase in productivity in this sector leads to an increase in wages, which is not detrimental to competitiveness. Since this increase in wages is passed through the whole economy there is a rise in relative prices in the non-tradable goods sector, where productivity has not grown at the same pace. Given that the price index is an average of these two sectors prices, there is an increase in the prices of domestic goods relative to those from abroad, which results in an appreciation of the real exchange rate. (See Coudert and Couharde, 2007)

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