Volatility of Triangular-Arbitrage-Free Exchange Rates and Bilateral Trade: A New Approach

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ABSTRACT

In this paper, we propose a new approach to resolve the potential reversal causality problem with assessing the effects of exchange rate volatility on bilateral trade flows. The approach is based on the introduction of the triangular-arbitrage-free exchange rates, through which the bilateral exchange rate between the trade partners could be decomposed into a pair of bilateral exchange rates of these two currencies to a third currency. Using a novel monthly bilateral-trade dataset between China and Singapore over 21 years, from 1993 to 2013, we not only empirically show the advantage of our new approach in correcting the biased estimation resulting from the conventional approach, but also figure out the mechanism of the true effects of interest.

Keywords: Triangular-Arbitrage-Free Exchange Rates, Volatility, Bilateral Trade

JEL Classification: F14, F31, F32

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1. Introduction

As a research question emerging with increased exchange rate volatility following the breakdown of the Bretton-Woods system in 1973, the relationship between exchange rate volatility and international trade flows has attracted a great deal of attention. In particular, the heavily debated question is whether exchange rate volatility depresses international trade.

Following the seminal work by Clark (1973), who established a negative relationship between exchange rate volatility and international trade based on a simple but relatively well-known model, Hooper and Kohlhagen (1978) redefined the model and tested empirically. However, Hooper and Kohlhagen (1978) failed to find any significant negative effects of exchange rate volatility on trade volume. Using similar methodology, but a real rather than nominal exchange rate risk measure, Cushman (1983) did report some significant negative impacts. Similarly, the IMF (1984) examined the effects of greater exchange rate volatility on global trade through running an extensive number of bilateral trade flow equations based on a specification similar to Cushman (1983), but with more recent observations, and concluded that the evidence concerning a negative effect of the increased exchange rate volatility on global trade was slim. More recently, numerous studies have followed, including Cushman (1986), Cushman (1987), Thursby and Thursby (1987), Koray and Lastrapes (1989), Pozo (1992), Gagnon (1993), Chowdhury (1993), Caporale and Doroodian (1994), Broll and Eckwert (1999), Aristotelous (2001), Barkoulas, Baum, and Caglayan (2002), IMF (2004), Tenreyro (2007), Byrne, Darby, and MacDonald (2008), Huchet-Bourdon and Korinek (2011) and Huchet-Bourdon and Korinek (2012). Unfortunately, however, no consensus about the effects of exchange rate volatility on the flow of trade has been achieved. For a more recent and detailed review, one may refer to Auboin and Ruta (2011).

While the literature has mainly focused on the effects of exchange rate volatility on trade volume, there are also discussion and investigation on the "reverse" direction – the effects of international trade on exchange rate volatility. Early in the 1960's, Mundell (1961) conjectured that trade flow would help to stabilize real exchange rate fluctuations, thus reducing the real exchange rate volatility. Empirically, Broda and Romalis (2011) figure out that ignoring the causal effect of trade on exchange rate volatility results in overestimation of the true impact of exchange rate volatility on trade. By employing the distance between trading partners as an instrumental variable (IV henceforth), they manage to show this point – "(Our) figures show a strong positive relationship between real exchange rate volatility and distance between trading partners. Since distance cannot be affected by volatility, this strong relationship suggests that greater distance between countries significantly increases bilateral exchange rate volatility through the effect of distance on the intensity of commercial relationship such as trade".

Obviously, the findings of Broda and Romalis (2011) suggest that the previous results without dealing with the potential reversal causality problem should be taken carefully, and furthermore, it's worth revisiting the assessment of effects of exchange rate volatility on bilateral trade flows. However, the IV suggested by Broda and Romalis (2011) seems to be faced with twofold problems. Firstly, this approach implicitly assumes that effects of exchange rate volatility on bilateral trade don't change over time since the distance between two countries is constant, and thus it is not applicable to dynamic analysis. Secondly, if one's interest lies on the bilateral trade between a specific pair of trading partners, he/she may find it powerless to use the distance between the two countries as an IV, again because it is constant.

In this paper, we are proposing another approach to resolve the potential reversal causality problem through introducing the triangular-arbitrage-free exchange rates, by which we mean to decompose the bilateral exchange rate between the trade partners into a pair of bilateral exchange rates of these two currencies to a third currency. Basically, the pair of decomposed exchange rates is not expected to be affected by the bilateral trade between the trade partners under discussion, but variations in the decomposed exchange rates would be translated into variations in the bilateral exchange rate between the trade partners and in turn affect the trade flow between the two countries. In this sense, the potential reversal causality problem is expected to be avoided. Based on a novel monthly bilateral-trade dataset between China and Singapore over 21 years, from 1993 to 2013, we estimated a modified gravity equation which incorporates the triangular-arbitrage-free decomposed exchange rates and provide strong evidence to show the advantages of this new approach.

The remainder of the paper proceeds as follows: Section 2 discusses the feasibility of the introduction of the triangular-arbitrage-free exchange rates as well as the econometric model to accommodate this modification; Section 3 presents the empirical results and discusses the robustness of the results; Section 4 concludes.

2. Data and Methodology

2.1 Data and Variables

For the empirical analysis, we novelly compile a dataset covering 252 months from January 1993 through to December 2013, including the bilateral trade data between China and Singapore, major macroeconomic statistics of China and Singapore, as well as various bilateral exchange rates, including those of CNY-SGD, CNY -USD, SGD -USD, CNY-SDR and SGD-SDR.[3]

With regards to our dataset, there are several features worthy highlighting. Firstly, researchers mostly employed annul data and quarterly data in the past, but seldom monthly data. Fortunately, we have collected considerably enough monthly data for our study and can investigate some short-run properties using these higher-frequency data; Secondly, due to the unavailability of monthly GDP data, we use the monthly retails sales data for both countries as a measure for monthly national incomes[4], and construct a Retail Sales Index (RSI) ; Thirdly, we follow the literature, and construct a measure for the bilateral exchange rate volatility based on the moving average method; that is, $V_t = \left[\frac{1}{m}\sum_{i=1}^{m}(lnR_{t+1-i} - lnR_{t-i})^2\right]^{1/2} \times 100\%$, where different m could be tried, with a benchmark value set to be 4.

Moreover, 11 month dummies are also defined, M_i $(i = 1, \dots, 11)$, corresponding to the first eleven months of a year and would be used to absorb the seasonality factors. Besides, considering the several relevant reforms/policies in both countries over the sample period from January 1993 to December 2013, including the admission of China to WTO in December 2001, the exchange rate regime reform of China in 2005, and the China-Singapore Free Trade Agreement (CSFTA) becoming effective in January 2009, we also define another three dummies as follows.

$$WTO_t = \begin{cases} 0, & if\ Month < 2001m12 \\ 1, & if\ Month \geq 2001m12 \end{cases}, \quad FTA_t = \begin{cases} 0, & if\ Month < 2009m1 \\ 1, & if\ Month \geq 2009m1 \end{cases}$$

$$Reform\_Dummy_t = \begin{cases} 0, & if\ Month < 2005m7 \\ 1, & if\ Month \geq 2005m7 \end{cases}.$$

[3] CNY, an abbreviation for "Chinese Yuan", is the ISO code for China's currency, Renminbi, which is also abbreviated as RMB; SGD refers to the Singapore dollar; USD refers to the US dollar, and SDR refers to the Special Drawing Right at the International Monetary Fund (IMF).

[4] Various correlation tests conducted on quarterly retails sales and quarterly GDP suggest that the retails sales are good measure for national incomes.

2.2 Triangular-Arbitrage-Free Exchange Rates

Due to the potential reversal causality problem figured out by Broda and Romalis (2011), we would not use the bilateral exchange rate of CNY-SGD directly in assessing the effects of interest, since the exchange rate of CNY-SGD as well as its volatility is highly likely to be affected by the bilateral trade between China and Singapore. Instead, we would like to argue that the bilateral trade between China and Singapore would be less likely to affect the bilateral exchange rates of CNY-USD and SGD-USD, which are expected to be determined by the bilateral economic relations between the two countries and US, respectively. However, if one examines the exchange rate regimes of China and Singapore, both of which claim a managed floating exchange rate regime, he/she may find that the US dollar plays a critical role in determining the exchange rate of CNY-SGD, in the sense that there is little triangular arbitrage among the three rates, CNY-USD, SGD-USD, and CNY-SGD.

Dividing the CNY-USD exchange rate (month end rate) by the SGD-USD exchange rate, we get a self-calculated CNY-SGD exchange rate, which turns out almost the same as the official data released by the Monetary Authority of Singapore (MAS). Furthermore, a simple OLS regression is run to test this finding, and we cannot reject the hypothesis that the official CNY-SGD Exchange Rate is equal to the self-calculated CNY-SGD Exchange Rate, as shown in Figure 1 below.

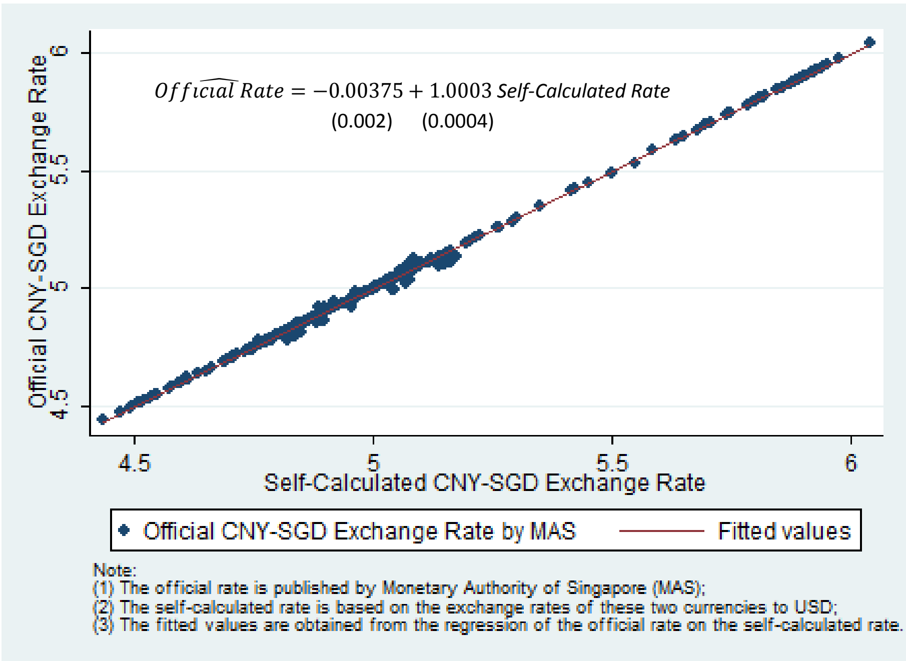

Figure 1 Illustration of the CNY-SGD Exchange Rate Regime

Therefore, this triangular-arbitrage-free property suggests we can decompose the CNY-SGD exchange rate into the CNY-USD exchange rate and the SGD-USD exchange rate. Moreover, from the practical perspective, the US dollar is the major invoicing currency in the bilateral trade between the two countries, although CNY has begun to be used partly since late 2010, and this provide another rational for the triangular-arbitrage-free exchange rate decomposition since both exporters and importers cares more about the rates of their domestic currencies against the US dollar.

2.3 Econometric Model

Following the literature, a modified gravity equation, which incorporates the triangular-arbitrage-free decomposed exchange rates, is specified as a benchmark to model the long-run bilateral exports between China and Singapore.

$$ln\left(Q_{jt}^{i}\right) = \theta_0^i + \Theta^i \cdot X_t + \mu_{jt}^i \tag{1}$$

where Q_{jt}^{i} denotes the monetary volume (in US dollars) of exports from country i to country j, $X_t = (lnR_{jt}^{US}, lnR_{it}^{US}, V_{jt}^{US}, V_{it}^{US}, lnCPI_{jt}, lnCPI_{it}, lnY_{jt}, lnY_{it}, Dummies)$, with R_{kt}^{US} denoting the spot price of USD in terms of country k's currency $(k = i, j)$, V_{kt}^{US} denoting the volatility of R_{kt}^{US} $(k = i, j)$ as defined in Section 2.1, CPI_{kt} denoting the consumer price index in country k $(k = i, j)$, Y_{kt} denoting the national income of country k $(k = i, j)$, and $Dummies$ referring to the dummy variables defined in Section 2.1, including WTO_t, FTA_t, $Reform\_Dummy_t$ and the 11 month dummies, and correspondingly, $\Theta^i = (\theta_1^i, \theta_2^i, \theta_3^i, \theta_4^i, \theta_5^i, \theta_6^i, \theta_7^i, \theta_8^i, \theta_9^i, \dots, \theta_{22}^i)$.

Different from specifications in most of the literature, we include not only the exchange rate volatilities, but also the exchange rate level, since revaluation of exchange rates is also expected to affect the trade volume in the long run. Besides, we also include interaction terms of $Reform\_Dummy_t$ with R_{kt}^{US} and V_{kt}^{US} $(k = i, j)$. Therefore, the coefficients of interest in this study are θ_1^i, θ_2^i, θ_3^i and θ_4^i, as well as coefficients of the interaction terms.

In addition, for the sake of comparison, we also estimate the conventional equation in the literature, without decomposing the bilateral CNY-SGD exchange rate, as follows:

$$ln\left(Q_{jt}^{i}\right) = \gamma_0^i + \Gamma^i \cdot X_t + \mu_{jt}^i \tag{2}$$

where $X_t = (lnR_{jt}^{i}, V_{jt}^{i}, lnCPI_{jt}, lnCPI_{it}, lnY_{jt}, lnY_{it}, Dummies)$, with R_{jt}^{i} denoting the exchange rate of currency i and j, V_{kt}^{US} denoting the volatility of R_{jt}^{i}, and $\Gamma^i = (\gamma_1^i, \gamma_2^i, \dots, \gamma_{20}^i)$.

3. Results and Discussion

3.1 Estimation Procedure

As is customary in time-series analysis, before estimating Equation (1) and (2), the stationary properties of each individual series are tested. The results based on the augmented Dickey-Fuller (ADF) unit root tests, as attached in the Online Appendix, indicate that all series but the CPI of China, RSI of Singapore and the CNY-SGD exchange rate are $I(1)$ at a 5% significance level.

The next step is to test for co-integration among the major variables of interest in Equation (1) and (2) using the Johansen co-integration approach. Various lags are tried and the results, also attached in the Online Appendix, suggest that there is a significant con-integration relationship among variables of major interest. Alternatively speaking, error-correction is necessary to assess the effects of exchange rate volatility on bilateral trade flows.

In this respect, given the estimation results for the long-run relationship, an error-correction model is specified as follows.

$$\Delta ln\left(Q_{jt}^{i}\right) = \phi_0^i + \sum_{k=0}^{T_1} \Phi^i \cdot \Delta X_{t-k} - \sum_{k=1}^{T_2} \eta_k^i \cdot ERROR_{jt-k}^{i} + \omega_{jt}^{i} \tag{3}$$

where Δ refers to the difference operator, the dummies like WTO_t, FTA_t and $Reform\_Dummy_t$ are not included in ΔX_{t-k}, and only the 11 month dummies are included. Correspondingly, $\Phi^i = (\phi_1^i, \phi_2^i, \phi_3^i, \phi_4^i, \phi_5^i, \phi_6^i, \phi_7^i, \phi_8^i, \phi_9^i, \dots, \phi_{19}^i)$, the term $ERROR_{jt-k}^{i}$ is defined as the residual series of Equation (1) and (2); that is, $ERROR_{jt-k}^{i} = ln\left(Q_{jt-k}^{i}\right) - ln\left(\widehat{Q_{jt-k}^{i}}\right)$, and, T_1 as well as T_2 is to be determined based on standard time series analysis procedures.

3.2 Main Results

We firstly estimate Equation (1) and (2) for both exports from China to Singapore and exports from Singapore to China, and coefficients of major interest are reported in Table 1. As one may find in Column (3) and (4), in the long run, depreciation of CNY against SGD (increase in the rate) is estimated to be significantly related with more export from China to Singapore before the 2005 exchange rate regime reform of China; however, after the 2005 reform, the sign turns to the opposite significantly. Moreover, depreciation of CNY against SGD is also significantly related with more export from Singapore to China over the whole period. Turning to Column (1) and (2), one may find that depreciation of CNY against USD is significantly related with less export from China to

Singapore, which does not change significantly after the 2005 exchange rate regime reform, while, other things being equal, depreciation of SGD against USD turns significantly related with more export from China to Singapore, which seems not affected by China's exchange rate regime reform. However, the negative correlation between the CNY-USD exchange rate and the exports from Singapore and China witnessed a sharp and significant change after the 2005 reform.

Table 1 Estimation of the Co-Integration Equation

	Log of Exports from China to Singapore	Log of Exports from Singapore to China	Log of Exports from China to Singapore	Log of Exports from Singapore to China
	(1)	(2)	(3)	(4)
Log of SGD-USD Rate	-0.838***	-1.582***		
	(4.90)	(6.30)		
Log of CNY-USD Rate	-0.475*	-1.559***		
	(1.93)	(3.32)		
Volatility of SGD-USD Rate	0.015	0.122***		
	(0.39)	(3.49)		
Volatility of CNY-USD Rate	-0.002	0.033*		
	(0.13)	(1.86)		
Log of CNY-SGD Rate			0.873***	1.210***
			(5.59)	(4.89)
Volatility of CNY-SGD Rate			0.016	0.114***
			(0.59)	(3.73)
Reform Dummy	1.191	-11.426***	2.747***	-0.158
	(0.96)	(5.98)	(4.26)	(0.19)
Interaction of Reform Dummy with the Log of CNY-USD Rate	-0.665	5.157***		
	(1.11)	(5.61)		
Interaction of Reform Dummy with the Log of SGD-USD Rate	0.985**	0.964**		
	(2.36)	(2.07)		
Interaction of Reform Dummy with Volatility of CNY-USD Rate	-0.234**	0.282***		
	(2.16)	(2.94)		
Interaction of Reform Dummy with Volatility of SGD-USD Rate	-0.129**	-0.160***		
	(2.32)	(2.97)		
Interaction of Reform Dummy with the Log of CNY-SGD Rate			-1.549***	0.001
			(3.89)	(0.00)
Interaction of Reform Dummy with Volatility of CNY-SGD Rate			-0.138***	-0.180***
			(2.97)	(3.40)
Adjusted R-squared	0.99	0.97	0.98	0.96

Note: (1) Figures in parentheses are the robust *t*-statistics; *, **, and *** denote significance levels of 10%, 5% and 1%.
(2) Only coefficients of major interest are reported in this table, and complete estimation results are attached in the Online Appendix.

Regarding the effect of exchange rate volatility on the trade flow, one may find that the effect of volatility in the CNY-SGD exchange rate on the export from China to Singapore is not significant in the long run before the 2005 reform but turns significantly negative after the reform, and that the effect on the export from Singapore to China is positive but falls sharply to negative after the 2005 reform. In the new approach, the effect of the CNY-USD exchange rate volatility on the export from

China to Singapore is insignificantly different from zero before the 2005 reform, but turns to be significantly negative after the reform; and the SGD-USD exchange rate volatility exhibits a similar pattern. What's is more interesting is the positive effect of the CNY-USD exchange rate volatility on the export from Singapore to China becomes even stronger after the 2005 reform, one explanation for which is that although the CNY-USD exchange rate stated exhibiting higher volatility since the 2005 reform, the direction of changes has always been the same – appreciation.

Secondly, based on the estimated co-integration equation, the error-correction model, Equation (3), is estimated with the appropriate number of lags chosen as 2, and coefficients of major interest are reported in Table 2. The significant negative signs in the one-month-lagged error equations across the four columns indicate that a proportion of deviations from the long-run relationship in one period would be corrected in the next period; in other words, higher (lower) export in one period than the level predicted by the long-run relationship is always followed by a decrease (increase) in the next period. What's more important is that the significant negative short-run effects of the CNY-SGD exchange rate on the bilateral trade seem to be misleading, since the triangular-arbitrage-free decomposition approach suggests that the effects result from the CNY-USD rate but not from the SGD-USD rate.

3.3 Robustness Checks and Discussion

These results in Section 3.2 indicate significant differences between the two approaches, which persist in both directions, and both the long-run and the short-run. To ensure the acceptability of the results, a number of robustness tests are performed. Firstly, various serial correlation tests indicate that there is no serial correlation in the residuals of the error-correction equation at the 5% level; Secondly, different exchange rate volatility measures, different price indices, as well as different measures for incomes are tried; Thirdly, different exchange rates are also tried, with the month-end exchange rates replaced by the month-average exchange rates, and the USD replaced by the FDR to get the triangular-arbitrage-free decomposition of the CNY-SGD exchange rates.

All of the tests above indicate that the findings in Section 3.2 are robust. In other words, we have not only confirmed the bias due to the reversal causality problem as figured out by Broda and Romalis (2011) but also provided a new strategy to resolve the problem, especially in a two-country context where Broda and Romalis (2011)'s IV does not work. To save space, the robustness results are attached in the Online Appendix.

Table 2 Estimation of the Error Correction Model

	First-Order Difference in Log of Exports from China to Singapore		First-Order Difference in Log of Exports from Singapore to China	
	(1)	(2)	(3)	(4)
L1. Error Equation	-0.736***	-0.735***	-0.861***	-0.774***
	(10.60)	(9.74)	(13.68)	(9.85)
L2. Error Equation	0.112*	0.124**	0.181**	0.218***
	(1.77)	(2.01)	(2.03)	(2.86)
D1. Log of SGD-USD Rate	0.297		-0.019	
	(0.64)		(0.04)	
LD. Log of SGD-USD Rate	0.108		0.204	
	(0.20)		(0.41)	
D1. Log of CNY-USD Rate	-1.443***		-1.197***	
	(7.78)		(3.38)	
LD. Log of CNY-USD Rate	0.240		0.304	
	(1.31)		(1.13)	
D1. Volatility of SGD-USD Rate	0.007		0.007	
	(0.18)		(0.17)	
LD. Volatility of SGD-USD Rate	-0.012		-0.026	
	(0.28)		(0.61)	
D1. Volatility of CNY-USD Rate	0.011		-0.016	
	(1.56)		(1.42)	
LD. Volatility of CNY-USD Rate	-0.015***		-0.016**	
	(3.54)		(2.01)	
D1. Log of CNY-SGD Rate		-0.432		0.026
		(0.87)		(0.05)
LD. Log of CNY-SGD Rate		-0.203		-0.366
		(0.41)		(0.61)
D1. Volatility of CNY-SGD Rate		0.034		0.022
		(0.77)		(0.44)
LD. Volatility of CNY-SGD Rate		-0.078***		-0.139***
		(3.09)		(2.78)
Adjusted R-squared	0.72	0.70	0.66	0.60

Note: (1) L1. refers to the first-order lag operator; L2. Refers to the second-order lag operator; D1. refers to the first-order difference operator; and LD. refers to the first-order lag of the first-order difference.
(2) Figures in parentheses are the robust *t*-statistics; *, **, and *** denote significance levels of 10%, 5% and 1%.
(3) Only coefficients of major interest are reported in this table, and complete estimation results are attached in the Online Appendix

4. Conclusion

We revisit the effects of exchange rate volatility on bilateral trade flows in this paper, with considering the causal effect of trade on exchange rate volatility. Rather than using the distance between trading partners as an IV proposed by Broda and Romalis (2011), which actually does not work for a specific pair of countries, we propose a new strategy to resolve the reversal causality problem with the introduction of the triangular-arbitrage-free decomposed exchange rates, through which the bilateral exchange rate between the trade partners could be decomposed into a pair of bilateral exchange rates of these two currencies to a third currency.

Based on a monthly bilateral-trade dataset between China and Singapore over 21 years, from 1993 to 2013, a modified gravity equation that incorporates the triangular-arbitrage-free decomposed exchange rates is estimated based on the error-correction approach. The empirical results support two main conclusions. Firstly, either in the long run or in the short run, the conventional approach in the literature ignoring the potential reversal causal effect tends to result in biased and even misleading estimation for the true impact of exchange rate volatility on trade. Secondly, our new approach proves to be able to figure out the mechanism of the true effects. For example, the seemingly negative short-run effects of the CNY-SGD exchange rate on the bilateral trade turn to be effects resulting from the CNY-USD rate but not from the SGD-USD rate. Besides, our robust results also add new evidence to the literature upon the effects of exchange rate variations, including variations of both the rate level and the rate volatility, on bilateral trade flows.

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