Exchange rate determination and dynamics in China: A market microstructure analysis

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Abstract

This paper provides a market-microstructure analysis of exchange rate dynamics in the Chinese foreign exchange market using a vector autoregressive (VAR) modeling framework. An index of order flow is constructed in the Chinese context to reflect excess demand pressure in the foreign exchange market. The VAR model is then estimated to examine whether, and to what extent, order flow influences the long-term level and short-term fluctuations of the Chinese exchange rate. Focusing on the relationship between cumulative order flow and the exchange rate of the Chinese renminbi (RMB) against the US dollar, we find that order flow as a measure of excess demand pressure explains a significant part of the fluctuations in the RMB-dollar exchange rate. Specifically, the results show that there is a long-term cointegrating relationship among the order flow, macro factors and the exchange rate. Overall, these findings are important in understanding the role of order flow in exchange rate determination and bear important implications for practitioners and market regulators.

Keywords: exchange rates; microstructure; order flow; foreign exchange

JEL classification: F31, G14, G15

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1. Introduction

With increasing empirical evidence showing that macroeconomic models of exchange rate determination perform poorly in capturing foreign exchange rate movements (Meese and Rogoff, 1983; Frankel and Rose, 1995), the market microstructure approach to the exchange rate has emerged as a new avenue to explore the forces driving exchange rate movements. Focusing on the pivotal role of order flow in the transaction process, recent theoretical and empirical works based on this approach have demonstrated that this new methodology has promising explanatory power for exchange rate changes (Evans and Lyons, 2002a). However, prior studies in this field have been primarily concerned with key currency pairs of mature economies, and little research has been conducted on the potential influence of order flow on the emerging markets.[1] Given China's growing importance in the world economy in general and international currency relations in particular, there is a pressing need for applying the recent research methodology to further our understanding of the Chinese exchange rate policy. The current research represents the latest attempt of such efforts.

This paper aims to shed some light on exchange rate determination in China using a VAR model, generated within the market microstructure framework, to estimate the relationship between order flow and the exchange rate in the Chinese foreign exchange market. Specifically, we seek to address the following questions:

(1) Does the order flow help to capture the exchange rate movements of Chinese currency, the renminbi (RMB) against the US dollar as representative of China's exchange rate?

[1] A notable exception is the recent work of Duffuor et al. (2011) who, by adopting the microstructure approach, examine the explanatory power of order flow in Ghanaian foreign exchange market and find that order flow has a significant, positive effect on the official exchange rate in both stable and crisis periods. Wu (2010) and Gereben et al. (2006) are two other studies on emerging markets that adopt a microstructure framework.

(2) How do the long- and short-term factors influence the relative value of the Chinese currency in the foreign exchange market?

The results of our analyses are of direct interest to regulators and policy makers in evaluating the potential role of order flow in influencing the exchange rate movements and to practitioners who invest on the basis of market microstructure variables, treating them as principal indicators for future market movements.[2] Furthermore, this paper adds to the growing literature studying the determinants of foreign exchange rates in a number of ways. First, while the microstructure approach has been used to investigate exchange rate dynamics for a range of major international currency pairs (Osler, 2006; Rime et al., 2010), academic studies of Chinese foreign exchange markets using such an important framework are limited. This lack of research is, perhaps, surprising given the importance of the Chinese markets in terms of both the volume and the value of trade and the growing popularity of the market microstructure approach to exchange rate research. This study presents one of the very few attempts to fill the gap in the literature. The results obtained may be particularly relevant in providing a deeper understanding of foreign exchange market in such an important economy. Second, unlike many previous studies, this paper employs a measure of country risk premium as an exogenous variable to control for the potential sources of common shocks on the exchange rate fluctuations, which appears to be another novelty in the literature.[3] Indeed, this may be a reason why the portion of the exchange rate movements explained by order flow is lower than what has been documented in more developed markets, but unlike previous

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[2] An increasing number of studies have found evidence of a relationship between microstructure variables such as order flow and exchange rates. This idea has drawn additional support from practitioners who believe that, aside from macroeconomic factors, such as interest rates and inflation, order flow is one of the most important forces behind major exchange rate movements.

[3] Wu (2010) argue that macroeconomic variables such as the interest rates, the exchange rates, and the country risk premiums may affect the order flow. Thus, careful attention needs to be paid to these potential sources of common shocks when studying the relationship between order flow and exchange rate movement.

studies in emerging markets, order flow remains a significant factor in our results.[4] Finally, our study takes into account a unique feature of emerging markets, namely, the existence of a strong government intervention and its impact on the exchange rate dynamics.

Overall, this paper contributes to the microstructure approach to the exchange rates research by taking a closer look at the behavior of the exchange rate in China, focusing on the impact of order flow on the exchange rate dynamics. We first construct a measure of order flow that is based on high frequency transaction data from the Chinese market, from which the cumulative daily order flow is calculated. In addition, we also consider the trading system reform and incorporate the consequences of market evolution into our analysis. Our sample period begins with June 2010 to take into account a new “managed floating” exchange rate system re-launched in mid-2010. Furthermore, a control variable (i.e., the country risk premium) is included in our empirical model because prior studies have shown that this risk factor is an important influence of exchange rate dynamics in emerging markets.[5] Finally, using the VAR modeling framework, we investigate whether the cumulative order flow is cointegrated with the exchange rate in the Chinese foreign exchange market.

The main findings of our investigation can be summarized as follows. First, our results indicate that unidirectional causality exists from order flow to exchange rate movements. Moreover, we find that a long-term cointegrating relationship exists between the RMB/USD exchange rate and its main determinants, i.e., the order flow, the proxy for macro influences and the country risk premium. More specifically, the estimated results show that order flow

[4] The authors are grateful to an anonymous referee for pointing this out.

[5] See, for instance, De Medeiro (2004) who find that the country risk premium is a significant factor in influencing the Brazilian foreign exchange market.

not only Granger causes exchange rate movements but also is a significant determinant of the exchange rate in the short run. In our sample, order flow explains approximately 19% of exchange rate movements for every $0.1m RMB/USD purchase. Overall, our findings are consistent with the view that in the Chinese market, order flow as a 'signed' measure of trading volume is able to explain a significant proportion of fluctuations in the exchange rate of the RMB against the US dollar.

The remainder of this paper is organized as follows. The next section briefly reviews previous literature on the microstructure approach to exchange rate dynamics. In section 3, we outline China's exchange rate policy to establish the background for the ensuing analysis. Data and methodological issues relating to our empirical investigation are discussed in section 4. Section 5 presents the estimation results and discusses their main implications. Finally, section 6 provides a summary and concluding remarks.

2. Related Literature

The microstructure approach underscores the central role of the trading process in the price formation in the foreign exchange market (Lyons, 1995). This process can be broadly grouped into three phases (Evans, 2011). First, the customers trade with their personal dealers. Then, these dealers carry their own customer orders to trade with other dealers through the electronic interdealer market; the transactions in this market are known as interdealer trades. In the last round, dealers trade with customers again to balance their net inventory position. In this process, the trading size and transaction position are the most important factors for these transactions. These critical parameters of the market are summarized by order flow, which is the net balance of buyer-initiated and seller-initiated foreign exchange market transactions (Lyons,2001). Measured as the sum of the signed seller-initiated and buyer-initiated orders in the empirical specification, order flow is considered an important information transmission mechanism linking price changes and dispersed information. Indeed, the explanatory role of order flow in exchange rate models has been the focal point of empirical studies in the market microstructure literature, which can be generally catalogued in terms of those using data of customer order flow and those using interdealer order flow. However, the majority of empirical research focuses primarily on the customer order flow as it conveys private information about not only fundamentals but also monetary policy (Rime, 2000; Bjonnes and Rime, 2005; Evans and Lyons, 2006).

Nevertheless, because of the availability of data, many studies have focused on the data of interdealer order flow from the electronic transaction market. For example, Danielsson et al., (2011) investigate 10-month order flow data from the Reuters D2000-2 data platform and find that order flow Granger causes the changes in exchange rate returns. Influential research by Evans and Lyons (2002a) use the interdealer order flow based on the 4-month data of the exchange rates between the deutschemark and the Japanese yen against the US dollar from Reuters D2000-1. In a radical departure from the conventional macro models, the authors develop a hybrid model that contains both a macro variable (interest differential) and a micro variable (order flow). They find that over 60% of the USD/DEM daily changes and 40% of the USD/JPY daily changes can be explained by order flow. In another study, Evans and Lyons (2002b) extend their dataset to seven currency pairs: the US dollar against the pound sterling, Belgian, French and Swiss francs, Swedish krona, Italian lira and Dutch guilder. They find that order flow may generate an R^2 up to 78% on a daily frequency. However, Fisher and Hillman (2003) extend the research of Evans and Lyons (2002b) but get much lower R^2 statistics results. Berger et al. (2008) show that interdealer order flow has a 0.65 correlation with the exchange rate of the EUR/USD.

Osler (2006) summarize three explanations of order flow driving exchange rate movements: the inventory effect, information effect, and downward-sloping demand and liquidity effects. The inventory effect refers to the situation whereby any deviation from the desired inventory level will expose dealers to risk. To avoid undesired risk, dealers will decrease (increase) their prices to attract more buying (selling) orders when their inventory positions are higher (lower) than desired levels. Inventory-based models can successfully explain the temporary changes in the exchange rate but fail to capture permanent exchange rate movements. Information-based models imply that order flow should permanently affect market prices. Hence, exchange rates should be cointegrated with cumulative order flow. Recent research has uncovered evidence for such a stable long-term relationship for several currency pairs (Bjonnes and Rime, 2005; Killeen et al., 2006). However, Boyer and Van Norden (2006) point out that these results are selective and, in some cases, the results are statistically weak and suffer from a small sample bias. They conduct cointegration tests on the dataset of Evans and Lyons (2002a), which is commonly used in other research. Strikingly, they find no evidence of a long-run relationship between order flow and the exchange rate. Osler (2006) also introduce 'downward-sloping demand and liquidity effects' to explain why order flow is important. He suggests where there is long-term downward-sloping demand with a growth in supply, price will decrease in the long run. If there are no changes in the fundamentals, then one country's currency demand is equal to the other country's currency supply. Rime et al.

(2010), however, argue that order flow of other currencies should be included in the model specification, as they can greatly increase the explanatory power of interdealer order flow.

In an early study of the New York Stock Exchange, Hasbrouck (1991) propose a simple linear VAR model for the microstructure study. Payne (2003) apply this modeling strategy to analyze the foreign exchange market. He draws on the 1-week exchange rate of USD/DEM from Reuters D2000-2, covering the time period from 6 October to 10 October 1997. The results show that 60% of the variation can be explained by the private information, suggesting that informed order flow has explanatory power for exchange returns. Froot and Ramadorai (2005) also set up a VAR model to test order flow as a major medium of fundamentals and exchange rate movements. They divide the exchange rate returns into permanent and transitory shocks and study the interactions between them. They illustrate that order flow is related to short-term currency returns but that fundamentals better explain long-term returns and values. These findings highlight the importance of research on the role of order flow in short-term dynamics and long-term determination of the exchange rate.

However, the extant literature has focused on the major currencies. For example, Ito et al. (1998) investigate the JPY/USD and find that the informed order flow can predict the exchange rate over the short time period. Rime (2000) examines five major currencies against the US dollar, DEM/USD, GBP/USD, CHF/USD CAD/USD and JPY/USD, from July 1995 to September 1999. The results of cointegration tests show that the exchange rates of DEM/USD, GBP/USD and CHF/USD have a cointegrating relationship with order flow, indicating that the lagged order flow has an explanatory power of exchange rate movements.

Researchers has also explored the explanatory power of order flow for many other major currencies, including the euro (Evans and Lyons, 2005), the deutschmark (Andersen et al., 2002), and the British pound (Berger et al., 2008).

In recent years, a growing number of studies have analyzed the explanatory power of order flow in emerging markets. Galati (2000) study the currencies of seven emerging markets—Colombia, Mexico, Brazil, India, Indonesia, Israel and South Africa—with 18-month daily trading volume data and finds that most trading volumes are significantly and positively correlated with volatility. Froot and Ramadorai (2005) examine 19 countries with more than four years' daily data and include 111 rates in their international portfolio flows. They find that these flows are strongly significant and positively correlated with contemporaneous exchange rate returns. Frankel (2010) survey the monetary policies of emerging markets and notes that many researchers have designed their models to take into account the unique features of emerging markets, such as imperfect institutions, moral hazard, default risk and illiquidity, asymmetric information, and government intervention. De Medeiros (2004) consider Brazil's foreign exchange market and introduces the country risk premium as an additional control variable. He finds that Brazil's order flow data have a weak performance compared with those in developed countries but that the country risk premium is more significant than other variables. Wu (2010) also add a risk premium as the control factor in his model. He examines both the temporary and permanent period behaviors of commercial and financial customer order flow in the Brazilian foreign exchange market with four years' daily customer transaction data. His results show that financial and intervention flows are positively related with exchange rate movements but that commercial flows are negatively associated with the exchange rate and have feedback effects.

Many other special conditions of emerging market figure prominently in such research. Gereben et al. (2006), for instance, explore the role of domestic and foreign customer flow in the Hungarian foreign exchange market and find that liquidity is largely determined by domestic customer flow while the information of foreign customer flows drives the fluctuations. Galac et al. (2006) study the role of market microstructures in explaining the relationship between trading volume, volatility and bid-ask spreads in Croatia. Ranjan et al. (2008) focus on the exchange rate movements of the Indian foreign exchange market. Duffuor et al. (2012) examine the role of end-user customer order flow in explaining the exchange rate changes in the Ghanaian market. They use the black and official market exchange rates to investigate the roles of expected and unexpected order flows and find that expected order flow has inefficient performance in the foreign exchange market.[6]

Motivated by these empirical studies and findings, we seek to determine in this paper the extent to which order flow explains the behavior of the exchange rate of an emerging market currency against an international key currency, i.e., the exchange rate of RMB against the US dollar. To facilitate such an investigation, it is important to briefly outline the microstructure of the Chinese foreign exchange market centered on the China Foreign Exchange Trading System (CFETS) so as to establish the background knowledge for this system, which is essential for understanding China's exchange rate movements from the market microstructure perspective.

[6] Outside the extant market-microstructure literature, Vygodina et al. (2008) documents that exchange rates overreact to changes in economic fundamentals over the short run but converge in a long run. Using an event-study methodology and the exchange rates of three MENA countries i.e., Egypt, Morocco and Turkey, Chortareas et al. (2012) shows that devaluation announcement caused excess volatility in these markets.

3. Microstructure of Foreign Exchange Market in China

The Chinese foreign exchange market is centered on the China Foreign Exchange Trading System (CFETS). Founded in April 1994, the CFETS is an institution that is under the direct control of China's central bank, the People's Bank of China (PBOC). As the central bank's interbank trading and foreign exchange division, the CFETS is authorized to organize all aspects of China's foreign exchange market under the guidelines to '[adopt] multiple technological means and trading patterns to meet market demands of various levels'. The core of the CFETS' functionality is the organization of China's foreign exchange transactions. The CFETS introduced a FX trading system in April 1994, first, for the currency pair of RMB/USD and, then, for other pairs between Chinese and other non-USD currencies and for foreign pairs between international currencies.[7]

The CFETS has played a significant role in safeguarding RMB exchange rate stability, transmitting Central Bank monetary policies, serving financial institutions and supervising market operations. The voice brokering began in July 2001, FX deposit brokering debuted in June 2002, and in June 2003, the paper quotation system was introduced. In May 2005, interbank trading in foreign currency pairs was introduced, followed in June of that year by interbank bond forward trading and in August by RMB/FX forward trading. Through the modes of electronic trading and voice brokering, the CFETS provides the interbank FX market, RMB lending, bond market and paper market with trading, clearing and surveillance services, and with the approval of the PBOC, it may also initiate developing other businesses (see Table 1).

[7] The operation then expands to interbank short-term financing activity, with the RMB credit lending system setting up in January 1996 and interbank bond trading in June 1997. In September 1999, CFET's trading information system was operating, and its official website launched in June 2000.

<Table 1 about here>

Although the CFETS has its headquarters in Shanghai and a back-up center in Beijing, there are a total of 18 sub-centers throughout the country. At the end of April 2008, the CFETS had 270 members, while its affiliated institution, the National Interbank Funding Centre (NIFC) had a total membership of 1564 as of 2010 (see Table 2).

<Table 2 about here>

All financial or non-financial institutions that satisfy the regulatory qualifications can apply for membership to the CFETS and conduct business accordingly. The interbank FX market employs an electronic matching system and an OTC (over the counter) trading system. Members can choose either mode. For electronic matching, members quote independently, and the trade system matches the quotations in priorities of price and then time. For OTC trading, the system provides technological facilities for members to negotiate directly on trading factors such as trading currencies, the exchange rates and amounts, according to the principle of 'bilateral credit, bilateral clearing'. Trading hours for RMB/foreign currency *spot* trading (including the trading in RMB against the USD, HKD, JPY and EUR) currently are from 9:30 to 15:30 for automatic price-matching transactions and from 9:30 to 16:30 for OTC transactions. The business hours are in Beijing time, and all the transactions are open Monday to Friday, excluding public holidays.[8] The business hours for RMB/foreign currency *forward* trading are from 9:30 to 17:30. A membership system applies for RMB/foreign currency forward trading, and the participants are confined to those who are licensed for financial derivatives trading issued by the supervisory department.

[8] For foreign currency/foreign currency spot trading, the system is open from 7:00 to 19:00. The currency pairs include EUR/USD, AUD/USD, GBP/USD, USD/JPY, USD/CAD, USD/CHF, USD/HKD and EUR/JPY. Finally, the RMB interbank lending operates from 9:00 to 12:00 for the morning session, followed by a lunch break, and then an afternoon session from 13:30 to 16:30.

The clearing of RMB/FX spot trading on the automatic price-matching system follows the principles of 'centralized, two-way and netted'. CFETS handles clearing for all trading members, with a settlement period of T+2 (two days after the transaction). While RMB settlement goes through the payment system of the PBOC, foreign currencies are cleared through overseas clearing systems. OTC transactions are to be settled with the settlement periods of T+2, T+1 or T+0 depending on the arrangements between the parties involved.[9] The CFETS is a computerized, real-time electronic trading system across the whole country. A digital certification center was established in 2002, with relay stations in seven major cities through which all members of CFETS are connected to the network. CFETS adopts a double-backup structure (in Shanghai and Beijing), while the national communication networks operated by different telecommunication companies serve as backups to each other.

4. Data and Methodology

4.1 Sample and Variables Constructions

Of the two major electronic trading platforms in the foreign exchange markets (EBS and Reuters), Reuters provides data not only on the number but also on the volume of trades. Thus, the original foreign exchange rate transaction data for this paper is sourced from Reuter 3000 Xtra, which provides the entire Chinese market information and updated news.[10] This

[9] The trading in foreign currency pairs follows the 'centralized and netted' principles for settlements. The settlement period is T+2. The forward trading in RMB/foreign currencies adopts the bilateral clearing mode, which can be either gross principal delivery at maturity or netted delivery depending on the difference between the agreed forward rate and the spot rate at maturity.

[10] For further information, please see *Reuters 3000 Xtra Spotlight China*.

database supplies tick-by-tick prices, including the high-frequency data for foreign exchange, futures, interest rates and other markets. In this paper, we focus on the Chinese foreign exchange spot market and trades from the China Foreign Exchange Trade System (CFETS). In particular, our initial dataset comprises foreign exchange transactions data of the Chinese RMB against the US dollar between 8 December 2009 and 2 June 2011, covering 360 trading days. Trades are recorded for the opening hours of each working day, in Beijing Time (GMT+8). The opening time before 13 December 2010 is from 9:30 to 17:30. After this date, the working time changes to from 9:30 to 16:30.[11] The spot exchange rate between the Chinese RMB and the US dollar (RMB/USD) P_t is the log of the exchange rate transaction price at the end of each working day's opening-time period. This dataset excludes public holidays.

The daily exchange rate movements are displayed in Figure 1. This figure shows that there are both oscillation and stabilizing periods during the whole sample period. Specifically, the exchange rate was almost fixed during the global financial crisis period. Therefore, we decided to move our starting period to 21 June 2010, the date on which the PBOC announced a new "managed floating" exchange rate policy.[12] The estimation period ends on 2 June 2011 when the latest data are available, and after excluding public holidays, a total of 232 observations are finally included in this sample period.

<Figure 1 about here>

[11] On 12 December 2010, the interbank foreign exchange market changed its closing time to 16:30. Initially, the order flow data are high frequency tick by tick data so we convert them into the daily order flow variable.
[12] On 19 June 2010 (Saturday), the PBOC announced that the RMB exchange rate fluctuation would follow a "managed floating" regime with reference to a basket of currencies.

Measurements of three further variables, accumulated order flow x_t, short-term interest rate differential $(i_t - i_t^*)$, long-term interest rate differential $(r_t - r_t^*)$, and country risk premium difference $(R_t - R_t^*)$, are as follows. First, to construct a spot order flow, a value of +1 is assigned to each buy trade and -1 to each sell trade. One-day spot order flow is then equal to the sum of the trade signs over the whole working period. The daily order flow x_t is the imbalance of the buyer-initiated orders and seller-initiated orders during the opening time of the working day (Evans and Lyons 2002a). Second, the short-term interest rate differential $(i_t - i_t^*)$ is the domestic daily overnight interest rate minus the foreign (US) daily overnight interest rate. The long-term interest rate differential $(r_t - r_t^*)$ is the Chinese daily 12-month interbank lending interest rate minus the US daily 12-month interbank lending interest rate. These interest rate data are annualized and sourced from DataStream. In addition, we include another variable, the country risk premium. A country's daily risk premium R_t on lending is equal to the prime-lending rate[13] minus the 3-month treasury bill rate.[14] Therefore, the country risk premium difference $(R_t - R_t^*)$ is the domestic minus the foreign risk premium. The descriptive statistics and correlation for our main variables are reported in Table 3.

<Table 3 about here>

The table shows clear evidence of a departure from normality, with most of variables failing to pass the JB normality test exclusive of order flow. The skewness for every variable under examination is under 3. From the correlation matrix, we can see that the associations between the long- and short-term interest rates and the exchange rate are all negative. More important, both the order flow and the country risk premium difference have a positive relation with the

[13] We use US bank prime loan and Chinese one-year lending rates.
[14] We chose China Central Bank 3-month bills and US 3-month Treasury bills (from Financial Times).

exchange rate. However, the interaction among these variables may be more complex than a simple correlation can capture. It is, therefore, interesting and informative to further investigate the extent to which these key variables interact in the subsequent sections.

4.1.1 Exchange Rate and Order Flow

Evans and Lyons (2002a) argue that a microstructure variable, order flow, has a strong positive correlation with the nominal exchange rate. Their original portfolio shift model is a very simple exchange rate determination model that contains the order flow information. The dynamics of exchange rates are determined by the accumulated signed order flow and by the macroeconomic information (such as changes in the interest rate differential). This model can be presented as:

$$\Delta P_t = \alpha \Delta M_t + \beta \Delta x_t \sim I(1) \tag{1}$$

where ΔP_t is the log spot exchange rate changes; ΔM_t is the innovations that capture the macroeconomic information (e.g., changes in the interest rate differential); Δx_t is the accumulated signed order flow. Figure 2a plots the original levels of the exchange rate and order flow, whereas Figure 2b displays the log spot exchange rate (P_t) and accumulated order flow, denoted by x_t.

<Figures 2a & 2b about here>

4.1.2 Exchange Rate and Interest Rate

According to the uncovered interest rate parity (UIP), in equilibrium, the expected returns on foreign assets, measured by domestic currency, are equal to that of the domestic assets. Thus, for one period, we have:

$$r_t = r_t^* - E\Delta p_t \tag{2}$$

For multiple periods, the UIP implies:

$$P_t = Ep_t + (r_t - r_t^*) \tag{3}$$

Considering the order flow and UIP, this model can be modified as:

$$\Delta P_t = \alpha\Delta(r_t - r_t^*) + \beta\Delta x_t + \epsilon_t \tag{4}$$

where the macroeconomic information ΔM_t has been replaced by the change of the long-term interest rate differential $\Delta(r_t - r_t^*)$. The reason is that the interest rate not only is the major driver of exchange rate changes but also is available in daily frequency and is, hence, convenient for empirical research. Δx_t is the accumulated order flow, and ϵ_t is the error term. Figure 3 displays the short- and long-term interest rates and country differences in China and the US. The short-term interest rate is clearly non-stationary. The interest rates of the two countries differ greatly. Therefore, we introduce the country risk premium for lending in our estimation.

<Figure 3 about here>

4.1.3 Term Spread and Country Risk Difference

One contribution of our model is the introduction of an additional variable, country risk premium, which is not present in the original Evans and Lyons' (2002) model. This variable is used in studies of emerging markets (Duffuor, Marsh and Phylaktis, 2011; Wu, 2010). Theoretically, the external borrowing cost spread represents a marginal loan for country i during the year t. In this study, China's risk premium for lending is equal to the prime-lending rate minus the 3-month treasury bill rate. The country risk premium difference $(R_t - R_t^*)$ then is the domestic risk premium minus the foreign risk premium. Evans (2011) outlines a micro-based macro model. In the model, the risk premium reflects the fact that the two risk-averse dealers play the role of market makers rather than individual investors in the two countries' economies.

For the exchange rate of a pair of currencies, the (log) spot exchange rate P_t is determined by the settings of the short-term interest rate according to the monetary policy of the two central banks (Evans, 2011). In our study, we define the domestic and foreign countries as China and the US, and the central banks of these two countries are the PBOC and the Federal Reserve (FED), respectively. All dealers quote a price of USD/RMB (in log) that is equal to:

$$P_t = Ep_t + (i_t - i_t^*) - R_t \qquad (5)$$

where P_t stands for the log of exchange rate; $(i_t - i_t^*)$ is the short-term interest rate differential; R_t indicates the country risk premium.

Combining equation (5) with equation (3), the long-term interest rate can be described as:

$$r_t = \frac{1}{T}\sum E_t i_t + R_t \tag{6}$$

Thus, the term spread between the short-term i_t and the long-term r_t is equal to:

$$(r_t - r_t^*) - (i_t - i_t^*) = (R_t - R_t^*) \tag{7}$$

The term spread is equal to the country risk premium difference $(R_t - R_t^*)$. The term spread, the Chinese and US risk premiums and their differences are plotted in Figure 4.

<Figure 4 about here>

4.2 Methodological Issues

The original model developed by Lyons (1995) and Evans and Lyons (2002a) has provided a foundation for the market microstructure approach to studying the exchange rate. However, in the empirical research, criticism against the linear regression model that is used by Evans and Lyons (2002a) in their original format has emerged. This criticism is not unreasonable given that if simultaneity bias exists, their model cannot explain it. In the context of the analysis of determinants of exchange rate movements, one should consider the feedback effect of the order flow's coefficient. In this case, a positive coefficient on order flow can be explained as either a positive exchange rate move or a positive feedback effect. Therefore, Evans and Lyons' estimation method can be inaccurate. In addition, Lyons' (1995) model is based on a single-dealer structure that is quote driven. The CFETS is, however, a multi-lateral system that is both order-driven and quote driven.

In this paper, we extend Evans and Lyons' (2002a) model and apply Hasbrouck's (1991) VAR framework to analyze the microstructure determinants of Chinese exchange rate movements.[15] The vector autoregressive model (VAR), as a system regression model implied by Sims (1980), was widely used in the recent literature (Froot and Ramadorai, 2005; Danielsson and Love, 2006; Wu, 2010) because VAR modeling is suitable for examining not only the long-run relationship between the exchange rate and order flow but also how the long-run structure affects the short-term feedbacks. More important, it takes into account the potential feedback effect on the standard OLS regression of the order flow's coefficient. Therefore, we start the current research by testing the empirical implications of the portfolio shift model (Evans and Lyons, 2002a) in a static framework. First, we conduct a cointegration analysis with the Johansen's (1995) trace test under the VAR setting. Then, we apply the graph-theoretic approach to examine the instantaneous causality relations between each variable (Demiralp and Hoover, 2003). Next, we extend the VAR framework to estimate the explanatory power of order flow for exchange rate movement in China.[16]

4.2.1 The VAR Model

Before estimating the VAR approach, we consider the assumptions of the model:

1. The public information is immediately reflected by the quotes, and
2. The informed traders exploit their profit through using their market orders.

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[15] This modeling framework not only has been applied for exchange rates research but also has been commonly used to analyze the microstructure of security market (Hasbrouck, 1991).

[16] In the modeling process, we follow the general-to-specific methodology (Hendry and Krolzig, 2001) to simplify the VAR to parsimonious VAR and to examine not only the long-run relationship among the variables of interest, including that between order flow and exchange rate movements, but also the behavior of the Chinese exchange rate in terms of its short-run dynamics. See Juselius (2006) for more detailed applications.

Let Y_t represent a vector of transaction characteristics and Z_t be the lag of each transaction characteristic, where t is an event-time observation counter. The VAR model is as follows:

$$Y_t = BZ_t + E_t \tag{8}$$

and,

$$Y_t = \begin{pmatrix} P_t \\ X_t \\ (i_t - i_t^*) \\ (r_t - r_t^*) \\ (R_t - R_t^*) \end{pmatrix}_{5\times 1} ; B = \begin{bmatrix} \beta_{1,1} & K & \beta_{1,5r} \\ \vdots & \vdots & \vdots \\ M & O & M \\ \vdots & \vdots & \vdots \\ \beta_{5,1} & L & \beta_{5,5r} \end{bmatrix}_{5\times 5r} ;$$
$$Z_t = \begin{pmatrix} P_{t-1} \\ \vdots \\ M \\ \vdots \\ R_{t-r} \end{pmatrix}_{5r\times 1} ; E_t = \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \end{pmatrix}_{5\times 1} . \tag{9}$$

where P_t is the log of spot exchange rate; X_t is order flow; $(i_t - i_t^*)$ is the short-term interest rate differential; $(r_t - r_t^*)$ is the long-term interest rate differential; $(R_t - R_t^*)$ is country risk premium difference. B are the matrices of coefficients to be estimated (β, K, M, O and L). Each VAR equation is estimated by OLS with heteroscedasticity robust standard errors.

4.2.2 Variable Space in the VAR Specification

Alternatively, our VAR specifications can also be expressed as follows:

$$Y_t = \Gamma Y_{t-1} + \varepsilon_t \tag{10}$$

Thus,

$$Y_t' = [P_t \quad X_t \quad (i_t - i_t^*) \quad (r_t - r_t^*) \quad (R_t - R_t^*)] \tag{11}$$

As discussed, we include the country risk premium in the variable space when investigating the long-term relation and short-term dynamics in the system for the RMB/USD spot exchange rate. The variable P_t and the companion matrix Γ are allowed for a general number of lags and are constant across currencies. $E[\varepsilon_t \quad \varepsilon_t'] = \Sigma$ is the covariance matrix, allowing residuals across the system equations for contemporaneous correlation.

5. Empirical Results and Discussions

Before estimating the VAR model outlined in section 4, we first check the stationarity of data. The results of the augmented Dickey-Fuller (ADF) tests show that the level data cannot reject the null hypothesis of having a unit root while the first difference data can, confirming that the variables are stationary as I (1) process.[17]

5.1 Cointegration Analysis

While the VAR has unique advantages as a modeling framework, a major challenge in deploying this framework is to determine the appropriate lag length for the variables in the system. Two methods for choosing the optimal VAR lag length have been suggested in the literature, one that is based on information criteria and another that is based on cross-equation restrictions. The cross-equation restriction method, however, requires the Block F-test, which would make it intractable in the VAR setting (Brooks, 2008). The number of lags included in

[17] The results relating to unit root tests are available from the authors on request.

our model is, therefore, determined on the basis of three criteria (likelihood ratio test (LR), Akaike information criterion (AIC) and Schwarz information criterion (SC)), starting the model with a high number of lags and proceeding until the optimal number is reached.[18]

Having identified the optimal lag length to be 4, we estimate an unrestricted VAR (4) to investigate the relation between the variables of interest using the Johansen cointegration test. The trace statistics was used as it is shown to be more robust to non-normality of errors compared with the maximal eigenvalue. The cointegration test results are reported in Table 4.

<Table 4 about here>

As shown in Panel A of Table 4, the full sample contains at least two cointegrating relationships. The null hypothesis of ($H_0 \colon r \leq 2$) cannot be rejected at the 5% significance level. The full sample with dummy also confirms two cointegrating relationships. Given these results, we set the cointegration rank =2 to restrict the system and form the cointegrated VAR (CVAR) to estimate the simultaneous equations within the setting of the I (0) VAR model. The long-run cointegration coefficients are given by β, while the feedback coefficients α give the short-term adjustment speed of the deviations from the long-run equilibrium returning to the cointegrating relationship. We test the unique cointegrating relationships in the cointegration space of the system, $Y_t' = [P_t \quad X_t \quad (i_t - i_t^*) \quad (r_t - r_t^*) \quad R_t \quad R_t^* \quad Trend]$. Panel B of Table 4 shows the test results. Hypothesis H_1 tests whether a trend exists in the cointegrating relationships, and the trend excluded in the model is rejected with the p-value

[18] We consider 22 working days in a month, 10 working days in a half-month and 5 working days in a week. Thus, initially, we set for the maximum lag length to be 22 and decrease the lag length with the unrestricted model. More specifically, by adopting the general-to-specific approach, we omit one lag at a time (from maximum lags to 0 lag) and re-estimate the unrestricted VAR with the same sample. The results show that the optimal lag length is 4; thus, we include 4 lags of each variable in the unrestricted VAR estimation. Various diagnostic tests were also carried out and show no serious evidence of model misspecification. The results relating to the lag length selection are not presented but are available from the authors on request.

of 0.0055. Hypotheses H_2 to H_6 test the long-run relations between $P_t = -X_t$ exchange rate and order flow, $(i_t - i_t^*) = -(r_t - r_t^*)$ interest rate spread, and $R_t = -R_t^*$ country risk difference in all cointegrating relationships and the joint test without trend. From the likelihood ratio (LR) test results, hypothesis H_5 is accepted with the p-value of 0.1727. It also shows that the exchange rate relates not only to the risk premium but also to the country risk difference. Thus, we test long-run homogeneity cointegrating relationships in Y_t'.

Panel A of Table 5 shows the test results on the stationarity of single relations.

<Table 5 about here>

Hypothesis H_9 states that the short-term interest rate is stationary with a p-value of 0.104. H_8 states that the order flow can be accepted as a stationary process at the 10% significance level. We next set the restrictions on α coefficient to test the long-run weak exogeneity in the system. In Panel B of Table 5, we set the α in a zero row to find the exclusively adjusting variables in the long-run equilibrium and to identify the Granger causality. The p-values for the LR test results are quite low, suggesting that there are no weak exogenous variables for the long-run beta parameters in this system. The Granger causality test shows that order flow Granger causes exchange rate movements and that lags of order flow are significant in explaining exchange rate movement. Overall, the result shows that unidirectional causality exists from order flow to exchange rate movements of the RMB/USD.

Combining the results of all the hypotheses that we tested, there are no fewer than two linear cointegration vectors. Taking into account the Johansen cointegration rank test and employing the Juselius (Juselius 2006) modeling approach, the following cointegration vectors would be stationary cointegrating relationships:

$$X_t \sim I(0),$$

$$(i_t - i_t^*) \sim I(0),$$

$$(r_t - r_t^*) - (i_t - i_t^*) = (R_t - R_t^*) \sim I(0).$$

According to the above equations, we test restrictions on cointegration vectors β and feedback coefficients α. There are several benefits from coefficient restrictions, such as identifying and restricting the cointegrating space. We set the restrictions and test them step by step. Thus, we restrict the feedback coefficients to zero, the P_t coefficient to 1 in both vectors, the order flow X_t coefficients to 1 in the second vector and remove trend. The result of the LR test of restrictions and the long-run structures are presented in Panel C of Table 5. The overall test statistic is $x^2(1) = 0.19854[0.6559]$, indicating that it is not unreasonable to impose these restrictions in the cointegrating vectors.[19] In addition, the results show that two cointegration equations (CIa and CIb) can be formulated for level data:

$$\mathrm{CIa} = -\mathrm{P_t} + 0.0023 * \mathrm{X_t} + 8.7879 * (\mathrm{i_t} - \mathrm{i_t^*}) - (\mathrm{r_t} - \mathrm{r_t^*}) + (\mathrm{R_t} - \mathrm{R_t^*}); \tag{12}$$

$$\mathrm{CIb} = 1.9129 * \mathrm{P_t} - 0.0009 * \mathrm{X_t} + (\mathrm{i_t} - \mathrm{i_t^*}) + 2.7807 * (\mathrm{r_t} - \mathrm{r_t^*}) - 0.1132 * (\mathrm{R_t} - \mathrm{R_t^*}). \tag{13}$$

From the above equations, we find that the cointegration coefficient β on the interest differential is correctly signed and significant. The coefficient on the variable of order flow is

[19] The estimation results for the long-run structures presented in this table also show that there are two small eigenvalues and two significant p-values. These values determine again that the cointegration rank is 2 and we have two cointegration equations.

significant and positive. Thus, the β coefficient on the order flow variable X_t is positive, which implies a higher RMB price of dollars when the net buying imbalance is higher. Given a β coefficient of 0.0023 in the RMB/USD exchange rate equation, every 1 % increase in order flow will increase the RMB price of the dollar by 23 basis points within the day. Moreover, the variable that captures the influence of macro fundamentals—the interest differential—is signed positive. This result may reflect that the interest differential can be considered a risk-free return on currency investment if the interest rate of the dollar i_t is not changed while the interest rate of the RMB i_t^* is increased. Under uncovered interest parity, RMB/USD may increase to allow for dollar depreciation. Hence, the long-run cointegration coefficient β on the interest differential is signed correctly. The long-run cointegration coefficient β on the country risk premium is also significant.

5.2 VAR and Error Correction Modeling

Using the long-run relationships given in equations (12) and (13) as the error correction terms, we now turn to the formulation and the estimation of an error correction model (VECM) for the differenced variables $[\Delta P_t \quad \Delta X_t \quad \Delta(i_t - i_t^*) \quad \Delta(r_t - r_t^*) \quad \Delta(R_t - R_t^*)]$. The maximum likelihood (ML) method is used to estimate our model because the system is reduced to a partial VECM, as insignificant variables were dropped from the system to reach the most parsimonious model. This method ensures the efficient and consistent parameter estimates.[20] The result from estimating the short-run VECM parameters for ΔP_t, ΔX_t, and $\Delta(R_t - R_t^*)$ are reported in Table 6.

[20] Hendry and Doornik (1994) explain that the reason for modeling a parsimonious VAR (PVAR) is to reduce the dependence and increase the invariance to change. Here, we follow the general-to-specific method as applied by Hendry and Krolzig (2004). After we simplify the PVAR results, the equations show the major parts of the system. In other words, only significant lags of independent variables are kept, containing the majority of information in a much simpler model.

<Table 6 about here>

To focus first on the equation for exchange rate movement ΔP_t, we find that the second lag of the order flow ΔX_{t-2} is significant. The coefficient on the error correction term θ is -0.0115, which shows that the short-term adjustment is negative and significant at the 10% level. The result is similar to that of unrestricted VAR, suggesting that order flow not only Granger causes exchange rate movements but also has explanatory power in capturing changes in the Chinese exchange rate in the short term. The long-run exchange rate movements influence the order flow and interest rate change in the short term.

Comparing our specification with that of Evans and Lyons (2002b), although the coefficients are both significant, the R^2 of our model is lower. Evans and Lyons (2002b) get 0.64 and 0.46, but our R^2 is only 0.13. There are two possible explanations for the different results. First, as mentioned previously, in developing countries, there tends to be more government interventions in the foreign exchange market. For example, in an analysis of order flow in Brazil, De Medeiros (2005) obtained a R^2 of 0.06. Second, for the long term, not only is order flow correctly signed and significant, but we also include the correctly signed interest rate differential and significant country risk premium.

Next, we turn to the estimation of order flow equation. The speed of adjustment of order flow toward the long-run relationship, as given in equation (12), is negative and highly significant. The exchange rate movement appears to be an important factor influencing the order flow. Finally, consistent with previous findings, the country risk premium has a negative relationship with the exchange rate movement. The country risk premium also reacts significantly to the long-term interest rate differential, as indicated by the γ coefficients and as shown before in equation (5).

5.3 Impulse Response Functions

More detailed insight on the casual relationship among the key variables can be obtained by analyzing their impulse response functions. First, we report the impacts of a shock to the system in different modeling configurations. Figure 5 shows the impulse responses to one SE (standard error) shock of each system variable in the exchange rate equation. In the figure, from the first to the fourth columns, these variables are order flow x_t, short-term interest rate differential $(i_t - i_t^*)$, long-term interest rate differential $(r_t - r_t^*)$, and country risk premium difference $(R_t - R_t^*)$. From the first to the last rows, the impulse response functions plotted are the dynamics of unrestricted VAR, restricted form VAR, just identified VECM and parsimonious VAR (PVAR), discussed in the previous section. Comparing unrestricted VAR to PVAR, we expect the estimated response of PVAR to be clearer and more concise to convey information about real economic phenomena.

<Figure 5 about here>

The equilibrium order flow impulse response shows the shocks of all the other variables. In the first horizon, the exchange rate responds immediately when a negative jump to order flow shocks are slightly shorter than other variables, excluding the RMB exchange rate itself. The first graph shows that the exchange rate movement occurs immediately and steadily in response to various shocks to order flow. The shock appears as a negative signal at very short horizons (first two horizons) but leads upward to 0.22% in the long run. It appears as a feedback effect in a short time period and then becomes steady over 10 periods.

The graphs of the other three variables show that they have a different appearance when compared with the next term order flow. The results show that the proportion of the interest rate differential decreases with time. In the long horizon, the order flow has a negative influence on the interest rate differential. The interest rate, both long- and short term, has a negative sign at first and then becomes stable, declining to the origin. The interbank interest rate differential jumps in response to exchange rate shocks; at first, it has a negative sign. After 2 periods, the sign changes to a positive sign and decreases with time. If the government increases the interest rate, they should have the same sign. This will be consistent with the strict monetary policy, implying that the market may have attracted some speculators, while also being controlled by government intervention. The country risk premium shows a similar tendency but is much more flexible. In the short horizon (first five periods), the country risk difference responds immediately to exchange rate movements and more strongly and repeatedly than other variables.

Having explored the exchange rate equation, we now examine the responses and dynamic simulation results of each variable in Figure 6.

<Figures 6 about here>

The figure shows the impulse responses of the system to one SE (standard error) shock to each variable equation, i.e., the order flow equation, short-term interest rate differential (i_t-i_t*) equation, long-term interest rate differential (r_t - r_t*) equation and country risk premium difference (R_t - R_t*) equation, given there are two cointegrating relationships in the system. In the figures, the X-axis shows that the number of 30 steps ahead has been selected; the Yaxis shows the impact on each variable. In the order flow equation, the exchange rate, short-term interest rate and CIa all have a positive impact on the order flow, but the effects of other variables are negative. These results are similar to the results shown in Table 6. For the short-term interest rate differential equation, the signs of responses are all positive except for that of the exchange rate. However, the country risk premium has a 1.5-period delay in affecting the short-term interest rate. For the long-term interest rate differential, only the order flow has a positive impact on the long-term interest rate. All the other impulse responses are negative. Panel D of this figure shows that the country risk premium difference has a one-period delay in responding to the interest rate shocks, both short term and long term. The exchange rate and order flow have opposite impacts on country risk premium; one is positive, and the other is negative.

5.4 Forecast Error Variance Decomposition

Finally, in this section, we decompose the forecast error variance of each variable into components to account for innovation in all the variables. In general, the more exogenous a variable is, the less its forecast error variance is explained by innovations in other variables. The variance decomposition of exchange rate movements in relation to other key variables is reported in Table 7.

<Table 7 about here>

The most exogenous variable in the system for the exchange rate appears to be order flow. The result shows that 19% of changes in the exchange rate variance are due to order flow. Thus, order flow can explain 19% of exchange rate changes within a day. Country risk premium difference accounts for 3.9% of exchange rate changes, while less than 1% is due to interbank interest rate differential. The interest rate differential has a much weaker performance than other variables in China's foreign exchange market. Hence, order flow and country risk are more influential determinants than the interest rate. Overall, changes in order flow explain more exchange rate movements than do other variables in the system.

6. Conclusion

This research investigates the long-term determinants and short-term dynamics of the Chinese exchange rate, with particular emphasis on the relative role of cumulative order flow. We construct a measure of daily order flow in the Chinese setting to reflect excess demand pressure in China's foreign exchange market. An additional variable, the country risk premium, is included in our investigation, along with the exchange rate, order flow and interest rate differential. To investigate the behavior of the Chinese exchange rate in terms of its short-run dynamics and long-run equilibrium, we apply a VAR framework to estimate both the long-run and short-run parameters and find that cumulative order flow is cointegrated with the RMB/USD exchange rate in China. The results also suggest that in the new Chinese exchange rate policy regime, order flow as a 'signed' measure of trading volume explains a significant part—approximately 19%—of the short-term fluctuations in the exchange rate of the RMB against the US dollar.

In summary, this paper uncovers the long term cointegrating relationship among variables under examination, including order flow, interest rates, and a proxy for macro influences. The short-run dynamics show that the fluctuations in the exchange rate of the RMB against the

US dollar can be explained by a measure of excess demand pressure, i.e., the order flow. The results show that order flow has a strong and positive explanatory power in the Chinese foreign exchange market. The coefficient β on the order flow variable X_t is positive, suggesting its positive association with the RMB price of the dollar. The coefficient is 0.0023 in the RMB equation, which implies that on a day with a 1% increase in the net purchase of dollars, the RMB price of the dollar would increase by 23 basis points. The results of impulse responses analyses indicate that the Chinese exchange rate responds immediately and more strongly than other variables (excluding exchange rates themselves) to the changes in order flow over the short horizon. In the long term, the interest rate differential has a strong influence on exchange rate movements. Country risk premium shows a similar tendency, but to a lesser extent. Comparing our specification with that of Evans and Lyons (2002b), we find an interesting detail. The coefficients on order flow in our research and in their research are both significant, but our R^2 is low at 0.13, while Evans and Lyons (2002b) obtained R^2 of 0.64 and 0.46. However, our result is consistent with the findings of similar research on emerging markets, such as that in Brazil. It seems that government intervention in the emerging foreign exchange market may be the reason for this difference.

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Table 1: Products and Services of CFETS

Membership	All the banks, non-banking financial institutions and non-financial corporations that satisfy the qualifications set by the regulators for interbank FX spot trading can apply for membership of CFETS and conduct principal trading in the interbank spot FX market.		
Trading mode	Electronic matching system: members quote independently and the trade system matches the quotations in priority of price and order.		
	Over the Counter (OTC) trading system: members negotiate directly according to the principle of 'bilateral credit, bilateral clearing'.		
Trading Hours (Beijing Time) Monday - Friday (Chinese holidays excluded)	RMB/foreign currency spot trading	Automatic price-matching transactions	9:30 to 15:30
		OTC transactions	9:30 to 16:30
	foreign currency/ foreign currency spot trading		7:00 to 19:00
	RMB/foreign currency forward trading		9:30 to 17:30
	RMB interbank lending		9:00 to 12:00 13:30 to 16:30
Trading Currency	RMB/foreign currency	USD, HKD, JPY, EUR	
	foreign currency/ foreign currency	EUR/USD, AUD/USD, GBP/USD, USD/JPY, USD/CAD, USD/CHF, USD/HKD, EUR/JPY	
Clearing	RMB/ foreign currency spot trading	Automatic price-matching trade system	centralized, two-way and netted T+2
		OTC transactions	T+2, T+1, T+0
	For foreign currency/ foreign currency spot trading		centralized and netted T+2
	RMB/foreign currency forward trading	Delivery at maturity or netted delivery based on the difference between the agreed forward rate and the spot rate at maturity.	
	RMB interbank lending	bilateral gross clearing according to the transaction notice T+ 1, T+0	
	RMB bond trading	payment after delivery delivery after payment delivery vs. payment	

Note:
This table outlines the major products and services that the China Foreign Exchange Trading System (CFETS) provide to the participants of the Chinese foreign exchange market. Source: China Money

Table 2: Memberships of CFETS and NIFC

Financial Institution	Number	Financial Institution	Number
Panel A: CFETS			
Solely state-owned bank	5	Foreign-funded bank, trust & investment company	137
Joint stock commercial bank	12	Rural credit co-operative	41
Policy bank	3	Non-banking financial institution	2
Urban commercial bank	56	Non-financial institutions	1
Authorized branch of a commercial bank	13	***Total***	***270***
Panel B: NIFC			
Solely state-owned bank	4	Financial company	57
Joint stock commercial bank	14	Rural credit co-operative	395
Policy bank	3	Trust & investment company	40
Urban commercial bank	111	Fund management company	53
Authorized branch of a commercial bank	144	Urban credit co-operative	34
Foreign-funded bank	77	Social security fund	1
Financial leasing company	4	Asset management company	5
Insurance company	82	Investment company	1
Securities company	90	Corporate pension	57
Investment fund	390	Auto financing company	1
Other	1	***Total***	***1564***

Note:
This table details the memberships of the China Foreign Exchange Trading System (CFETS) and that of its affiliated institution, the National Interbank Funding Centre (NIFC). Source: China Money

Table 3: Descriptive Statistics and Correlations of the Key Variables

	Exchange Rate P_t	**Order Flow** x_t	**Short-term Interest Rate Differential** $(i_t - i_t^*)$	**Long-term Interest Rate Differential** $(r_t - r_t^*)$	**Country Risk Premium Difference** $(R_t - R_t^*)$
Panel A: Summary Statistics					
Obs.	232	232	232	232	232
Mean	1.8940	-39.3580	0.0198	0.0265	0.1437
Std. Dev.	0.0150	23.6460	0.0107	0.0095	0.0616
Skewness	0.1416	-0.2556	2.8379	0.2346	-0.61522
Excess kurtosis	-1.1800	0.0997	9.0617	-1.5225	-1.1815
JB Normality test	25.841 [0.0000]**	2.6163 [0.2703]	616.60 [0.0000]**	67.1850 [0.0000]**	112.98 [0.0000]**
Panel B: Correlation Matrix					
$\boldsymbol{P_t}$	1.0000	0.3005	-0.5175	-0.9605	0.8597
$\boldsymbol{x_t}$	**0.3005**	1.0000	-0.1723	-0.1342	0.0485
$\boldsymbol{(i_t - i_t^*)}$	-0.5175	-0.1723	1.0000	0.4821	-0.3505
$\boldsymbol{(r_t - r_t^*)}$	-0.9605	-0.1342	**0.4821**	1.0000	-0.9248
$\boldsymbol{(R_t - R_t^*)}$	0.8597	0.0485	-0.3505	**-0.9248**	1.0000

Note:
This table reports the descriptive statistics and correlations of the five key variables i.e., the log of spot exchange rate P_t, the order flow x_t, the short-term interest rate differential (i_t - i_t*), the long-term interest rate differential (*rt* - *rt**) equation, and the country risk premium difference (R_t - R_t*). The interest rate data are all transformed according to this formula: $\log(1 + I_t/100)$.

Table 4: Johansen Cointegration Tests

Panel A Cointegration Rank Tests					
Rank	$H_0: r \leq 0$	$H_0: r \leq 1$	$H_0: r \leq 2$	$H_0: r \leq 3$	$H_0: r \leq 4$
Eigenvalue	0.2216	0.1618	0.0791	0.0325	0.0158
Loglik	3635.184	3655.664	3665.224	3669.062	3670.911
Trace test	129.58	71.454	30.494	11.373	3.6968
Probability	[0.0000]**	[0.0090]**	[0.4790]	[0.8490]	[0.7810]

Panel B Restriction tests on cointegrating equations							
	P_t	X_t	$(i_t - i_t^*)$	$(r_t - r_t^*)$	R_t	R_t^*	Trend
Unrestricted: Strong Convergence							
β_1	0.3437	-0.0006	1.0000	4.4495	0.1712	-0.3793	-0.0004
β_2	1.0000	-0.0002	-0.0601	-0.0131	-0.2225	-0.0594	0.0002
$H_1: Trend = 0, x^2(2) = 5.8056\ [0.0055]$; Strong Convergence							
β_1	3.1028	-0.0018	1.0000	5.0113	-0.3867	-0.5055	**0.00**
β_2	1.0000	-0.0011	-2.5377	-0.0360	-0.4325	1.2700	**0.00**
$H_2: P_t = -X_t, x^2(2) = 10.824$ $[0.0045]^{**}$; Weak Convergence							
β_1	**-0.0006**	**0.0006**	1.0000	5.0436	0.5569	0.0709	-0.0005
β_2	**1.0000**	**-1.0000**	202.46	-13.555	-442.92	-610.49	-0.0600
$H_3: (i_t - i_t^*) = -(r_t - r_t^*), x^2(2) = 13.419[0.0012]^{**}$; Strong Convergence							
β_1	-35.755	0.0207	**1.0000**	**-1.0000**	7.5887	0.9392	-0.0056
β_2	1.0000	0.0117	**-100.93**	**100.93**	12.284	46.280	-0.0096
$H_4: (i_t - i_t^*) = -(r_t - r_t^*), Trend = 0, x^2(4) = 19.351[0.0007]^{**}$; Strong Convergence							
β_1	1.8437	-0.0029	**1.0000**	**-1.0000**	-1.3576	-0.2210	**0.00**
β_2	1.0000	-0.0003	**-1.6671**	**1.6671**	0.0080	0.7502	**0.00**
$H_5: R_t = -R_t^*, x^2(2) = 3.5124[\mathbf{0.1727}]$; Strong Convergence							
β_1	1.6581	-0.0011	4.8251	22.354	**1.0000**	**-1.0000**	-0.0021
β_2	1.0000	-0.0006	-0.0730	0.1618	**-0.1804**	**0.1804**	0.0001
$H_6: R_t = -R_t^*, Trend = 0, x^2(4) = 11.439[0.0220]^{*}$; Strong Convergence							
β_1	-1.0658	0.0021	5.6790	0.0823	**1.0000**	**-1.0000**	**0.00**
β_2	1.0000	-0.0006	0.1855	1.3832	**-0.1016**	**0.1016**	**0.00**

Notes:
This table summarizes the results of Johansen cointegration tests. If r denotes the number of significant cointegration vectors, then the Johansen trace statistics test the hypotheses of at most four, three, two, one and zero cointegrating vectors. *denotes significance at the 5% level; **denotes significance at the 1% level.

Table 5: Hypotheses Tests on the Cointegrated Relations

Panel A Tests on the Stationarity of Single Relations

	P_t	X_t	$(i_t - i_t^*)$	$(r_t - r_t^*)$	$(R_t - R_t^*)$	$x^2(1)$	Prob.
H_7	1	0	0	0	0	3.3176	[0.069]
H_8	0	1	0	0	0	2.7275	**[0.099]**
H_9	0	0	1	0	0	2.6407	**[0.104]**
H_{10}	0	0	0	1	0	3.6491	[0.056]
H_{11}	0	0	0	0	1	3.6090	[0.058]

Panel B Granger Causality Test / Long-run Weak Exogeneity

	P_t	X_t	$(i_t - i_t^*)$	$(r_t - r_t^*)$	$(R_t - R_t^*)$
$x^2(4)$	8.1825	36.547	25.859	9.3057	17.900
Prob.	[0.0851]	$[0.0000]^{**}$	$[0.0000]^{**}$	[0.0539]	$[0.0000]^{**}$

Panel C The Identified Long-run Structures

$\boldsymbol{P_t}$	$\boldsymbol{X_t}$	$(\boldsymbol{i_t - i_t^*})$	$(\boldsymbol{r_t - r_t^*})$	$(\boldsymbol{R_t - R_t^*})$	LR test restrictions
β: Cointegrating Vectors					$\beta_{11} = -1$
1.9129	-0.0009	1.0000	2.7807	-0.1133	
-1.0000	0.0023	8.7879	-1.0000	1.0000	$\beta_{14} = -1$
α: Feedback Coefficients with 2 Ranks					
-0.0183 (0.0083)	629.69 (113.30)	-0.0613 (0.0239)	0.0007 (0.0009)	0.0305 (0.0741)	$\beta_{15} = 1$
0.0009 (0.0012)	-58.887 (15.880)	-0.0117 (0.0033)	0.0003 (0.0001)	-0.0067 (0.0104)	$\beta_{23} = 1$

Notes:
This table reports the results of hypotheses tests on the cointegrated relations among our key variables. One vector restriction is applied on β in testing the stationarity. *denotes significance at the 5% level; **denotes significance at the 1% level. The trace test statistic indicates 1 cointegrating relationship at the 5 % level. The system then is restricted by cointegration rank 2. The cointegration coefficients β and adjustment coefficients α with their standard errors are all shown in ( ) in the table. The lag interval is 1 to 4. The LR test result is $x^2(1) = 0.19854[\mathbf{0.6559}]$.

Table 6: Estimates of the Error Correlation Modeling

	ΔP_t	ΔX_t	$\Delta(R_t - R_t^*)$
Constant	0.0425 (0.0241)	-0.2577 (0.2410)	-
α_1	-0.1970** (0.0648)	-0.2048* (0.0896)	-0.9915 (0.5740)
α_2	-	0.2237* (0.0881)	-
α_3	-	-	-0.9044 (0.4880)
β_1	-0.8765 (0.5674)	-	-
β_2	-1.0055* (0.4521)	-	-
θ	-0.0115 (0.0064)	-0.8575** (0.0822)	-
φ_3	-	-	0.6450** (0.1610)
γ_1	-	-	-11.6000* (5.5500)
γ_2	-	-	17.9300** (6.1400)
γ_3	-	-	-21.3000** (4.9800)
δ_1	-	-	-0.3038** (0.0608)
δ_2	-	-	-0.2982** (0.0701)
δ_3	-	-	-0.1355** (0.0517)
R-square	0.13	0.21	0.27

Notes:
This table presents the results of estimating the following short-run VECM equations, for ΔP_t, ΔX_t, and $\Delta(R_t - R_t^*)$:

$$\Delta P_t = C + \alpha 1 * \Delta P_{t-1} + \beta 1 * \Delta X_{t-1} + \beta 2 * \Delta X_{t-2} + \theta * CIb_{t-1} + \varepsilon_{p,t}$$

$$\Delta X_t = C + \alpha 1 * \Delta P_{t-1} + \alpha 2 * \Delta P_{t-2} + \theta * CIa_{t-1} + \varepsilon_{X,t}$$

$$\begin{aligned}\Delta(R_t - R_t^*) = {} & \alpha 1 * \Delta P_{t-1} + \alpha 3 * \Delta P_{t-3} + \varphi 3 * \Delta(i_{t-3} - i_{t-3}^*) + \gamma 1 * \Delta(r_{t-1} - r_{t-1}^*) + \gamma 2 \\ & * \Delta(r_{t-2} - r_{t-2}^*) + \gamma 3 * \Delta(r_{t-3} - r_{t-3}^*) + \delta 1 * \Delta(R_{t-1} - R_{t-1}^*) + \delta 2 \\ & * \Delta(R_{t-2} - R_{t-2}^*) + \delta 3 * \Delta(R_{t-3} - R_{t-3}^*) + \varepsilon_{R,t}\end{aligned}$$

Standard errors are all shown in ( ) *denotes significance at the 5% level; **denotes significance at the 1% level.

Table 7: Decomposition of Exchange Rate Variance

Horizon	P_t	X_t	$(i_t - i_t^*)$	$(r_t - r_t^*)$	$(R_t - R_t^*)$	**S.E.**
5	90.6102	5.3382	0.1062	0.1564	3.7889	0.0027
10	83.8929	11.9628	0.06370	0.1423	3.9383	0.0040
20	78.5886	17.2970	0.1312	0.0714	3.9117	0.0059
30	76.8319	**19.0794**	0.1406	0.0465	**3.9017**	0.0074

Notes:
This table presents the results of decomposing the forecast error variance of each variable into components to account for innovation in all the variables. S.E. denotes the standard error. We test for a time horizon of 30 days with Cholesky Decomposition.

Figure 1: The Daily Exchange Rate Movements, RMB/USD

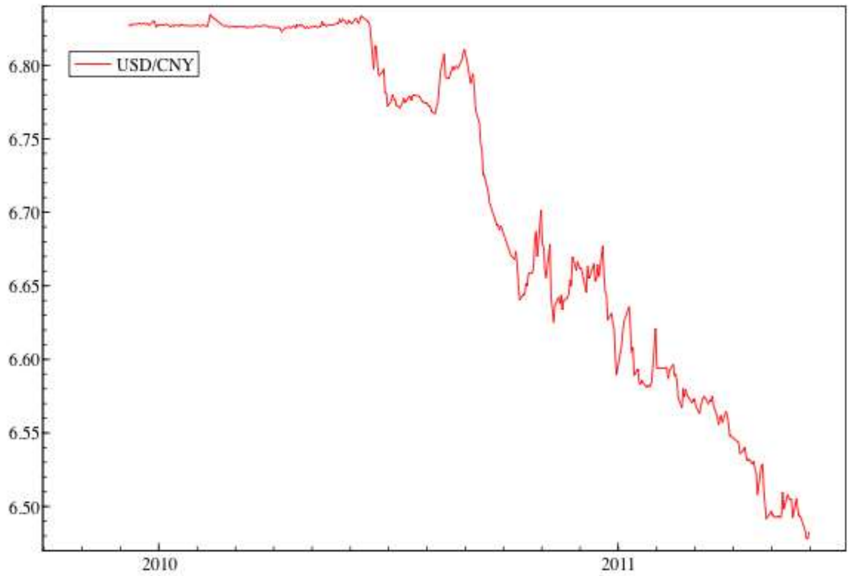


Figure 2a: Chinese Exchange Rate and Order Flow, 21/06/2010-2/06/2011

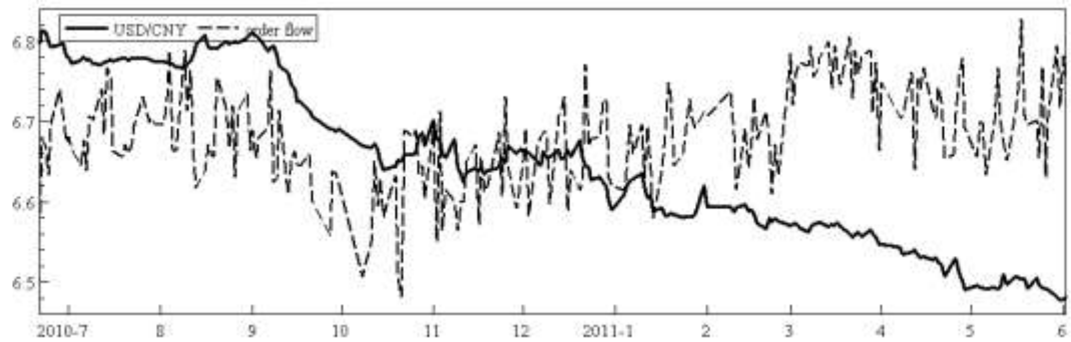


Figure 2b: Log Exchange Rate and Accumulated Order Flow, 21/06/2010-2/06/2011

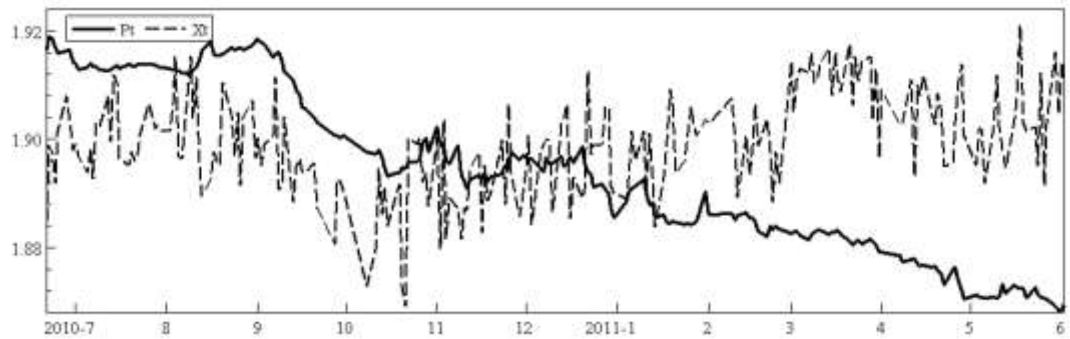


Figure 3: Nominal Short and Long-term Interest Rates in China and the US

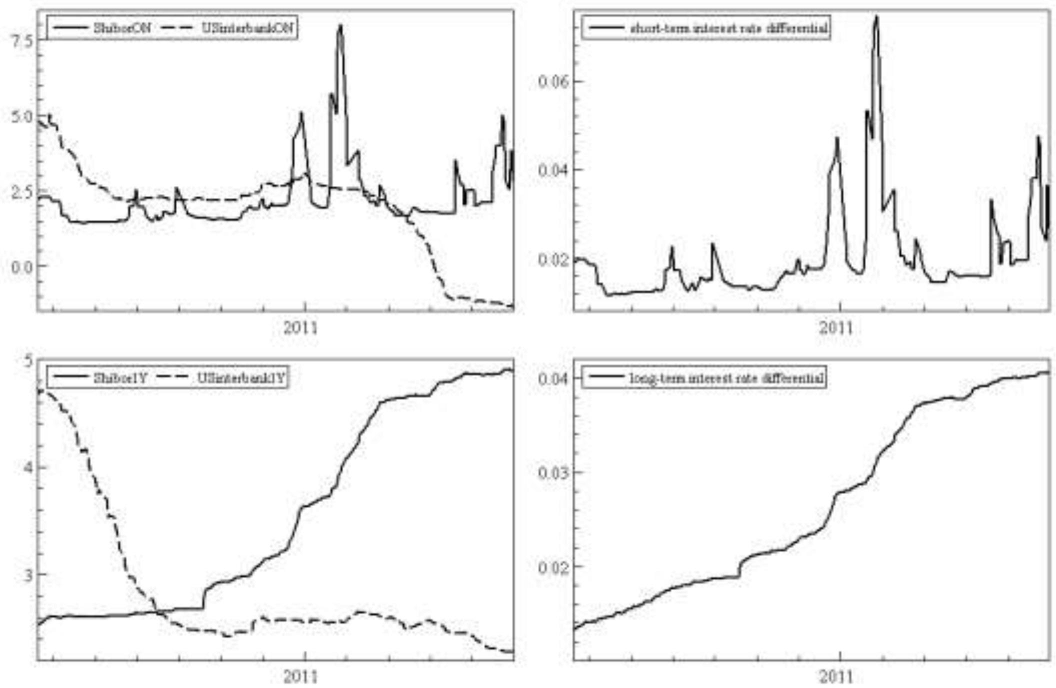


Figure 4: Term Spread, China and US Risk Premium and Their Differences

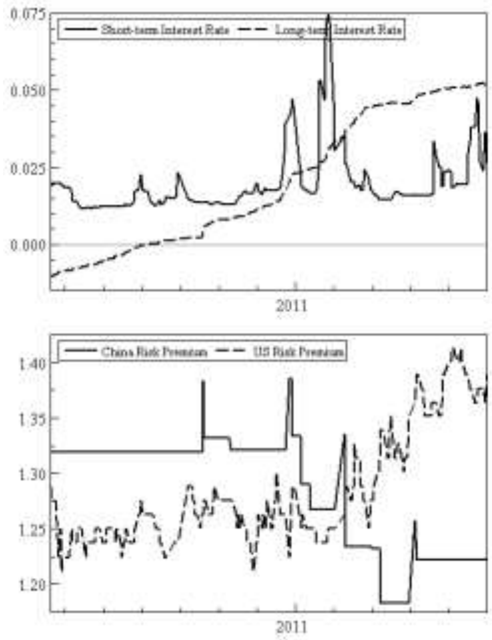
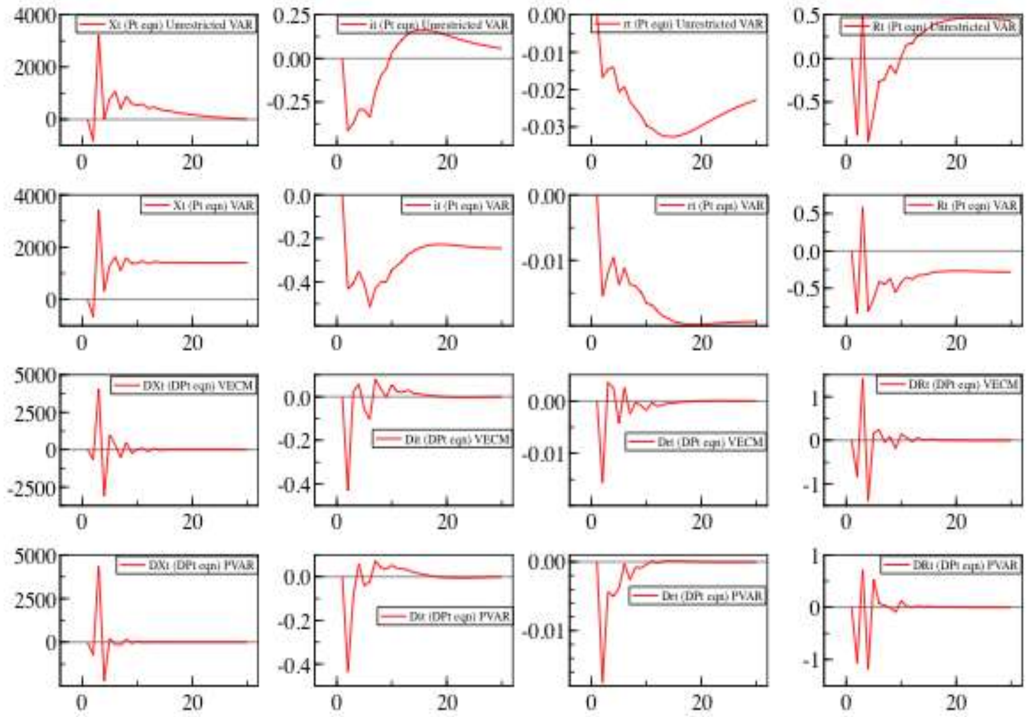


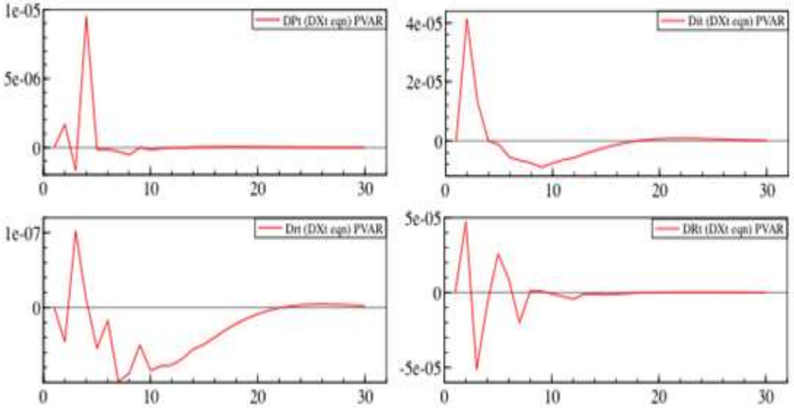
Figure 5: Responses of CNY/USD to the Shocks in the Unrestricted VAR, Reduced Form VAR, Just Identified VECM and Parsimonious VAR



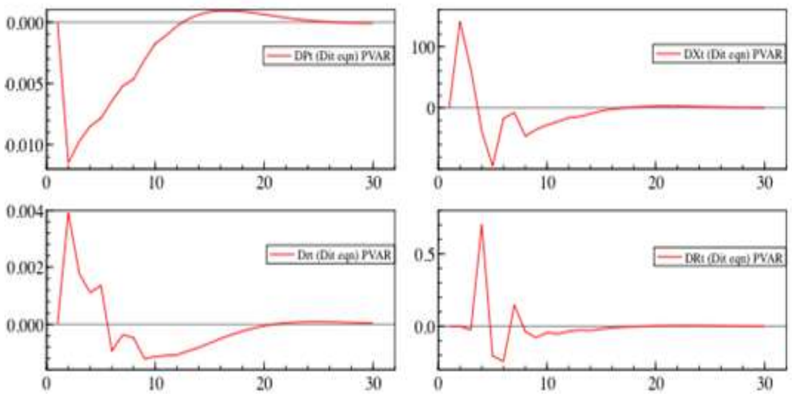
Notes:
This table presents the impulse responses of the Chinese exchange rate to one standard error shock from the order flow (DXt), short-term interest rate differential (Dit), long-term interest rate differential (Drt) and country risk premium (DRt). We test for a time horizon of 30 days.

Figure 6: Responses to Shocks in the Parsimonious VAR

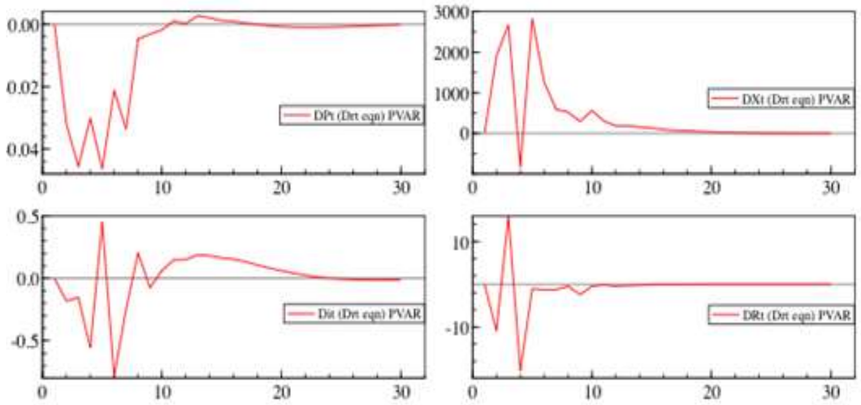
Panel A: Responses to order flow shocks



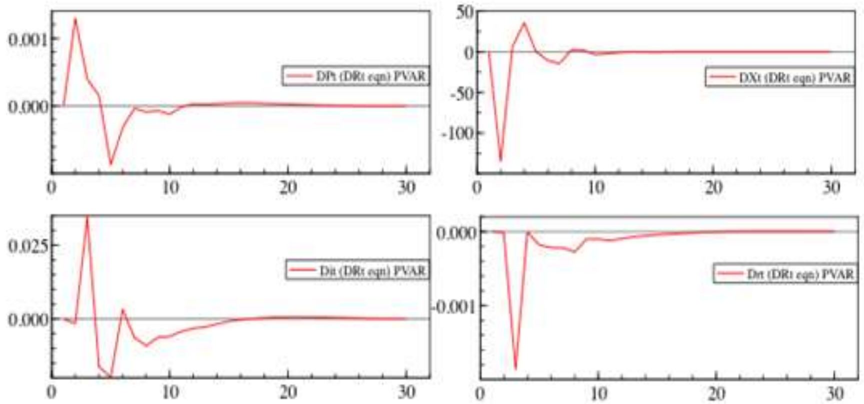
Panel B: Responses to short-term interest rate differential shocks



Panel C: Responses to long-term interest rate differential shocks



Panel D: Responses to country risk premium difference shocks



Notes:

This table presents the impulse responses of each variable to one standard error shock from the order flow (DX_t), short-term interest rate differential (Di_t), long-term interest rate differential (Dr_t) and country risk premium (DR_t). PVAR denotes the Parsimonious VAR model. We test for a time horizon of 30 days.