Macroeconomic Consequences of Foreign Exchange Futures Market for Inflation Targeting Economies

Syarifuddin, Ferry

Bank Indonesia

December 2020

Macroeconomic Consequences of Foreign Exchange Futures Market for Inflation Targeting Economies

Abstract

Although the discussion on foreign exchange (FX) futures market has drawn significant concern in the economic literature, this paper is the first attempt to address how the FX futures market impacts macroeconomic conditions with the inflation targeting regime. We use a dataset comprising of four emerging market countries with inflation targeting regime and active FX futures market, namely Brazil, Mexico, Turkey, and India, from January 2015 to December 2018. By utilizing Bayesian Panel Vector Autoregressions, we find that the FX futures rate shocks significantly affect the macroeconomic environment and monetary policy due to the strong relationship between the spot and futures market. We also find the initial indication of the market squeezing mechanism in the FX futures market. However, it occurs only in a small magnitude and a short period and thus, the spot exchange rate, inflation rate, and economic growth would not fluctuate abnormally. Our findings are robust for the various robustness checks.

Keywords: Foreign Exchange Futures Market, Inflation Targeting Framework, Macroeconomy, Emerging Economies.
JEL Classifications: E52, E58, G23

I Introduction

The more financially integrated economies of Emerging Markets and Developing Economies (EMDEs) are inherently associated with higher foreign exchange (FX) volatility. This is likened to placing their fortunes partly in the hands of others (Obstfeld, 2012). In view of this, the FX derivatives market (i.e., futures and options as hedging instruments) have a crucial role in mitigating risks given the uncertainty of the FX dynamics in the future.[1] Over the last two decades, the Notional Amount of Outstanding Positions (NAOP) as the proxy of FX derivatives activity in the EMDEs-FX derivatives market have grown considerably (see Figure 1). The NAOP in EMDEs was approximately seven billion US dollars in 2002 and reached 172 billion USD in late 2019. Proportionally, it comprised almost 20 percent of the world-level NAOP in exchange-traded FX futures and options markets.

Figure 1 is here

However, although the FX futures market provides some risk hedging, many researchers have also scrutinized the potential adverse effect of the FX futures market. A voluminous literature has argued that growing activities in the FX futures market destabilize the spot FX market. It has been demonstrated that the introduction of the FX futures market in India induced the volatility of the spot exchange rate (Niti & Anil, 2014; Sharma, 2011). Nath and Pacheco (2017) examined the volatility clustering pre- and post-introduction of the FX futures market and found that the underlying FX was relatively more volatile in the post-futures period. Biswal and Jain (2019) also illustrated a two-way inter-market linkage between the FX spot and futures market, with changes in volumes in either market significantly influencing the volatility of the corresponding markets. They also suggested that the Reserve Bank of India (RBI) should intervene formally in the FX futures market as part and parcel of exchange rate management policy. Furthermore, just like other financial markets, the FX futures market accommodates speculative motives that may include market misuse; potentially harming the spot exchange market. The seminal paper of Kyle (1992) had demonstrated how the market agents in the futures market interact and how market manipulation can occur. In the futures market, squeezers and corners (i.e., market manipulator) will cause hedgers to lose money on significant short positions when hedging is active. In contrast, when hedging is inactive, hedgers make money on small short positions. In other words, the speculators will hold off trading for the sake of squeezing when hedging activity is active. Consequently, this will drive up the FX futures rate to one that meets the desired level of the squeezers. Due to the close relationship between the FX futures market and the spot exchange rate market (see, for example, Garcia, Medeiros, & Santos, 2015; Inci & Lu, 2007), a depreciating FX futures rate could then be transmitted to the spot exchange rate.

Another strand of literature sheds light on the empirical relationship between the futures market and the macroeconomy. Bailey & Chan (1993) demonstrated that the spot and futures market's price spread significantly reflects the macroeconomic risk exposure to asset markets. Miffre (2001) investigated the empirical relationship between the predictability of futures returns and the business cycles and found that the FX futures market produces anomalous predictability patterns which are possibly caused by the presence of procyclical futures in the data. Chevallier (2009) examined the impact of macroeconomic conditions on carbon futures return and found that

[1] The derivatives market (e.g., options and futures) allows the investors to hedge the risks associated with the underlying instruments (see Reilly and Brown, 2012).

carbon futures prices correlate with the changes in macroeconomic conditions, implying the importance of fuel-switching behavior of power producers.

However, the question as to whether the FX futures market impacts macroeconomic conditions has drawn no concern in the literature. This question is essential. Given the risks and the growing activities of the FX futures market, the policymaker, especially the central bank, should pay attention to the impact of FX futures on the underlying FX market as this can potentially affect the central bank's policy objectives for exchange rate stability, inflation rate target, and economic growth. More specifically, this issue is pertinent for developing economies that have adopted the inflation targeting framework. For these economies, ensuring a stable FX is essential to avoid excessive FX volatility since this could cause an adverse effect on the inflation rate via the exchange rate pass-through (ERPT) mechanism (Caselli & Roitman, 2016; Céspedes, Chang, & Velasco, 2004; Menkhoff, 2013).

Our aim for this paper is to find out whether FX futures market have impacts for the macroeconomic environment. To do this, we will analyze how the FX futures market affect macroeconomic conditions, especially for those countries that have adopted the inflation targeting regime. In tracing the FX futures market's consequences on macroeconomic conditions, our hypotheses are as follows: First, depreciation on the FX futures rate would be responded to by the depreciation in the spot exchange rate via covered interest rate parity mechanism. Subsequently, depreciated spot exchange rates would be transmitted to inflation and economic growth via pass-through mechanisms in which depreciation causes a rise in the burden of foreign currencies, and driving the import price (Menkhoff, 2013). In the case of trade volume shocks, which reflects speculative motives, they could increase hedging activities where open interest and trade volume hedge the expectation of future spot FX movements, providing liquidity in the futures market. This then induces the availability of risk transfer and leads to a stronger and more stable spot exchange rate (Grossman & Miller, 1988). This consequently generates a lower inflation rate and higher economic growth due to reduced exchange rate risks. However, the FX futures market is also inherently associated with risks, with occurrences such as the squeezing mechanism or market manipulation, where speculators hold the trade when hedging is active to meet the desired rate of speculators (Kyle, 1992). In other words, the trade volume would respond to increasing open interest in the opposite way. Consequently, it could lead to a higher cost of hedging and exchange rate risks that could be transmitted to inflation and economic growth.

We test our hypothesis by conducting dynamic analysis using the Bayesian Pooled Panel Vector Autoregressions (VAR) approach. We exploit a dataset comprising of four emerging market economies with inflation targeting regimes (ITF) and active FX futures markets, namely, Brazil, Mexico, Turkey, and India, for the period of January 2015 to December 2018. In specifying the empirical model, we extend a unifying monetary framework developed by Kim (2003) to capture the role of the FX futures market activities while simultaneously controlling sterilized FX interventions, which are regular occurrences in ITF monetary regimes (Ghosh, Ostry, & Chamon, 2016).

Our empirical results shed light on three crucial findings. First, FX futures rate shocks have a significant effect on the macroeconomic environment and implementation of monetary policies due to the strong relationship between the spot and futures market. It implies that FX futures rate changes are important for emerging markets that pursue inflation targeting regimes. Second, we find that there are negative responses of trade volumes due to open interest shocks. This suggests that when hedging is active, speculators tend to hold transactions and *vice versa,* implying the initial indication of a market squeezing mechanism (see Kyle, 1992). However, we find that the response of the spot exchange rate and the FX futures rate is statistically unchanged due to the open interest shocks. This indicates initial incentives for market squeezing, but not its ability to do so, which is possibly constrained by regulations. Hence, it would not significantly stimulate an abnormal fluctuation of the FX futures rate, spot exchange rate, inflation rate, and economic growth. Third, we find neutrality for trade volume shocks in the FX futures market on the spot exchange rate and thus, neither monetary policy nor the macroeconomy are impacted. This finding extends the argument for trade volume neutrality where the trade volume in the FX futures market is neutral not only to the spot exchange rate but also to the macroeconomic conditions.

Our findings contribute to the literature in the following ways. First, although Bailey & Chan (1993) have investigated the empirical relationship between the price spread of spot-futures and macroeconomic risks, this paper looks further into the relationship between spot and futures prices and shows that they also significantly affect macroeconomic conditions and exchange rate management policies. Second, different from Kyle (1992), which only discussed the theoretical foundation of market squeezing, this paper suggests that market squeezing could be mitigated by the regulations. There is consequently no impact on fluctuations in the futures FX rate and, therefore, has little consequence for severe macroeconomic impacts. Third, our empirical results also find that there is neutrality of trade volume shocks in the FX futures market on the spot exchange rate. This finding supports the argument of the neutrality of the trade volume in the FX futures market (see for example, Bessembinder & Seguin 1992; Kumar, Poornima, & Sudarsan 2017; Jochum & Kodres 1998; Guru 2010). However, complementary to these works, our results demonstrates that macroeconomic conditions are also neutral to trade volume shocks in the FX futures market.

This paper is organized as follows: Section II discusses the methodological aspects, including data, variables, and econometric specification. Section III discusses the estimation results. Section IV explores the robustness checks. Section V provides the concluding remarks.

II Empirical Strategy

A. Data and Variables

We use a monthly balanced-panel with a total of 192 observations comprising four ITF-EMDEs which have an active FX futures market, i.e., Brazil, India, Mexico, and Turkey, from 2015:01 to 2018:12. In selecting the observations, we rely on two main criteria as follows: First, we look at six ITF-EMDEs countries with active FX futures market, i.e., Brazil, Colombia, India, Mexico, Turkey, and South Africa. However, the FX futures market data for both Colombia and South Africa are not complete for particular periods. Second, our econometric approach requires a balanced-panel that restricts our total observations (see next sub-section). For instance, the FX futures market in Turkey was only introduced in January 2015, while the FX futures in Brazil, India, and Mexico were formally started in 1991, 2008, and 1998, respectively.

Table 1 is here

Our empirical variables are displayed in Table 1. For the FX futures market variables, we utilize open interest, trade volume, and FX futures contract price. The open interest is frequently employed in the existing literature to capture hedging activities in the FX futures market (Bhargava & Malhotra, 2007; Guru, 2010; Nath & Pacheco, 2017). The daily average of FX futures market turnover is utilized to represent the trading activities in the FX futures market, obtained from the Triennial Survey of Bank for International Settlements (BIS). This data is frequently used in various research and policy reports to depict the transactional size of FX derivatives, especially trading activities in the FX futures market (e.g., S. Gopinath, 2010; Guru, 2010; International Monetary Fund, 2015, 2018). We also employ the FX futures contract price to represent the rate of FX futures as it is crucial to establish the linkage between the FX futures market and spot FX market (Biswal & Jain, 2019; Floros & Salvador, 2016; Garcia et al., 2015; Guru, 2010; Jochum & Kodres, 1998; Wang, Yang, & Simpson, 2008). For the variables that control the conduct of monetary policy, we follow Kim (2003), which comprise FX intervention, money growth, and policy rate. Lastly, we use the nominal spot exchange rate, industrial production index, and consumer price index to represent the macroeconomic indicators. We first normalize the FX futures rate and spot FX rate by dividing the actual value with the base month (January 2015) to ensure the comparable value among countries. We then transform the data with log-differenced.

Table 2 presents the descriptive statistics of the variables as follows.

Table 2 is here

B. Econometric Approach

In previous works of literature, the standard VAR is frequently employed to examine the market linkage between the futures market and spot market in a single country (see, for example, Jochum & Kodres 1998; Bhargava & Malhotra 2007; Guru 2010; Floros & Salvador 2016). In this paper, we extend the investigation, which comprises not only the inter-linkage between FX futures and spot market but also the consequences of FX futures market activities on the macroeconomy for a panel of selected developing inflation targeting countries. For this purpose, we utilize the Panel Vector Autoregressive (PVAR). The PVAR model is basically built on the same logic as the standard VAR model, with the cross-sectional features extended (Canova & Ciccarelli, 2013). Suppose we have the following standard unrestricted P-VAR equation:

$$y_{it} = \boldsymbol{\varphi_i} x_{it} + \boldsymbol{\omega_i} w_{it} + \varepsilon_{it} \quad (1)$$

where y_{it} is a M-dimensional vector of endogenous variables for unit $i = 1, 2, \dots, N$ and period $t = 1, \dots, T$. While $\boldsymbol{\varphi_i}$ and $\boldsymbol{\omega_i}$ respectively denote matrix coefficients associated with $x_{it} = \left(y'_{it-1}, y'_{it-2}, \dots, y'_{it-p}\right)'$ and a matrix coefficient related to the lags of $w_{it} = (x'_{1t}, \dots, x'_{i-1t}, x'_{i+1t}, \dots, y'_{Nt})'$.

From the equation above, it illustrates three main features of the PVAR comprising cross-sectional heterogeneity (CH), static interdependencies (SI), and dynamic interdependencies (DI). The cross-sectional heterogeneity is concerned with the relationship between y_{it} and their lags $x_{it} = \left(y'_{it-1}, y'_{it-2}, \dots, y'_{it-p}\right)'$. In the cross-country case, CH restriction implies that $\boldsymbol{\varphi_i} = \boldsymbol{\varphi_j} = \boldsymbol{\varphi}$, which indicates that the parameters $(\boldsymbol{\varphi})$ are homogenous across countries. For the second restriction, namely DI, it relates to the parameter of lagged relation across units, $\boldsymbol{\omega_i}$, where the restricted DI rules out the cross-unit spillover, $\boldsymbol{\omega_i} = \mathbf{0}$. The last restriction, SI, is associated with the contemporaneous linkage of cross-country shocks in the system, $\boldsymbol{\Sigma_{ij}} = \mathbf{0}$. It considers whether shocks are interrelated among countries and variables.

However, these features frequently lead to over-parameterization, the curse of dimensionality (Feldkircher, Huber, & Pfarrhofer, 2020), which difficult to tackle using frequentist methods[2]. More specifically, Bayesian methods provide an effective way to explore a sizeable

[2] In other words, the unrestricted P-VAR with P lag(s) ought to, at least, employ $(NK)^2P$ autoregressive coefficients and $\frac{NK(NK+1)}{2}$ free parameters in the error covariance matrix (Koop & Korobilis, 2016).

dimensional space using Markov Chain Monte Carlo (MCMC) algorithms (Feldkircher et al., 2020). Therefore, it is worth stressing that a considerable number of literature rely on Bayesian-based methods to estimate PVAR models (see, for instance, Canova & Ciccarelli, 2009, 2013; Koop & Korobilis, 2016).

In this paper, we specifically employ the pooled Bayesian PVAR developed by Canova & Ciccarelli (2009, 2013), which restricts the cross-sectional heterogeneity and dynamic and static interdependencies. The intuition behind the restrictions and the use of the Bayesian approach is in the following: First, our cross-sectional observations are similar in terms of the monetary policy framework and economic status. Second, we assume the absence of dynamic and static interdependencies because our observations are those of developing countries, which contain no spillover effect. Third, our observations are limited due to data availability and the utilization of the Bayesian approach thus helps to overcome the curse of dimensionality due to the relatively small number of observations.

More specifically, the pooled Bayesian PVAR adopts the standard normal-Wishart identification (Canova & Ciccarelli, 2009, 2013; Dieppe, Legrand, & Van Roye, 2016). Suppose that we formulate the VAR model in the matrix form as follows:

$$\underbrace{vec(Y)}_{NnT\times 1} = \underbrace{(I_n \otimes X)}_{NnT\times n(np+m)} \underbrace{vec(B)}_{n(np+m)\times 1} + \underbrace{vec(\varepsilon)}_{NnT\times 1}$$
$$y = \bar{X}\beta + \varepsilon \tag{2}$$

For the prior of β, it is assumed to be normal as for the normal-Wishart, while we use inverse Wishart for the prior of the variance-covariance matrix (Σ_c) in the following equations:

$$\beta \sim \mathcal{N}(\beta_0, \Sigma_c \otimes \Phi_0) \tag{3}$$

$$\Sigma_c \sim IW(S_0, \alpha_0) \tag{4}$$

where Φ_0, α_0, and S_0 respectively denote the variance of parameters in pooled sample variables, the prior degree of freedom, and $n \times n$ scale matrix for the prior.

Given the prior of β and Σ_c, we obtain the posterior distribution using the Bayesian rule by combining the likelihood function with the prior distribution as follows:

$$\pi(\beta, \Sigma_c | y) \propto |\,\Sigma_c|^{-k/2} \exp\left[-\frac{1}{2} tr\{\,\Sigma_c{}^{-1}[(B-\bar{B})'\bar{\Phi}^{-1}(B-\bar{B})]\}\right]$$
$$\times\, |\,\Sigma_c|^{-(\bar{\alpha}+n+1)/2} \exp\left[-\frac{1}{2} tr\{\Sigma_c{}^{-1}\bar{S}\}\right] \tag{5}$$

with $\bar{\Phi} = [\bar{\Phi}_0^{-1} + X'X]^{-1}$; $\bar{B} = \bar{\Phi}[\bar{\Phi}_0^{-1}B_0 + X'Y]$; $\bar{\alpha} = NT + \alpha_0$; and $\bar{S} = Y'Y + S_0 B_0'\bar{\Phi}_0^{-1}B_0 - \bar{B}'\bar{\Phi}^{-1}\bar{B}$, we obtain the following equation by marginalizing β and Σ_c:

$$\pi(\Sigma_c | y) \sim IW(\bar{\alpha}, \bar{S}) \tag{6}$$

$$\pi(\beta | y) \sim MT(\bar{B}, \bar{S}, \bar{\Phi}, \tilde{\alpha}) \tag{7}$$

where $\tilde{\alpha} = \bar{\alpha} - n + 1 = NT + \alpha_0 - n + 1$.

C. Specifying the Model Estimate

In specifying the model, we extend a unifying monetary framework developed by Kim (2003) to capture the role of the FX futures market activities while simultaneously controlling the sterilized FX intervention, which is regularly used in an ITF regime (Ghosh et al., 2016). Our model estimate is thus expressed in the following equation:

$$X_{it} = \boldsymbol{\tau} x_{it} + \varepsilon_{it} \tag{8}$$

where X_{it} denotes a vector of endogenous variables. Specifically, our variables comprise FX intervention (SI), money aggregate (M), domestic interest rates (r^d), economic growth (y), exchange rates (S), and inflation rates (π), as well as three more variables as the representation of FX futures market activity: Open interest (OP) as a representation of hedgers activity, trade volume (TV) representing of speculators' activity, and the FX futures contract price (F). The matrix of lagged endogenous variables is $x_{it} = (X'_{it-1}, X'_{it-2}, \ldots, X'_{it-p})'$, while $\boldsymbol{\tau}$ and ε_{it} are a matrix of coefficients associated with x_{it} and a vector of shocks. We use four lags, $p = 4$, in our model.

In estimating the Impulse-response Function (IRF), we utilize the Cholesky ordering in which the variables are ordered from the least endogenous to the most endogenous based on our hypothesis. We thus order the variables based on our transmission hypothesis as follows.

$$X_{it} = \{OP_{it}, TV_{it}, F_{it}, S_{it}, SI_{it}, M_{it}, r_{it}^{d}, CPI_{it}, y_{it}\} \tag{9}$$

Table 3 is here

To satisfy the standard procedure of the VAR model estimation, we perform unit root tests using various approaches *viz*, Im, Pesaran, and Shin (IPS), Augmented Dickey-Fuller (ADF), and Phillip-Peron (PP). We use the Schwartz Information Criterion (SIC) for the lag length selection. Our unit root tests illustrate that our variables are stationary at any confidence interval (see Table 8). Also, all of our unit root tests are consistent across the different methods used, indicating that our variables are robustly stationary.

Figure 2 is here

We also perform tests to verify the stability of the VAR model and to confirm the validity of the Impulse Response Function (IRF). The results of the stability tests are displayed in Figure 2. As depicted, the roots of the characteristic polynomial (modulus) lie below one, confirming the validity of the Panel VAR estimation.

III Results and Discussion

This section discusses the empirical findings of the macroeconomic consequences of the FX futures market activities. Our discussion focuses on the impact of FX futures rate, trade volume, and open interest shocks on domestic macroeconomic conditions. In addition to the discussion, we also provide some policy implications derived from our empirical results and specific experiences of related countries.

A. Empirical Results

Our empirical results for the IRF and Variance Decompositions analysis are displayed in Figures 3 and 4, respectively.

We first scrutinize the impact of the trade volume shock. We observe that the open interest increased significantly in the second period in response to trade volume shocks. This suggests that increasing the volume of trade in the FX futures market would induce activities of the hedgers. The growing transactions in the FX futures market incentivize hedgers to hedge their underlying assets. Furthermore, we find no significant response of the FX futures rate to trade volume shocks. This finding confirms the work of Tornell and Yuan (2012) which found an insignificant correlation between trading measures and future market movements. We also find no significant spot exchange market responses to the trade volume shocks. This verifies that there is a neutral effect of trading activities in the FX futures market on the spot market. Bessembinder and Seguin (1992) found no evidence of an empirical linkage between trading activity in the FX futures market and spot FX market movements. Kumar, Poornima, and Sudarsan (2017) also examined the role of FX futures introduction on spot volatility and found that spot volatility was indifferent between before and after the introduction of the FX futures market in India. Jochum and Kodres (1998) found that the FX futures market neither destabilizes nor stabilizes the underlying spot FX market. Given its neutrality on the spot exchange rate, we find that neither economic growth nor inflation rate responds significantly to FX futures trade volume shocks.

We next proceed with the analysis of the impact of open interest shock. Trade volume decreased significantly in the first period, suggesting that when hedging is active, speculators tend to hold transactions and *vice versa.* This implies the initial indication of a market squeezing mechanism (see Kyle, 1992). However, we find that both the spot exchange rate and FX futures rate are insignificant. This suggests that there are initial incentives for market squeezing, but not the ability to do so, due possibly to constraints from regulations. This finding also supports the premise of neutrality of trading activities on the spot FX market. Guru (2010) argued that neither speculative nor hedging activities in the FX futures market induce volatility significantly in the spot FX market. We similarly find that neither FX intervention nor the policy rate responds significantly since these policies are generally aimed at particular levels of exchange rate fluctuations (Ghosh et al., 2016). We also find no significant response on economic growth and the inflation rate. In general, our findings illustrate that shocks from open interest, for which the trade volume responded negatively in the initial period, do not exacerbate fluctuations in the macroeconomy. This finding confirms the importance of regulations to limit abnormal behavior in the market. It is vital that FX futures market operations have in place a surveillance system, comprising price monitoring, positions monitoring, and market abuse mitigation and investigation. Jarrow (1992) indicated that market manipulation, such as squeezing or cornering, can only be undertaken by large traders. This means that positions monitoring and limitation would be a useful tool to prevent such market manipulations. The Central Bank of Brazil and Reserve Bank of India have conducted currency operations in the FX futures market to ensure its smooth function. Intuitively, such operations could prevent sudden stops in trade volumes by offsetting the decrease in trade volumes by speculators. This would mean that the domino effect of FX futures rate depreciation on the macroeconomy could be anticipated effectively.

Figure 3 is here

We find that FX futures rate shocks could be sterilized promptly. The spot exchange rate depreciated significantly due to FX futures rate shocks. The significant positive response of the spot exchange rate to FX futures shocks confirms the theory of Covered Interest Rate Parity (CIRP), which is the actualization of the law of one price between two countries' interest rates, adjusted to the hedge value. This finding also confirms a robust relationship between the spot FX and FX futures markets. In response to the depreciated exchange rate, the central bank reacts with sterilized FX intervention, which is characteristic of exchange rate management in an ITF regime

(Ghosh et al., 2016). Due to the exchange rate depreciation, we find that the inflation rate increases significantly during the impact period but then start to recover in the following four periods, while economic growth slows significantly only during the impact period. Our empirical results confirm the premise that depreciated spot exchange rates would be transmitted to the inflation rate *via* pass-through mechanisms, emanating from exacerbations in foreign currencies and import prices (Menkhoff, 2013).

We now proceed to the examination of the variance decomposition of the macroeconomic indicators (see Figure 4). We find that the FX futures rate has a considerable role in terms of contributing to the formation of exchange rate returns, by approximately 66 percent to 80 percent, while both trade volume and open interest comprise only about 2 percent. The FX futures rate also contributes significantly to the inflation rate variance by about approximately 20 percent, while the trade volume and open interest jointly contribute around 3 percent. This finding suggests that the FX futures rate has a crucial role in spot price discovery, meaning that the FX futures market is an unbiased-predictor for spot FX movement (Inci and Lu 2007). M. Garcia et al. (2015) demonstrated that the FX futures rate creates the price discovery of the spot exchange rate in Brazil. We also find that the trade volume, open interest, and FX futures rate are relatively significant in forming the economic growth variance at nearly 10 percent, which even higher than the spot exchange rate, monetary policy, and inflation rate. This shows that the FX futures market has a role in determining the future movement of economic growth, albeit in a minimal way. The FX futures market has an essential function since both hedging and speculative activities in the market can determine the amount of liquidity in the economy (Mihaljek, 2005).

Based on these findings, we shed light on several pieces of crucial evidence. First, FX futures rate shocks have impacts on the macroeconomic environment and the conduct of monetary policy due to its role in the price discovery of the spot exchange rate. Second, the negative response of trade volume from open interest shocks imply that there is a squeezing mechanism in the FX futures market. However, this only occurs in a small magnitude and for a short time frame and prices do not, therefore, fluctuate abnormally. This shows that the relevant authorities have placed comprehensive surveillance on the FX futures market, mitigating risks and dampening any abnormal fluctuations in the FX futures rate, spot exchange rate, inflation rate, and economic growth. Third, our empirical findings illustrate the crucial role of the FX futures rate in explaining the variance of the exchange rate and inflation rate. Fourth, we also find that elements of the FX futures market are relatively essential in describing the variance in economic growth compared to other variables.

Figure 4 is here

B. Policy Implications

In terms of policy practices, our empirical results have several implications. The first is the critical role of micro-prudential authorities in ensuring a well-functioning FX futures market, which is inherently associated with risks such as market manipulations. Authorities handling micro-prudential issues, have to develop a robust surveillance system that monitors, mitigates, and enforces regulations when indications of abnormal behavior in the market are detected. The common standards of surveillance systems mostly comprise price monitoring, positions monitoring, and market abuse mitigation and investigation.

However, the regulatory framework related to the Brazilian FX futures market has a unique and robust control in restricting market misuse. Due to the *Plano Real* in 1994, only a few agents could directly access the foreign exchange related market, including the futures market, which includes only currency operations, international trade contracts, trade financing or loans, or any obligations where involves the creditor or debtor domiciled outside Brazil (International Monetary Fund, 2015). This regulation for restricted access has led to the minimization of risks due to abnormal market behavior, such as market manipulation or circular trading.

At the same time, the central bank also has an essential role in ensuring a well-functioning FX futures market through its currency operations. The Central Bank of Brazil (CBB) and Reserve Bank of India (RBI) have conducted currency operations in their respective FX futures markets to ensure their proper functioning (see, for instance, Kohlscheen and Andrade 2014; Nedeljkovic and Saborowski 2019).[3] Intuitively, such operations could prevent sudden stops in trade volumes by immediately offsetting decreasing trade volumes and restoring market activities.

IV Robustness Checks

For the robustness checks, we apply four robustness strategies as follows: First, we use an alternative variable ordering to estimate the Panel VAR model. For this, we estimate the Panel Granger Causality to order the variables from the most exogenous to the most endogenous, and re-estimate the Panel VAR model using Bayesian Pooled PVAR with $p = 4$. Second, we conduct the sensitivity test by performing five different lag structures of the Panel VAR estimation using the Pooled Bayesian PVAR and examine whether the estimated IRFs are consistent. This test is essential since the VAR model is basically sensitive to the lag structure (Hafer & Sheehan, 1989). Third, we re-estimate the primary estimation using a Large BVAR developed by Banbura, Giannone, & Reichlin (2010). As mentioned by Canova & Ciccarelli (2013), Large BVAR is similar to the Panel BVAR. Performance evaluation performed by Feldkircher et al. (2020) also illustrated that large scale BVAR performs well in estimating Panel VAR. Lastly, we substitute exchange rate returns with exchange rate volatility, which is estimated using Bayesian PVAR.[4]

Table 4 is here

Alternative Variables Ordering. For the alternative variables ordering, we conduct the Panel Granger causality (PGC) test as the foundation for the Cholesky VAR ordering (see Table 4). The PGC test resulted in the following: (i) *DOPIN* and *DTV1* are determined by only one variable, which also explains the causality relation between these two variables; (ii) *DLOGFXFUT* and

[3] Also see RBI Bulletin *(continuously updated)*, Chapter 4 Sales/Purchases of US Dollar by the RBI.

[4] See Appendix F for the estimations of exchange rate volatility.

DLOGFX are only explained by the changes in policy rate (*DPR*); (iii) Both *DLOGFXFUT* and *DLOGFX* significantly Granger-cause FX intervention; (iv) *DLOGIPI* is merely affected by *DTV1* and *DLOGCPI*; (v) *DLOGFXFUT*, *DLOGFX*, and *DPR* Granger-cause *DLOGIPI*; (vi) *DLOGFXFUT*, *DLOGFX*, *DLOGM3*, and *DLOGCPI* significantly Granger-cause *DPR*; and (vii) *DLOGM3* is significantly Granger-caused by *DLOGFXFUT*, *DLOGFX*, *DPR*, and *DLOGCPI*. Based on these results, we consider the following Cholesky ordering: $X_{it} = \{OP_{it}, TV_{it}, F_{it}, S_{it}, SI_{it}, y_{it}, CPI_{it}, r_{it}^{d}, M_{it}\}$. As we can see, this ordering form is slightly different from our primary ordering, where r_{it}^{d} and M_{it} shift to the most endogenous variables. This order is reasonable since monetary policy instruments are implemented based on the consideration of several variables such as inflation rate and exchange rate (see e.g., Clarida, Galí, and Gertler 2000; Benes et al. 2015; Canzoneri and Cumby 2014; Bekareva, Meltenisova, and Kravchenko 2019; Nechio, Carvalho, and Nechio 2019; Caporale et al. 2018). Our results for the alternative ordering are robustly consistent with the benchmark ordering (see Equation 9). This ordering also results in the identical modulus value with the estimation of the benchmark, implying that the estimation satisfies the stability condition (see Appendix B).

Alternative Lag Structure. For the sensitivity test, we re-estimate the Panel VAR model using various lag structures, i.e., $p = \{2,4,6,8,10\}$. Based on these estimations, the IRFs produce identical results to the primary lag structure ($p = 4$) (see Appendix C). The Panel VAR estimations also indicate a stability condition, implying that our findings are robust for the various lag structures.

Alternative Panel VAR Estimator. By utilizing Large BVAR, we find that both the impulse response function and variance decomposition results are approximately identical (see Appendix D). Large BVAR captures the asymmetric relationship between trade volume and open interest and its neutral impact on the macroeconomy. At the same time, our robustness test also illustrates that the FX futures rate is significantly essential, where the shocks are significantly responded to by the exchange rate, inflation rate, and economic growth. Also, the shocks of the FX futures rate are significantly responded to by monetary policy. In analyzing the variance decomposition, we also find similar results with the primary estimation as follows: the FX futures rate has a considerable role in contributing to exchange rate returns by about 46 percent, while both trade volume and open interest make up less than one percent. Second, we find that the FX futures rate also explains the variance in the inflation rate by more than 15 percent. Third, we find that elements of the FX futures market, i.e., open interest, trade volume, and FX futures rate, jointly explain the variance in economic growth by about approximately 5 percent, which higher than other variables.

Alternative Variable. We employ the Bayesian PVAR (Canova & Ciccarelli, 2009, 2013) in a different model specification that substitutes the exchange rate return with exchange rate volatility (see Appendix E). Our empirical results demonstrate that neither the shocks of open interest nor trade volume significantly affect exchange rate volatility, inflation rate, economic growth, and the conduct of sterilized FX intervention. For the FX futures rate, we find that the shocks are significantly responded to by exchange rate volatility, inflation rate, economic growth, and the sterilized FX intervention mechanism. For the variance decomposition analysis, we find that the FX futures rate is significant for explaining the variance in exchange rate volatility and inflation rate by 19 percent and 18 percent, respectively. We also find that elements of the FX futures market, i.e., open interest, trade volume, and FX futures rate, jointly explain the variance in economic growth by more than 7 percent, which higher than other variables. In conclusion, our fourth robustness test is consistent with our primary results.

V Concluding Remarks

This paper examines whether the FX futures market impacts emerging markets' macroeconomic conditions that adopt the inflation targeting regime. We make a dynamic empirical analysis using the Bayesian Pooled PVAR approach, which comprises four emerging economies with inflation targeting regimes and active FX futures markets, i.e., Brazil, Mexico, Turkey, and India, from January 2015 to December 2018. In specifying the empirical model, we extend a unifying monetary framework developed by Kim (2003) to capture the role of the FX futures market activities while simultaneously controlling sterilized FX interventions, which are regularly employed in ITF monetary regimes (Ghosh et al., 2016).

Our empirical results shed light on three crucial findings. First, FX futures rate shocks have impacts on the macroeconomic environment and the conduct of monetary policy due to its role in the price discovery of the spot exchange rate. Second, the negative response of trade volume from open interest shocks imply that there is a squeezing mechanism in the FX futures market. However, this only occurs in a small magnitude and for a short time frame and prices do not, therefore, fluctuate abnormally. This shows that the relevant authorities have placed comprehensive surveillance on the FX futures market, mitigating risks and dampening any abnormal fluctuations in the FX futures rate, spot exchange rate, inflation rate, and economic growth. Third, our empirical findings illustrate the crucial role of the FX futures rate in explaining the variance of the exchange rate, and inflation rate. Fourth, we also find that elements of the FX futures market are relatively essential in describing the variance in economic growth compared to other variables.

In terms of policies, our empirical results have several implications. First is the critical role of micro-prudential regulations in ensuring a well-functioning FX futures market, which is inherently associated with risks as in market manipulations and the like. Authorities dealing with micro-prudential issues have to develop a robust surveillance system that monitors, mitigates, and enforces regulations whenever abnormal behavior in the market is discovered. Coupled with this is essential role that the central bank plays in ensuring a well-functioning FX futures market through its currency operations. For instance, the Central Bank of Brazil (CBB) and Reserve Bank of India (RBI) have conducted currency operations in their respective FX futures markets to ensure their proper functioning. These types of operations could serve to prevent trade volumes from sudden drops by the immediate offset of the decreased trade volumes and restore market activities.

Declaration of Interest: None

References

Bailey, W., & Chan, K. C. (1993). Macroeconomic Influences and the Variability of the Commodity Futures Basis. *The Journal of Finance*, *48*(2), 555–573. https://doi.org/10.1111/j.1540-6261.1993.tb04727.x

Banbura, M., Giannone, D., & Reichlin, L. (2010). Large Bayesian Vector Auto Regressions. *Journal of Applied Econometrics*, *25*, 71–92. https://doi.org/1002/jae.1137

Behera, B., & Swain, A. K. (2019). The Effects of Introducing Currency Futures on Spot Exchange Rates – A Review of Related Literature. *International Journal of Management Studies*, *VI*(1(6)), 01. https://doi.org/10.18843/ijms/v6i1(6)/01

Bekareva, S., Meltenisova, E., & Kravchenko, N. (2019). Central banks' inflation targeting and real exchange rates: Cointegration with structural breaks. *Model Assisted Statistics and Applications*, *14*(1), 89–102. https://doi.org/10.3233/MAS-180451

Benes, J., Berg, A., Portillo, R., & Vavra, D. (2015). Modelling sterilized interventions and balance sheet effects of monetary policy in a new keynesian framework. *Open Economies Review*, *26*(1), 232–264. https://doi.org/10.1007/s11079-014-9320-1

Bessembinder, H., & Seguin, P. J. (1992). Futures-Trading Activity and Stock Price Volatility. *The Journal of Finance*, *47*(5), 2015–2034. https://doi.org/10.1111/j.1540-6261.1992.tb04695.x

Bhargava, V., & Malhotra, D. K. (2007). The relationship between futures trading activity and exchange rate volatility, revisited. *Journal of Multinational Financial Management*, *17*(2), 95–111. https://doi.org/10.1016/j.mulfin.2006.05.001

Biswal, P. C., & Jain, A. (2019). Should central banks use the currency futures market to manage spot volatility? Evidence from India. *Journal of Multinational Financial Management*, 100596. https://doi.org/10.1016/j.mulfin.2019.100596

Canova, F., & Ciccarelli, M. (2009). Estimating Multicountry VAR Models. *International Economic Review*, *50*(3), 929–959. https://doi.org/10.1111/j.1468-2354.2009.00554.x

Canova, F., & Ciccarelli, M. (2013). Panel vector autoregressive models: A survey. *Advances in Econometrics*, *32*(15), 205–246. https://doi.org/10.1108/S0731-9053(2013)0000031006

Canzoneri, M., & Cumby, R. (2014). Optimal Exchange Intervention in an Inflation Targeting Regime: Some Cautionary Tales. *Open Economies Review*, *25*(3), 429–450. https://doi.org/10.1007/s11079-013-9287-3

Caporale, G. M., Helmi, M. H., Çatık, A. N., Menla Ali, F., & Akdeniz, C. (2018). Monetary policy rules in emerging countries: Is there an augmented nonlinear taylor rule? *Economic Modelling*, *72*(October 2017), 306–319. https://doi.org/10.1016/j.econmod.2018.02.006

Caselli, F., & Roitman, A. (2016). Non-Linear Exchange Rate Pass-Through in Emerging Markets. *IMF Working Papers*, *16*(1), 1. https://doi.org/10.5089/9781513578262.001

Céspedes, L. F., Chang, R., & Velasco, A. (2004). Balance sheets and exchange rate policy. *American Economic Review*, *94*(4), 1183–1193. https://doi.org/10.1257/0002828042002589

Chevallier, J. (2009). Carbon futures and macroeconomic risk factors: A view from the EU ETS. *Energy Economics*, *31*(4), 614–625. https://doi.org/10.1016/j.eneco.2009.02.008

Clarida, R., Galí, J., & Gertler, M. (2000). Monetary policy rules and macroeconomic stability: Evidence and some theory. *Quarterly Journal of Economics*, *115*(1), 147–180. https://doi.org/10.1162/003355300554692

De Mol, C., Giannone, D., & Reichlin, L. (2008). Forecasting using a large number of predictors: Is Bayesian shrinkage a valid alternative to principal components? *Journal of Econometrics*, *146*(2), 318–328. https://doi.org/10.1016/j.jeconom.2008.08.011

Dieppe, A., Legrand, R., & Van Roye, B. (2016). The BEAR toolbox. *ECB Working Paper Series*, (1934). Retrieved from https://www.ecb.europa.eu/pub/pdf/scpwps/ecbwp1934.en.pdf?4c09bd3d9f294ae6b8111b8a59b8cea8

Feldkircher, M., Huber, F., & Pfarrhofer, M. (2020). Factor Augmented Vector Autoregressions, Panel VARs, and Global VARs. In P. Fuleky (Ed.), *Macroeconomic Forecasting in the Era of Big Data* (Fifth, pp. 65–93). Gewerbestrasse 11, 6330 Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-030-31150-6

Floros, C., & Salvador, E. (2016). Volatility, trading volume and open interest in futures markets. *International Journal of Managerial Finance*, *12*(5), 629–653. https://doi.org/10.1108/IJMF-04-2015-0071

Garcia, M., Medeiros, M., & Santos, F. (2015). Price Discovery in Brazilian FX Markets. *Brazilian Review of Econometrics*, *35*(1), 65–94. https://doi.org/10.12660/bre.v35n12015.46423

Ghosh, A. R., Ostry, J. D., & Chamon, M. (2016). Two targets, two instruments: Monetary and exchange rate policies in emerging market economies. *Journal of International Money and Finance*, *60*, 172–196. https://doi.org/10.1016/j.jimonfin.2015.03.005

Gopinath, S. (2010). Over-the-counter derivative markets in India. *Fsr Financial*, (14), 61–69. Retrieved from http://www.centerforfinancialstability.org/fsr/fra_fsr_201007.pdf#page=69

Grossman, S. J., & Miller, M. H. (1988). Liquidity and Market Structure. *The Journal of Finance*, *43*(3), 617–633. https://doi.org/10.1111/j.1540-6261.1988.tb04594.x

Guru, A. (2010). Interplay Between Exchange Traded Currency Futures Markets, Spot Markets and Forward Markets: A Study on India. *Indian Economic Review*, *45*(1), 111–130. https://doi.org/http://www.jstor.org/stable/29793956

Hafer, R. W., & Sheehan, R. G. (1989). The sensitivity of VAR forecasts to alternative lag structures. *International Journal of Forecasting*, *5*(3), 399–408. https://doi.org/10.1016/0169-2070(89)90043-5

Inci, A. C., & Lu, B. (2007). Currency futures-spot basis and risk premium. *Journal of International Financial Markets, Institutions and Money*, *17*(2), 180–197. https://doi.org/10.1016/j.intfin.2005.10.003

International Monetary Fund. (2015). Brazil: Selected Issues; IMF Country Report 15/122; May 12, 2015, (15), 102. Retrieved from https://www.imf.org/external/pubs/cat/longres.aspx?sk=42929.0

International Monetary Fund. (2018). *Financial Sector Assessment Program*. *Financial Sector Assessment Program*. https://doi.org/10.1596/978-0-8213-6652-3

Jarrow, R. A. (1992). Market Manipulation , Bubbles , Corners , and Short Squeezes. *The Journal of Financial and Quantitative Analysis*, *27*(3), 311–336. https://doi.org/10.2307/2331322

Jochum, C., & Kodres, L. (1998). *Does the Introduction of Futures on Emerging Market Currencies Destabilize the Underlying Currencies* (IMF Working Paper No. WP/98/13).

Kadiyala, K. R., & Karlsson, S. (1997). Numerical methods for estimation and inference in Bayesian VAR-models. *Journal of Applied Econometrics*, *12*(2), 99–132. https://doi.org/10.1002/(SICI)1099-1255(199703)12:2<99::AID-JAE429>3.0.CO;2-A

Kim, S. (2003). Monetary policy, foreign exchange intervention, and the exchange rate in a unifying framework. *Journal of International Economics*, *60*(2), 355–386. https://doi.org/10.1016/S0022-1996(02)00028-4

Kohlscheen, E., & Andrade, S. C. (2014). Official FX interventions through derivatives. *Journal of International Money and Finance*, *47*, 202–216. https://doi.org/10.1016/j.jimonfin.2014.05.023

Koop, G., & Korobilis, D. (2016). Model uncertainty in Panel Vector Autoregressive models. *European Economic Review*, *81*(September 2015), 115–131. https://doi.org/10.1016/j.euroecorev.2015.09.006

Kumar, A. (2015). Impact of Currency Futures on Volatility in Exchange Rate. *Paradigm*, *19*(1), 95–108. https://doi.org/10.1177/0971890715585204

Kumar, T. K. D., Poornima, B. G., & Sudarsan, P. K. (2017). Effectiveness of Currency Futures Market in India: An Empirical Investigation. *IIM Kozhikode Society & Management Review*, *6*(2), 196–203. https://doi.org/10.1177/2277975217704606

Kyle, A. S. (1992). A Theory of Futures Market Manipulations. In P. Weller (Ed.), *The Theory of Futures Market* (p. 272). Cambridge, Massachusetts 02142: Blackwell Publishers.

Menkhoff, L. (2013). Foreign exchange intervention in emerging markets: A survey of empirical studies. *World Economy*, *36*(9), 1187–1208. https://doi.org/10.1111/twec.12027

Miffre, J. (2001). Economic activity and time variation in expected futures returns. *Economics Letters*, *73*(1), 73–79. https://doi.org/10.1016/S0165-1765(01)00475-X

Mihaljek, D. (2005). *Survey of central banks' views on effects of intervention* (BIS Papers No. 24). *BIS Papers*.

Nath, G., & Pacheco, M. (2017). Currency futures market in India: an empirical analysis of market efficiency and volatility. *Macroeconomics and Finance in Emerging Market Economies*, *11*(1), 47–84. https://doi.org/10.1080/17520843.2017.1331929

Nechio, F., Carvalho, C., & Nechio, F. (2019). *Taylor Rule Estimation by OLS* (FRBSF Working Paper No. 2018–11). https://doi.org/10.24148/wp2018-11

Nedeljkovic, M., & Saborowski, C. (2019). The Relative Effectiveness of Spot and Derivatives-Based Intervention. *Journal of Money, Credit and Banking*, *51*(6), 1455–1490. https://doi.org/10.1111/jmcb.12594

Niti, G., & Anil, M. (2014). Currency Futures Impact on the Volatility of Exchange Rate. *Asian Journal of Multidimensional Research*, *3*(4), 8–18.

Obstfeld, M. (2012). Financial flows, financial crises, and global imbalances. *Journal of International Money and Finance*, *31*(3), 469–480. https://doi.org/10.1016/j.jimonfin.2011.10.003

Oliveira, F. N. (2020). New evidence on the effectiveness of interventions in the foreign exchange market in Brazil. *Brazilian Review of Finance*, *18*(2), 29. https://doi.org/10.12660/rbfin.v18n2.2020.80115

Reilly, F. K., & Brown, K. C. (2012). *Investment Analysis & Portfolio Management*. (J. Sabatino, Ed.) (Tenth Edit). 5191 Natorp Boulevard Mason, OH 45040 USA: South-Western Cengage Learning.

Sharma, S. (2011). *An Empirical analysis of the relationship between Currency futures and Exchange Rates Volatility in India* (RBI Working Paper Series No. WPS (DEPR): 1/2011).

Tornell, A., & Yuan, C. (2012). SPECULATION AND HEDGING IN THE CURRENCY FUTURES MARKETS: ARE THEY INFORMATIVE TO THE SPOT EXCHANGE RATES. *Journal of Futures Markets*, *32*(2), 122–151. https://doi.org/10.1002/fut

Wang, T., Yang, J., & Simpson, M. W. (2008). U.S. monetary policy surprises and currency futures markets: A new look. *Financial Review*, *43*(4), 509–541. https://doi.org/10.1111/j.1540-6288.2008.00206.x

Figure 1
Quarterly Notional Amount of Outstanding Positions in Exchange-traded FX Futures and Options, EMDEs and ADEs (2000-2019)

Source: Bank for International Settlements (BIS).
Notes: Value represented in millions of USD. The dashed orange line indicates the total notional amount of outstanding positions (NAOP) in all currencies. The stacked yellow column represents the NAOP for exchange-traded futures and options in EMDEs in which comprises South African Rand (ZAR), Hungarian Forint (HUF), New Turkish Lira (TRY), Russian Rouble (RUB), Mexican Peso (MXN), Poladian Zloty (PLN), Indian Rupee (INR), Norwegian Krone (NOK), Brazilian Real (BRL), Renminbi (CNY). The stacked blue column represents the NAOP in Advanced and Developed Economies (ADEs) that covers Euro (EU), Pound Sterling (GBP), New Zealand Dollar (NZD), Swedish Krona (SEK), Canadian Dollar (CAD), Korean Won (KRW), US Dollar (USD), Australian Dollar (AUD), Japanese Yen (JPY), Swiss Franc (CHF), Singapore Dollar (SGD).

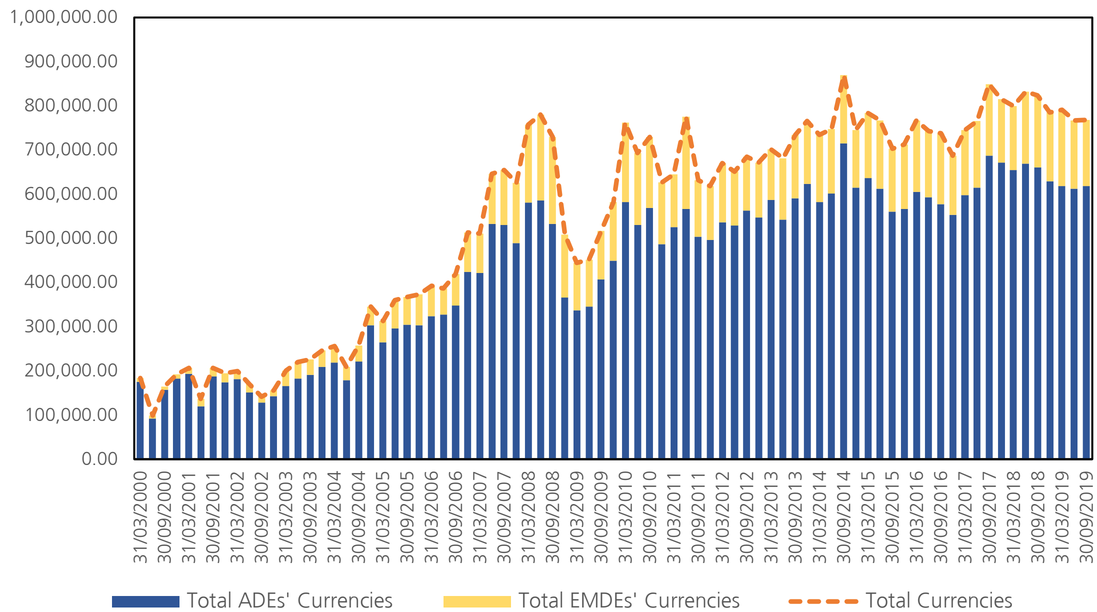


Table 1
Variables

Notes: Table 1 exhibits the variables' profiles utilized in this paper. It presents the description, data transformation, unit of account, and data source.

Variables	Description	Data Transformation	Unit of Account	Source
Open interest (OP)	The total value of FX futures contracts	First-differenced	Millions of USD	Bloomberg
Trade volume (TV)	The daily average of monthly turnover in the FX futures market.	First-differenced	Millions of USD	Triennial Survey, Bank for International Settlements (BIS)
FX futures contract price (F)	FX futures rate	Log-differenced	Returns	Bloomberg
FX Intervention (SI)	Changes in Stock of Foreign Exchange Reserves	Level	Millions of USD	IMF
Money aggregate (M)	The Broad monetary (M3)	Log-differenced	Percentage of Growth rate	FRED
Domestic interest rates (r^d)	Policy rate	First-differenced	Basis Point	IMF and CEIC
Economic growth (y)	Industrial Production Index (IPI)	Log-differenced	Growth	IMF
Exchange rates (S)	Nominal FX	Log-differenced	Returns	IMF
Inflation Rate (CPI)	Consumer Price Index	Log-differenced	Growth	BIS

Table 2
Descriptive Statistics

Notes: Table 2 presents descriptive statistics which comprise mean, median, maximum value, minimum value, standard deviation, and observations. The statistics results in the Table are obtained from the transformed variables, shown in Table 1.

	Mean	Median	Maximum	Minimum	Std. Dev.	Observations
FX Intervention	68.62	-5.96	12199.92	-8924.26	3439.89	180
Inflation Rate	0.01	0.00	0.06	-0.01	0.01	180
Exchange Rate	0.01	0.01	0.27	-0.11	0.04	180
FX Futures Rate	0.01	0.00	0.28	-0.14	0.04	180
Economic Growth	0.00	0.00	0.19	-0.25	0.07	180
Money Growth	0.01	0.01	0.06	-0.04	0.01	180
Open Interest	72.83	12.79	30213.00	-32294.00	6165.89	180
Policy Rate	0.07	0.00	9.00	-1.00	0.85	180
Trade Volume	67.58	17.50	80615.00	-76338.00	8438.55	180

Table 3
Unit Root Test (Level)

Notes: Table 3 presents the results of unit root tests conducted on transformed data (see the most-right column). The lag length specifications for unit root tests are automatically determined based on Schwartz Information Criteria. The null hypothesis stands for the existence of unit root. Our unit root tests indicate that the variables used in this model are stationary at any conventional level.

		Im, Pesaran and Shin W-stat	ADF - Fisher Chi-square	PP - Fisher Chi-square	Data Transformation
Trade Volume (DTV1)	Statistic	-14.4367	99.8032	95.6747	First Differenced
	Prob.	0.0000	0.0000	0.0000	
Policy Rate (DPR)	Statistic	-7.2848	61.8590	78.1210	First Differenced
	Prob.	0.0000	0.0000	0.0000	
Open Interest (DOPIN)	Statistic	-12.2115	117.8320	112.5210	First Differenced
	Prob.	0.0000	0.0000	0.0000	
Broad Money (DLOGM3)	Statistic	-11.8229	113.2350	123.4880	Differenced Log
	Prob.	0.0000	0.0000	0.0000	
Economic Growth (DLOGIPI)	Statistic	-10.6141	104.4450	94.5942	Differenced Log
	Prob.	0.0000	0.0000	0.0000	
Exchange Rate (DLOGFX)	Statistic	-12.5387	119.7930	124.8630	Differenced Log
	Prob.	0.0000	0.0000	0.0000	
Futures FX Rate (DLOGFXFUT)	Statistic	-12.4193	118.1840	120.3400	Differenced Log
	Prob.	0.0000	0.0000	0.0000	
Inflation Rate (DLOGCPI)	Statistic	-5.9196	49.4288	44.4511	Differenced Log
	Prob.	0.0000	0.0000	0.0000	
FX Intervention (CH_FXRES)	Statistic	-10.5338	97.7437	98.5961	Level
	Prob.	0.0000	0.0000	0.0000	

Figure 2
Roots of the Characteristic Polynomial (Modulus)

Notes: Figure 2 depicts the roots of the characteristic polynomial (modulus) utilized to identify the stability condition of the estimated PVAR model. The vertical axis denotes the modulus value. The horizontal axis represents the number of roots (φ) where $\varphi = k \times p$. k and p respectively denote the number of endogenous variables and the number of lags. The horizontal bar (blue) and dashed line (orange) represent the actual modulus values and modulus baseline, respectively.

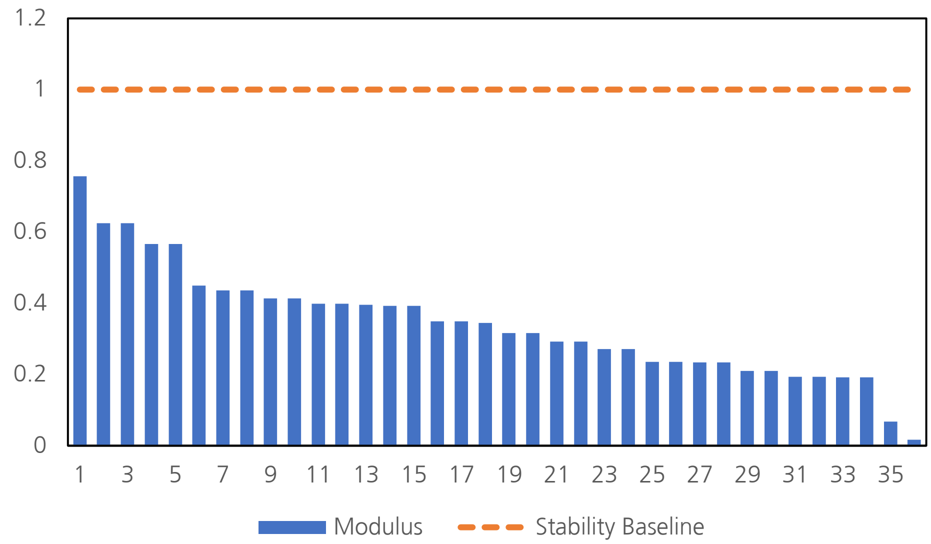


Figure 3
Impulse Response Function (IRF)

Notes: Figure 3 portrays the Impulse Response Function (IRF) obtained from the PVAR model specification expressed in equation (9). The horizontal axis denotes the period. The blueline represents the impulse response of particular variables due to given DOPIN, DTV1, and DLOGFXFUT. The light blue area expresses a five percent confidence interval. DOPIN, DTV1, DLOGFXFUT, DLOGFX, CH_FXRES, DLOGM3, DPR, DLOGCPI, and DLOGIPI respectively represent $OP_{it}, TV_{it}, F_{it}, S_{it}, SI_{it}, M_{it}, r_{it}^{d}, CPI_{it}, y_{it}$

Shocks from:

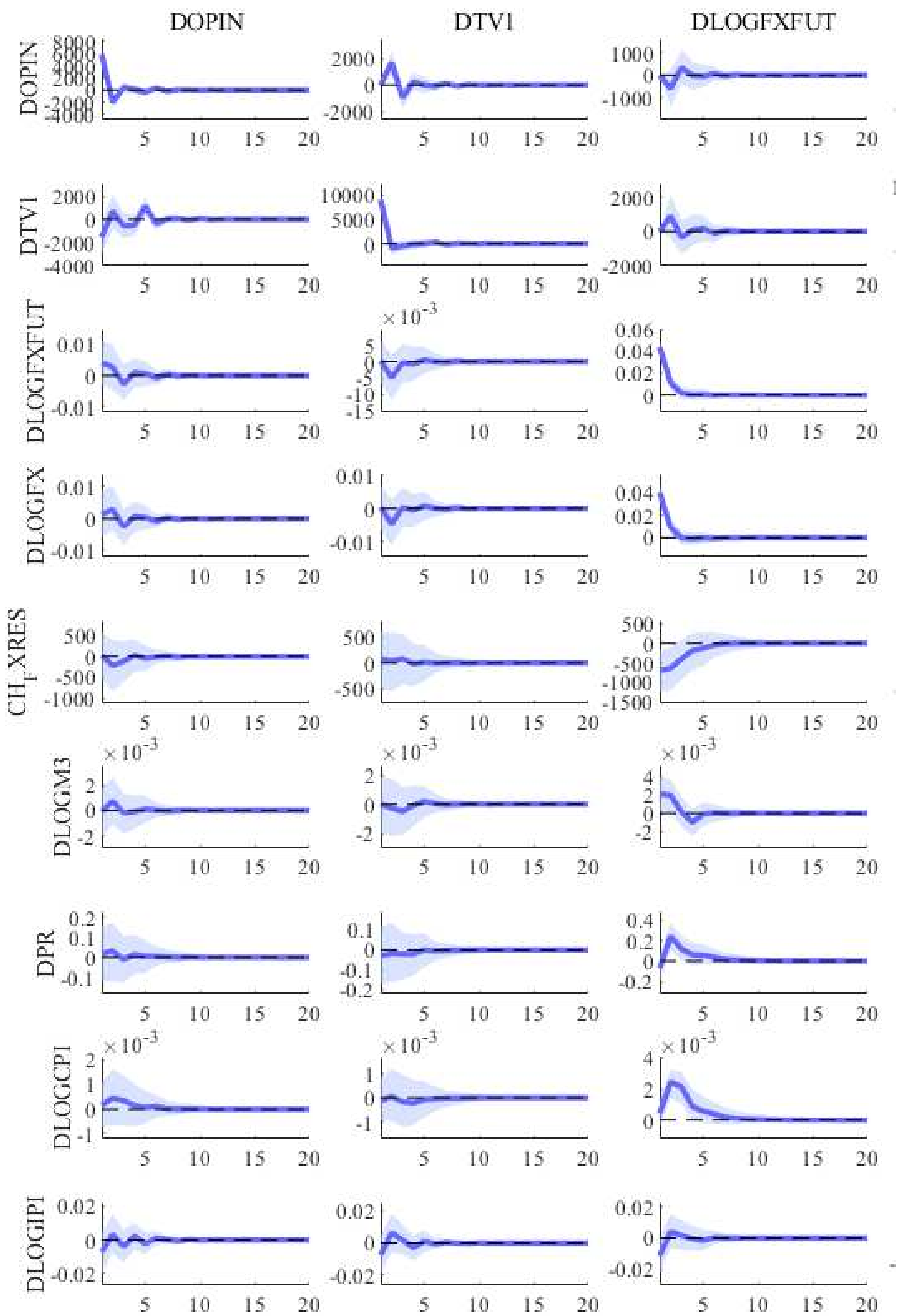


Figure 4
Variance Decomposition

Notes: Figure 4 portrays the Forecast Error Variance Decomposition (FEVD) derived from the estimated PVAR model, which is specified in equation (9). The horizontal axis denotes the period. The vertical axis expresses the percentage of shock contribution of particular variables on the variance of particular variables. The light blue area expresses a five percent confidence interval. DOPIN, DTV1, DLOGFXFUT, DLOGFX, CH_FXRES, DLOGM3, DPR, DLOGCPI, and DLOGIPI respectively represent $OP_{it}, TV_{it}, F_{it}, S_{it}, SI_{it}, M_{it}, r_{it}^{d}, CPI_{it}, y_{it}$

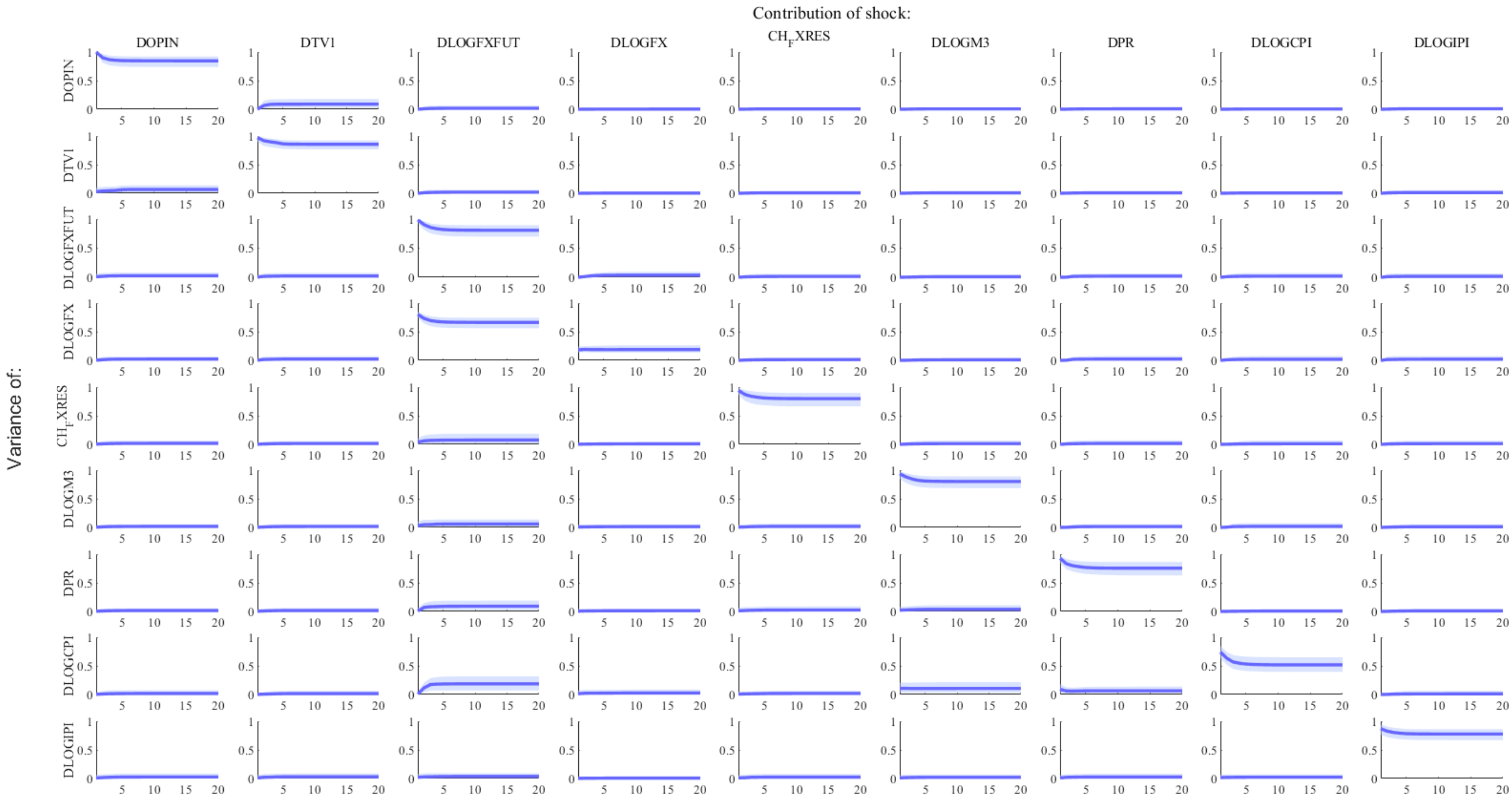


Table 4
Panel Granger Causality

Notes: Table 4 portrays the Panel Granger causality test. We utilize the stacked tests (common coefficients) which uses asymptotic F-statistic. Variables listed in the first-row act as the regressors, while variables listed in the first column as the dependent variables. The null hypothesis explains that the regressor does not Granger-cause the dependent variable. The asterisks *, **, and *** denote statistical significance at 10 percent, 5 percent, and 1 percent, respectively. DOPIN, DTV1, DLOGFXFUT, DLOGFX, CH_FXRES, DLOGM3, DPR, DLOGCPI, and DLOGIPI, respectively represent $OP_{it}, TV_{it}, F_{it}, S_{it}, SI_{it}, M_{it}, r_{it}^{d}, CPI_{it}, y_{it}$

	DOPIN	DTV1	DLOGFXFUT	DLOGFX	CH_FXRES	DLOGM3	DPR	DLOGCPI	DLOGIPI
DOPIN		4.40***	1.37	1.46	0.74	0.12	0.03	0.42	0.23
DTV1	21.41***		1.73	1.56	0.41	0.29	0.14	0.66	1.24
DLOGFXFUT	1.91	1.38		1.10	1.40	1.17	7.75***	1.21	1.52
DLOGFX	1.71	1.48	1.75		0.92	1.36	9.77***	0.74	2.10
CH_FXRES	0.25	0.80	3.06**	3.43**		2.29	0.50	0.12	0.68
DLOGM3	0.32	0.58	5.78***	3.83***	1.92		10.78***	5.72***	0.91
DPR	0.23	0.02	5.87***	5.11***	2.37	6.32***		3.52**	0.35
DLOGCPI	0.07	0.46	14.76***	12.15***	1.29	7.37	9.49***		0.18
DLOGIPI	1.71	3.13**	1.23	1.58	2.65	0.78	1.81	3.31**	

Appendix A
Large Bayesian VAR

The Large Bayesian VAR utilizes the Minnesota prior procedure with modification suggested by (Kadiyala & Karlsson, 1997). Specifically, the Minnesota prior forms that equations are concentrated around the random walk with drift. Let us now rewrite the standard PVAR model by considering multi-country variables as an extensive system of VAR:

$$Y_t = c + A_1 Y_{t-1} + \cdots + A_p Y_{t-p} + u_t \tag{10}$$

Let $Y_{t-1} = (y_{1,t}, \dots, y_{n,t})'$ as a vector of n endogenous random variables; $c = (c_1, \dots, c_n)'$ is n-dimensional vector of constant; u_t denotes n-dimensional Gaussian white noise where the covariance matrix expressed as follows $\mathrm{E}(u_t u_t') = \Psi$; and $A_1, \dots, A_p$ are $n \times n$ dimensional of AR matrices.

By imposing the Minnesota prior, the mean prior mean can be expressed as the following representation:

$$Y_t = c + Y_{t-1} + u_t \tag{11}$$

Equation (11) expresses the prior belief, which organizes the diagonal elements of A_1 to converge to one, while $A_1, \dots, A_p$ toward zero. In other words, this prior illustrates that the more recent own lags provide more reliable information than the other variables and more distant lags. More specifically, these prior beliefs are also imposed by the following prior distribution of coefficients:

$$\mathrm{E}\big[(A_k)_{ij}\big] = \begin{cases} \delta_i, & j = i \\ 0, & \text{otherwise} \end{cases}; \quad \mathrm{V}\big[(A_k)_{ij}\big] = \begin{cases} \dfrac{\lambda^2}{k^2}, & j = i \\ \vartheta \dfrac{\lambda^2}{k^2} \dfrac{\sigma_i^2}{\sigma_j^2}, & \text{otherwise} \end{cases} \tag{12}$$

where $\mathrm{E}\big[(A_k)_{ij}\big]$ denotes the prior mean value of A_k, $\mathrm{V}\big[(A_k)_{ij}\big]$ represents the prior variance of A_k, persistent data prior belief is denoted by $j = i$, and otherwise for stationary data prior belief. Formerly, the Minessota prior sets $\delta_i = 1$ for all i, meaning that the belief incorporates with persistent variables, non-stationary. However, Banbura et al. (2010) argued that this prior remains inadequate for the variables that are described by substantial mean reversion or stationary data. Therefore, δ_i is set to zero for the white noise prior belief with stationary variables.

For the prior variance, several significant coefficients are denoted in equation (12). First, the hyperparameter, λ, governs the overall tightness of the prior distribution around the random walk, $\delta_i = 1$, or white noise, $\delta_i = 0$, coefficients. The posterior distribution tends to equal with prior distribution when $\lambda \to 0$, reflecting that the data do not influence the estimations. On the contrary, when $\lambda \to \infty$, the posterior expectations concur with the OLS estimates. De Mol, Giannone, and Reichlin (2008) argue that λ should be chosen conditional to the size of the information sets to overcome over-fitting problems. The factor $1/k^2$, where $k = n + 1$, is the degree that determines the decrease (increase) of the prior variance when the number of lags and the variability of data, σ_i^2/σ_j^2, increase (decrease). On the other hand, the coefficient $\vartheta \in (0,1)$

regulates the degree to which the lags of other variables are either less or more important than the own lags in shaping the belief on the prior variance.

For the structural analysis, however, the Minnesota prior would be somewhat problematic because the assumption is related to both the fixed and diagonal covariance matrix and needs to take account of possible correlations among the cross-variables residuals. In this regard, therefore, it necessary to impose a normal inverted Wishart prior. Let us rewrite the VAR with $p = 1$ as a system of multivariate regressions as follows:

$$\underset{[T \times n]}{Y} = \underset{[T \times k]}{X} \; \underset{[k \times n]}{B} + \underset{[T \times n]}{U} \tag{13}$$

In order to match the Minnesota prior and equation (13), which is utilized as the regularization solution to the matrix inversion problem, it is necessary to add dummy observations in the following equation:

$$Y_d = \begin{bmatrix} \text{diag}(\delta_1\sigma_1, \dots, \delta_n\sigma_n)/\lambda \\ 0_{n(p-1)\times n} \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ \text{diag}(\sigma_1, \dots, \sigma_n) \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ 0_{1\times n} \end{bmatrix} \quad X_d = \begin{bmatrix} J_p \otimes \text{diag}(\sigma_1, \dots, \sigma_n)/\lambda & 0_{np\times 1} \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots & \\ 0_{n\times np} & 0_{n\times 1} \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots & \\ 0_{1\times np} & \varepsilon \end{bmatrix} \tag{14}$$

where $J_p = \text{diag}(1, 2, \dots, p)$. The first block imposes the prior beliefs on the AR coefficients, the second block captures the prior covariance matrix, and the last block represents the uninformative prior for the intercept coefficient. We now proceed with the augmentation of the equation (12) with the dummy observation in equation (13):

$$\underset{[T_* \times n]}{Y_*} = \underset{[T_* \times k]}{X_*} \; \underset{[k \times n]}{B} + \underset{[T_* \times n]}{U_*} \tag{15}$$

where $T_* = T + T_d$, $Y_* = (Y'Y_d')'$, $X_* = (X'X_d')$, and $U_* = (U'U_d')'$. Based on equation (15), the posterior takes the form as follows:

$$\begin{gathered} \text{vec}(B)|\Psi, Y \sim N\left(\text{vec}\left(\tilde{B}\right), \Psi \otimes (X_*'X_*)^{-1}\right) \\ \Psi|Y \sim iW\left(\tilde{\Sigma}\, T_d + 2 + T - k\right) \end{gathered} \tag{16}$$

with $\tilde{B} = (X_*'X_*)^{-1}X_*'Y_*$ and $\tilde{\Sigma} = \left(Y_* - X_*'\tilde{B}\right)'\left(Y_* - X_*'\tilde{B}\right)$.

Appendix B
Robustness I: Alternative Variables Ordering

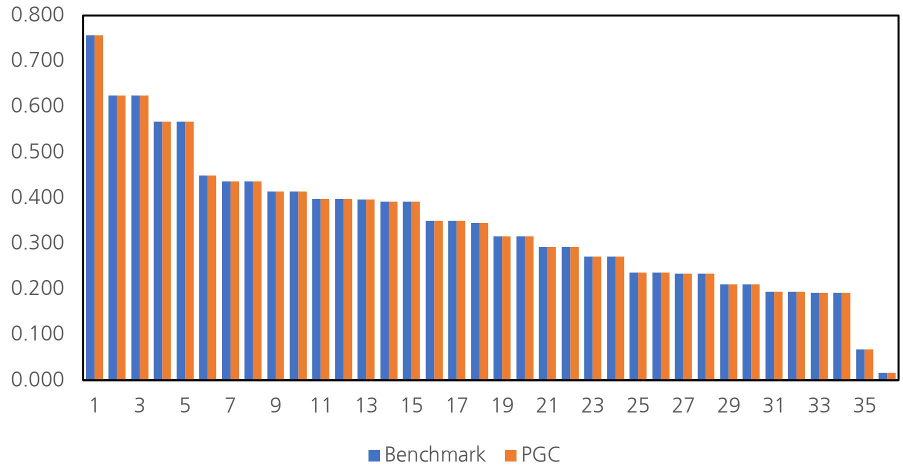
Table 5
Comparative IRF Output Between Benchmark Ordering and PGC Ordering

Notes: Table 5 exhibits the IRF output from benchmark ordering and Panel Granger-based ordering (PGC). For the response variables, we exclude FX intervention, policy rate, and money growth as these variables act only as of the control variables. The bold numbers represent the significant responses at five percent confidence.

		Open Interest		Trade Volume		FX Futures Rate	
Response of:		Benchmark Ordering	PGC Ordering	Benchmark Ordering	PGC Ordering	Benchmark Ordering	PGC Ordering
Open Interest	1	**6451.1270**	**6451.1270**	0.0000	0.0000	0.0000	0.0000
	2	**-2008.1552**	**-2019.0746**	**1893.9755**	**1904.6067**	-556.7760	-567.2956
	3	442.4975	453.2506	-890.3377	-896.6943	248.2978	261.7296
	4	210.9156	202.2287	225.2556	213.7984	-73.3067	-89.0273
	5	-441.0790	-441.2124	55.4441	46.8075	-38.1466	-41.3934
Trade Volume	1	**-1925.3413**	**-1925.3413**	**10330.6021**	**10330.6021**	0.0000	0.0000
	2	668.4143	712.1027	-314.7877	-293.4339	1025.4734	1034.8147
	3	-576.7276	-591.7308	-376.0345	-364.7083	-341.9729	-338.9269
	4	-600.8613	-601.0638	-65.7629	-73.2202	90.1520	86.4442
	5	1213.0213	1212.2366	-33.0514	-48.5608	220.0349	213.1376
FX Futures Rate	1	0.0063	0.0063	0.0008	0.0008	**0.0463**	**0.0463**
	2	0.0020	0.0020	-0.0053	-0.0053	**0.0120**	**0.0119**
	3	-0.0029	-0.0028	-0.0009	-0.0010	0.0023	0.0025
	4	0.0011	0.0011	-0.0010	-0.0010	0.0009	0.0008
	5	0.0011	0.0012	0.0003	0.0003	0.0008	0.0008
Exchange Rate	1	0.0032	0.0032	0.0005	0.0005	**0.0421**	**0.0421**
	2	0.0016	0.0017	-0.0053	-0.0054	**0.0092**	**0.0091**
	3	-0.0033	-0.0033	-0.0004	-0.0004	0.0005	0.0006
	4	0.0010	0.0009	-0.0007	-0.0008	-0.0001	-0.0001
	5	0.0006	0.0006	0.0006	0.0006	-0.0001	0.0000
Inflation Rate	1	0.0002	0.0002	-0.0001	-0.0001	0.0006	0.0006
	2	0.0005	0.0005	0.0001	0.0001	**0.0030**	**0.0030**
	3	0.0003	0.0003	-0.0002	-0.0002	**0.0025**	**0.0025**
	4	0.0000	0.0001	-0.0003	-0.0003	**0.0011**	**0.0012**
	5	0.0001	0.0001	-0.0001	-0.0001	0.0007	0.0007
Economic Growth	1	-0.0103	-0.0102	-0.0094	-0.0095	-0.0083	-0.0088
	2	0.0058	0.0066	0.0065	0.0064	0.0026	0.0028
	3	-0.0038	-0.0038	0.0029	0.0028	0.0018	0.0017
	4	0.0027	0.0028	-0.0024	-0.0029	-0.0003	-0.0004
	5	-0.0023	-0.0022	0.0011	0.0011	-0.0006	-0.0006

Figure 5
Modulus Values for Benchmark and PGC-based Ordering of PVAR

Notes: Figure 5 depicts the roots of the characteristic polynomial (modulus) for the Benchmark ordering and PGC-based ordering. The vertical axis denotes the modulus value. The horizontal axis represents the number of roots (φ) where $\varphi = k \times p$, and k denotes the number of endogenous variables.



Appendix C
Robustness II: Sensitivity Test

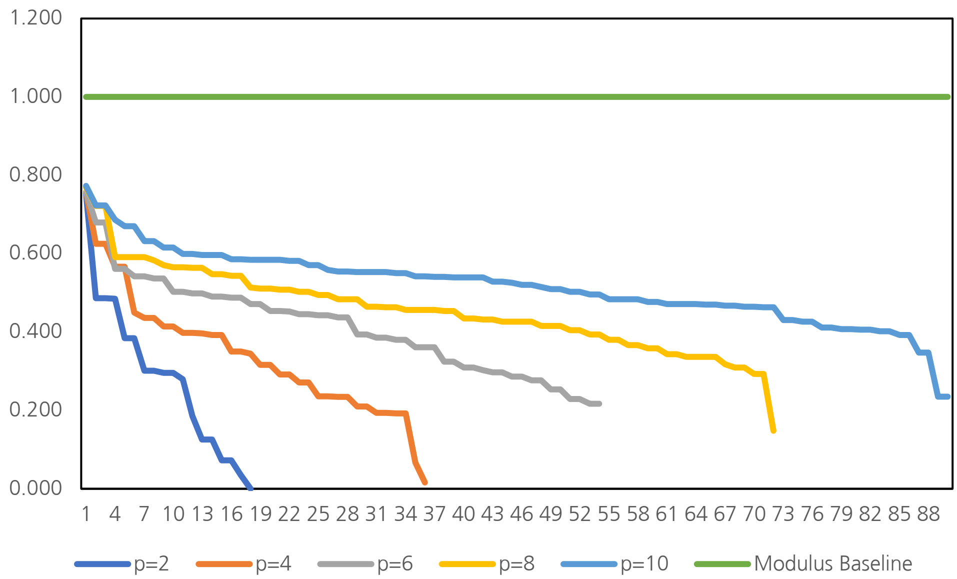
Table 6
Estimated IRF for Sensitivity Test

Notes: Table 6 displays the results from the sensitivity test. More specifically, we perform five different lag structures (p) of Panel VAR estimation estimated using Pooled Bayesian PVAR developed by (Canova & Ciccarelli, 2009, 2013), where $p = \{2, 4, 6, 8, 10\}$. The bold numbers represent the significant responses of particular variables due to shocks from Open Interest, Trade Volume, and FX Futures Rate at five percent confidence. For the response variables, we exclude FX intervention, policy rate, and money growth as these variables act only as of the control variables.

Response of:		Shocks from: Open Interest					Trade Volume					FX Futures Rate				
		$p = 2$	$p = 4$	$p = 6$	$p = 8$	$p = 10$	$p = 2$	$p = 4$	$p = 6$	$p = 8$	$p = 10$	$p = 2$	$p = 4$	$p = 6$	$p = 8$	$p = 10$
Open Interest	1	**6631.6**	**6451.1**	**6612.9**	**6625.0**	**6873.4**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2	**-1986.0**	**-2008.2**	**-2124.6**	**-2158.0**	**-2147.0**	**1786.6**	**1894.0**	**1790.4**	**1834.1**	**1921.2**	-649.0	-556.8	-562.1	-462.9	-427.8
	3	433.1	442.5	502.8	504.4	571.5	-720.6	-890.3	-776.5	-951.6	-930.6	247.2	248.3	170.1	179.9	151.6
	4	-53.0	210.9	240.0	247.1	219.2	60.1	225.3	217.1	270.5	301.9	-116.8	-73.3	-113.0	-110.0	-132.7
Trade Volume	1	**-2309.1**	**-1925.3**	**-2072.9**	**-2022.6**	**-2028.7**	**10609.1**	**10330.6**	**10660.9**	**10786.2**	**11181.9**	0.0	0.0	0.0	0.0	0.0
	2	819.5	668.4	620.0	744.7	806.1	225.7	-314.8	48.5	-430.4	-294.3	1013.8	1025.5	1003.0	951.5	895.4
	3	-342.3	-576.7	-632.8	-713.0	-718.3	-246.7	-376.0	-288.8	-324.9	-330.8	-399.5	-342.0	-295.3	-332.6	-318.7
	4	-60.7	-600.9	-586.6	-656.2	-669.8	-73.9	-65.8	-109.1	-142.4	-131.1	-79.6	90.2	124.3	8.9	83.1
FX Futures Rate	1	0.004	0.006	0.005	0.005	0.004	0.001	0.001	0.001	0.000	0.001	**0.047**	**0.046**	**0.044**	**0.045**	**0.046**
	2	0.003	0.002	0.001	0.001	0.002	-0.005	-0.005	-0.005	-0.006	-0.006	**0.013**	**0.012**	**0.012**	**0.015**	**0.015**
	3	-0.002	-0.003	-0.003	-0.003	-0.003	-0.001	-0.001	-0.001	-0.001	-0.001	0.002	0.002	0.003	0.004	0.004
	4	0.000	0.001	0.002	0.002	0.002	-0.001	-0.001	-0.001	-0.001	-0.001	0.001	0.001	0.000	0.001	0.001
Exchange Rate	1	0.002	0.003	0.002	0.002	0.002	0.000	0.001	0.001	0.000	0.000	**0.042**	**0.042**	**0.041**	**0.043**	**0.043**
	2	0.002	0.002	0.001	0.001	0.001	-0.005	-0.005	-0.005	-0.006	-0.006	**0.009**	**0.009**	**0.010**	**0.012**	**0.013**
	3	-0.003	-0.003	-0.003	-0.004	-0.004	-0.001	0.000	-0.001	-0.001	-0.001	0.000	0.001	0.002	0.002	0.002
	4	0.000	0.001	0.002	0.002	0.001	-0.001	-0.001	-0.001	-0.001	-0.001	0.000	0.000	0.000	0.000	0.000
Inflation Rate	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	109.087	0.000	0.001	0.001	0.001	0.000	0.000
	2	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	-1.075	0.000	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**
	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	74.620	0.000	**0.002**	**0.003**	**0.002**	**0.003**	**0.003**
	4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	15.596	0.000	**0.001**	**0.001**	**0.001**	**0.001**	**0.002**
Economic Growth	1	-0.008	-0.010	-0.011	-0.012	-0.012	-0.010	-0.009	-0.010	0.000	-0.010	-0.012	-0.008	-0.011	-0.011	-0.011
	2	0.005	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.000	0.006	0.003	0.003	0.002	0.001	0.001
	3	-0.004	-0.004	-0.004	-0.004	-0.004	0.003	0.003	0.003	-0.001	0.003	0.002	0.002	0.002	0.003	0.003
	4	0.001	0.003	0.003	0.004	0.003	-0.001	-0.002	-0.003	0.000	-0.003	0.001	0.000	0.000	0.000	0.000

Figure 6
Modulus Values for Five Different Lag Structures of PVAR

Notes: Figure 6 depicts the roots of the characteristic polynomial (modulus) utilized to identify the stability condition of five different lag structures (p) of Panel VAR estimations estimated using Pooled Bayesian PVAR. We investigate the following lag structures: $p = \{2, 4, 6, 8, 10\}$. The vertical axis denotes the modulus value. The horizontal axis represents the number of roots (φ) where $\varphi = k \times p$, and k denote the number of endogenous variables. The horizontal bar (blue) and dashed line (orange) represent the actual modulus values and modulus baseline, respectively.

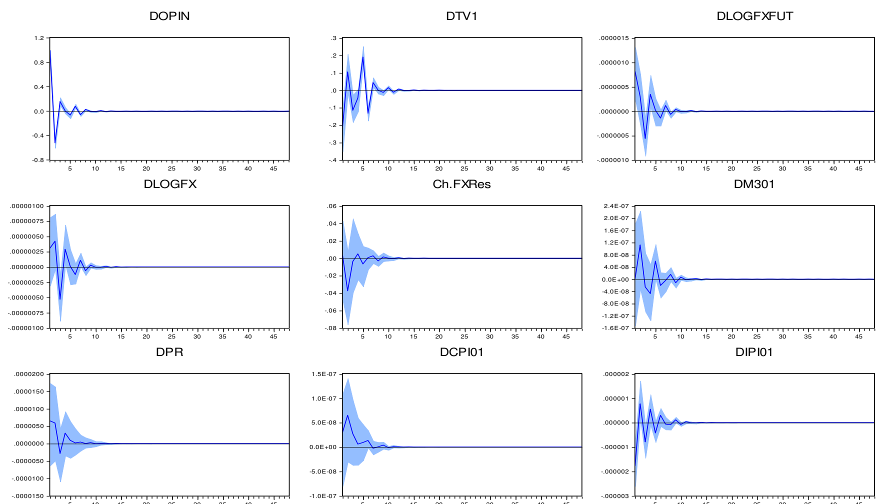


Appendix D
Robustness Test III: Large Bayesian VAR Estimation

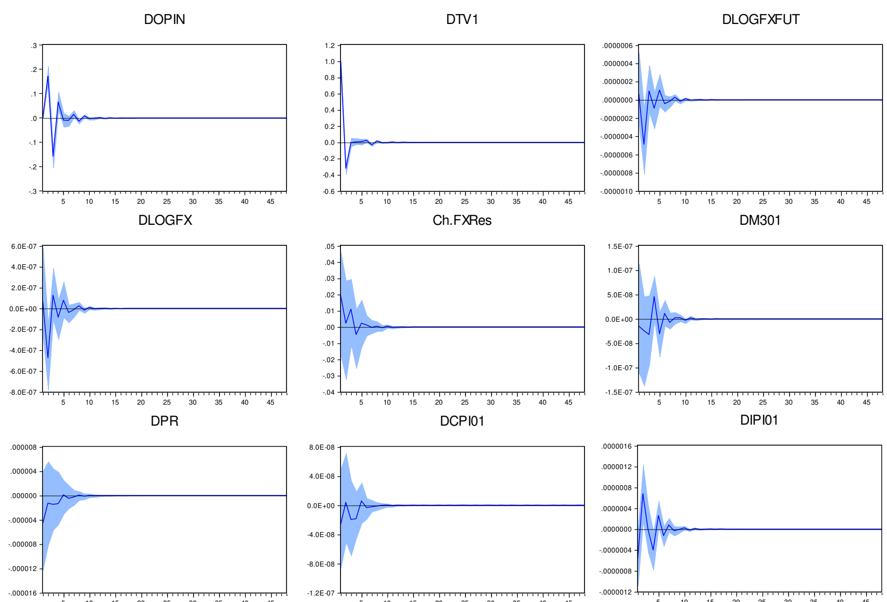
Figure 7
Impulse Response Function (IRF)

Notes: Figure 7 portrays the Impulse Response Function (IRF) obtained from the PVAR estimated using Large Bayesian VAR. The horizontal axis denotes the period. The blueline represents the impulse response of particular variables due to given DOPIN, DTV1, and DLOGFXFUT. The light blue area expresses a five percent confidence interval. DOPIN, DTV1, DLOGFXFUT, ERVOL, CH.FXRES, DM301, DPR, DCPI01, and DIPI01 respectively represent $OP_{it}, TV_{it}, F_{it}, EV_{it}, SI_{it}, M_{it}, r_{it}^{d}, CPI_{it}, y_{it}$

Impulse response functions to DOPIN, (lambda = 0.100 , tau = 1.000)



Impulse response functions to DTV1, (lambda = 0.100 , tau = 1.000)



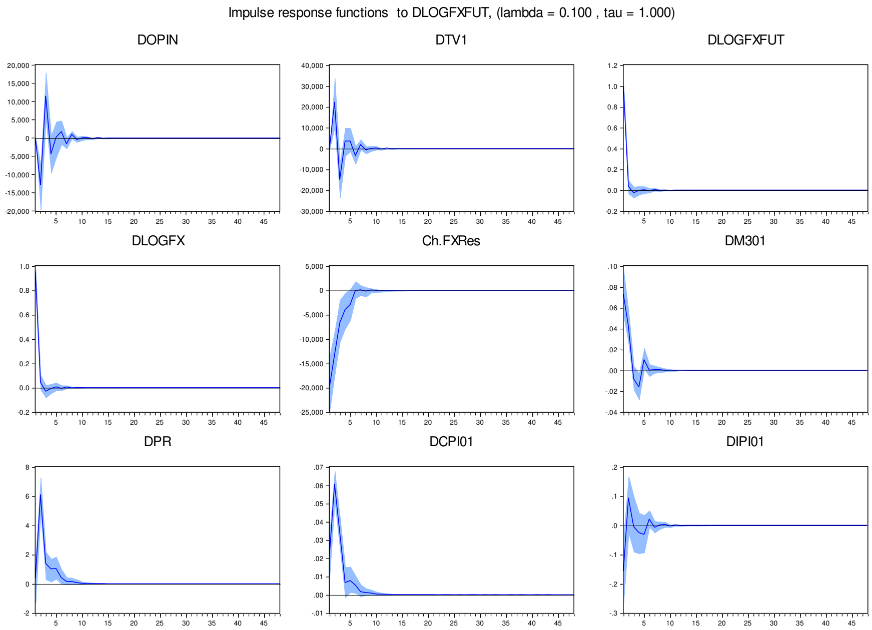


Table 7
Variance Decomposition

Notes: Table 7 portrays the Forecast Error Variance Decomposition (FEVD) derived from the PVAR model estimated using Large Bayesian VAR. The numbers exhibited in the tables denote the percentage contribution of variables in explaining the variance of particular variables. R2, R5, R10, R15, R25, R30, R35, and R45 denote the period related to the FEVD.

Exchange Rate (DLOGFX)									
	DOPIN	DTV1	DLOGFXFUT	DLOGFX	CH_FXRES	DLOGM3	DPR	DLOGCPI	DLOGIPI
R2	0.18	0.38	46.44	51.59	0.12	0.01	0.02	0.78	0.50
R5	0.42	0.42	45.87	51.05	0.16	0.03	0.66	0.83	0.60
R15	0.44	0.43	45.85	51.03	0.16	0.03	0.66	0.83	0.61
R25	0.44	0.43	45.85	51.03	0.16	0.03	0.66	0.83	0.61
R35	0.44	0.43	45.85	51.03	0.16	0.03	0.66	0.83	0.61
R45	0.44	0.43	45.85	51.03	0.16	0.03	0.66	0.83	0.61
Inflation Rate (DCPI01)									
	DOPIN	DTV1	DLOGFXFUT	DLOGFX	CH_FXRES	DLOGM3	DPR	DLOGCPI	DLOGIPI
R2	0.20	0.07	12.32	1.73	0.33	12.33	5.94	67.91	0.05
R5	0.22	0.13	15.19	2.32	0.39	12.01	6.31	64.18	0.09
R15	0.22	0.13	15.26	2.33	0.39	12.01	6.31	64.11	0.10
R25	0.22	0.13	15.26	2.33	0.39	12.01	6.31	64.11	0.10
R35	0.22	0.13	15.26	2.33	0.39	12.01	6.31	64.11	0.10
R45	0.22	0.13	15.26	2.33	0.39	12.01	6.31	64.11	0.10
Economic Growth (DIPI01)									
	DOPIN	DTV1	DLOGFXFUT	DLOGFX	CH_FXRES	DLOGM3	DPR	DLOGCPI	DLOGIPI
R2	1.66	0.86	1.14	0.94	0.39	1.10	1.57	2.58	88.96
R5	2.08	1.08	1.16	1.05	0.80	1.34	2.03	2.58	87.37
R15	2.13	1.11	1.17	1.05	0.80	1.34	2.03	2.58	87.34
R25	2.13	1.11	1.17	1.05	0.80	1.34	2.03	2.58	87.34
R35	2.13	1.11	1.17	1.05	0.80	1.34	2.03	2.58	87.34
R45	2.13	1.11	1.17	1.05	0.80	1.34	2.03	2.58	87.34

Appendix E
Robustness Test IV: Bayesian PVAR with Exchange Rate Volatility

Figure 8
Impulse Response Function

Notes: Figure 8 portrays the Impulse Response Function (IRF) obtained from the PVAR model specification with exchange rate volatility (ERVOL). The horizontal axis denotes the period. The blueline represents the impulse response of particular variables due to given DOPIN, DTV1, and DLOGFXFUT. The light blue area expresses a five percent confidence interval. DOPIN, DTV1, DLOGFXFUT, ERVOL, CH_FXRES, DLOGM3, DPR, DLOGCPI, and DLOGIPI respectively represent $OP_{it}, TV_{it}, F_{it}, EV_{it}, SI_{it}, M_{it}, r_{it}^{d}, CPI_{it}, y_{it}$.

Shocks from:

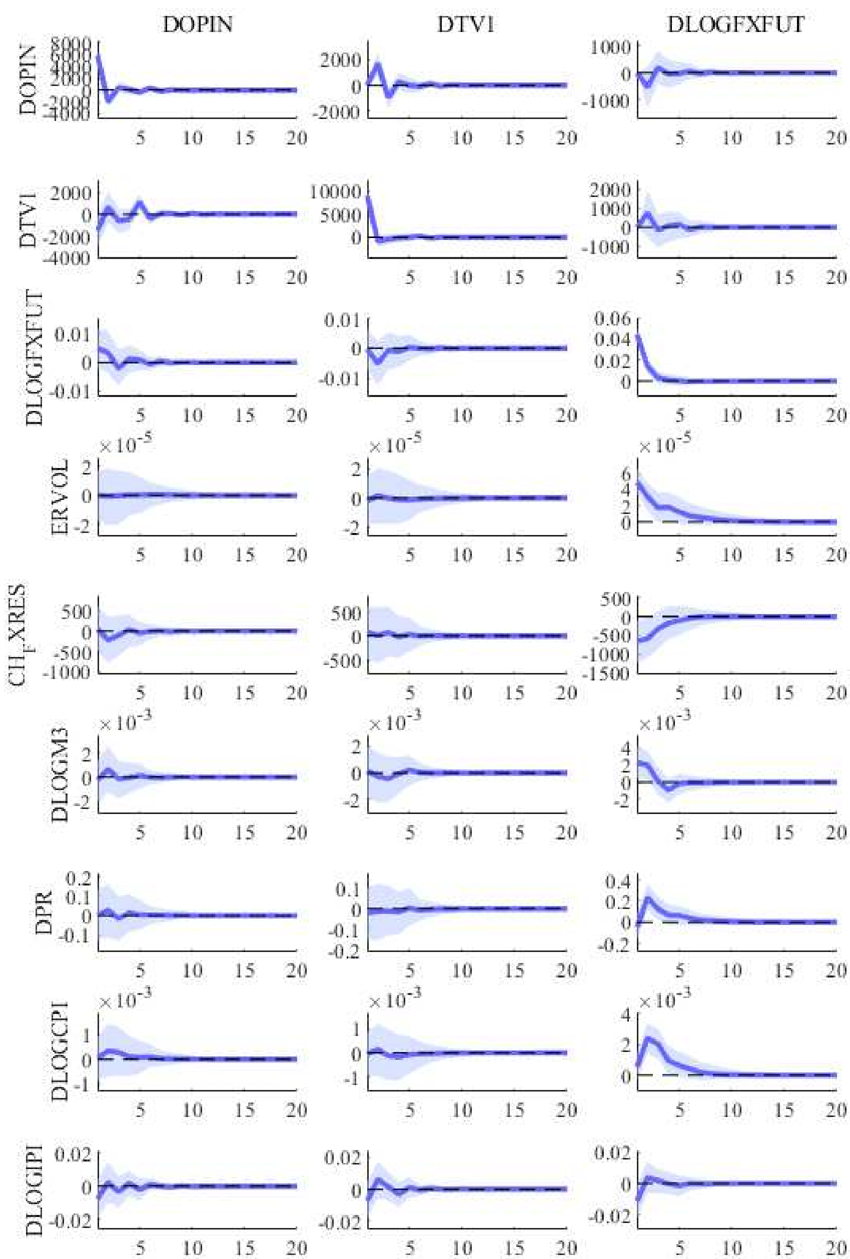
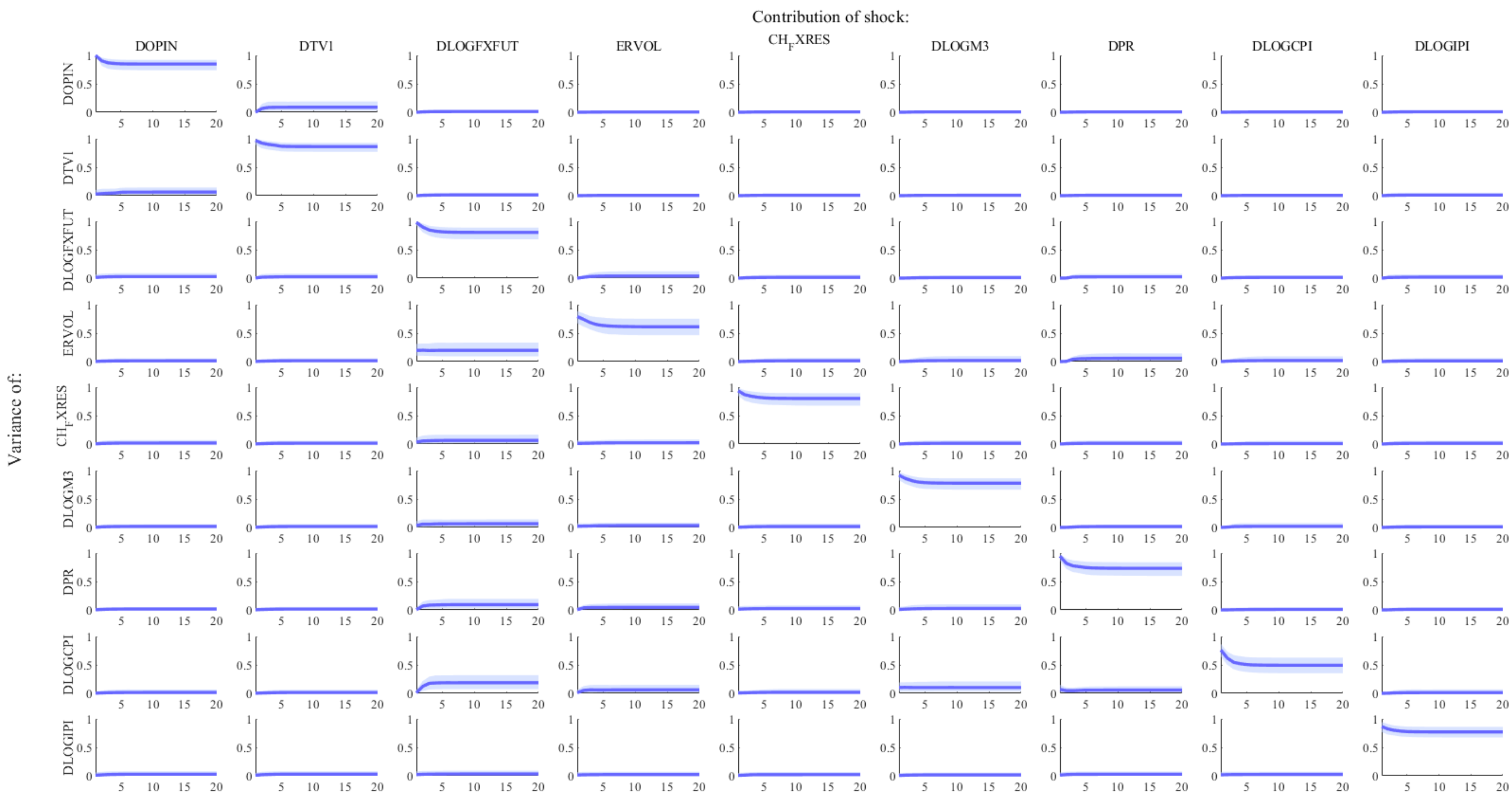


Figure 9
Variance Decomposition

Notes: Figure 9 portrays the Forecast Error Variance Decomposition (FEVD) derived from the estimated PVAR model, specified by substituting DLOGFX with exchange rate volatility (ERVOL). The horizontal axis denotes the period. The vertical axis expresses the percentage of shock contribution of particular variables on the variance of particular variables. The light blue area expresses a five percent confidence interval. DOPIN, DTV1, DLOGFXFUT, ERVOL, CH_FXRES, DLOGM3, DPR, DLOGCPI, and DLOGIPI respectively represent $OP_{it}, TV_{it}, F_{it}, EV_{it}, SI_{it}, M_{it}, r_{it}^{d}, CPI_{it}, y_{it}$.



Appendix F
Exchange Rate Volatility Estimations

Table 8
Unit Root Test (Augmented Dickey-Fuller)

Notes: Automatic lag length selection based on Schwartz Information Criteria. The null hypothesis stands for the existence of unit root.

		DLOGBRL	DLOGINR	DLOGMXN	DLOGTRY
With Constant	t-Statistic	-40.4092	-38.2112	-38.0789	-18.6020
	Prob.	0.0000	0.0000	0.0000	0.0000
With Constant & Trend	t-Statistic	-40.4010	-38.2061	-38.0664	-18.5955
	Prob.	0.0000	0.0000	0.0000	0.0000
Without Constant & Trend	t-Statistic	-40.3346	-38.1775	-38.0479	-18.3487
	Prob.	0.0000	0.0000	0.0000	0.0000

Table 9
ARMA Estimations, Heteroscedasticity Test, and Autocorrelation Test

Notes: The asterisk *, **, and *** denotes statistical significance at 10 percent, 5 percent, and 1 percent, respectively. Numbers in the parentheses ( ), represent the HAC-corrected standard error. The ARMA model is estimated using Conditional Least Squares (CLS).

	Brazilian Real	Indian Rupee	Mexican Peso	Turkish Lira
C	0.000482* (0.000269)	0.000145 (0.0000906)	0.000292 (0.000233)	0.000767*** (0.000271)
AR(1)	-0.819224*** (0.263392)	0.873792*** (0.110022)	-0.538104*** (0.094845)	-0.56808 (0.354743)
AR(2)	-0.617291*** (0.169619)		-0.803488*** (0.09065)	-0.171561 (0.289584)
AR(3)				-0.180323 (0.18509)
MA(1)	0.745238*** (0.267852)	-0.876672*** (0.109692)	0.517472*** (0.084927)	0.717249* (0.366113)
MA(2)	0.577807*** (0.176888)		0.847968*** (0.079806)	0.20486 (0.355933)
MA(3)				0.044088 (0.204201)
R-squared	0.009756	0.004659	0.009088	0.044451
Adjusted R-squared	0.006937	0.003245	0.006267	0.040361
ARCH (1) Test	111.0553***	12.6763***	42.45307***	928.526***
Breusch-Godfrey Serial Correlation LM Test	0.052314	1.371629	0.39012	0.396881
Observations	1410	1411	1410	1409

Table 10
GARCH Estimations

Notes: The asterisk denotes statistical significance *, **, and *** at 10 percent, 5 percent, and 1 percent, respectively. Numbers in the parentheses ( ), represent the HAC-corrected standard error.

	Brazilian Real	Indian Rupee	Mexican Peso	Turkish Lira
		Mean Equation		
C	0.000472** (0.000235)	0.000123* (0.0000701)	0.000138 (0.000435)	0.000626*** (0.000199)
AR(1)	-1.209852*** (0.232142)	-0.92081*** (0.032052)	-0.796741*** (0.198051)	-0.016241 (0.458088)
AR(2)	-0.569346** (0.237469)		-0.88189*** (0.174697)	-0.169503 (0.244832)
AR(3)				0.377078** (0.18432)
MA(1)	1.175602*** (0.243478)	0.947171*** (0.026261)	0.761843*** (0.205798)	0.095971 0.457838)
MA(2)	0.524544** (0.249735)		0.871182*** (0.177838)	0.148289 (0.238662)
MA(3)				-0.379504** (0.170517)
		Variance Equation		
C	0.0000226*** (0.00000339)	0.00000201*** (0.000000201)	0.0000445** (0.0000174)	0.00000135*** (0.000000342)
RESID(-1)^2	0.149949*** (0.018574)	0.149994*** (0.017814)	0.149996*** (0.057891)	0.142199*** (0.012876)
GARCH(-1)	0.599949*** (0.04515)	0.599994*** (0.031429)	0.599996*** (0.147753)	0.85471*** (0.013912)
R-squared	0.007691	0.00233	0.005184	0.024808
Adjusted R-squared	0.004866	0.000913	0.002352	0.020635
ARCH (1) Test	2.732443*	0.934881	3.277351*	3.334062*
Observations	1410	1411	1410	1409

Figure 10
The Monthly Average of Daily Volatility

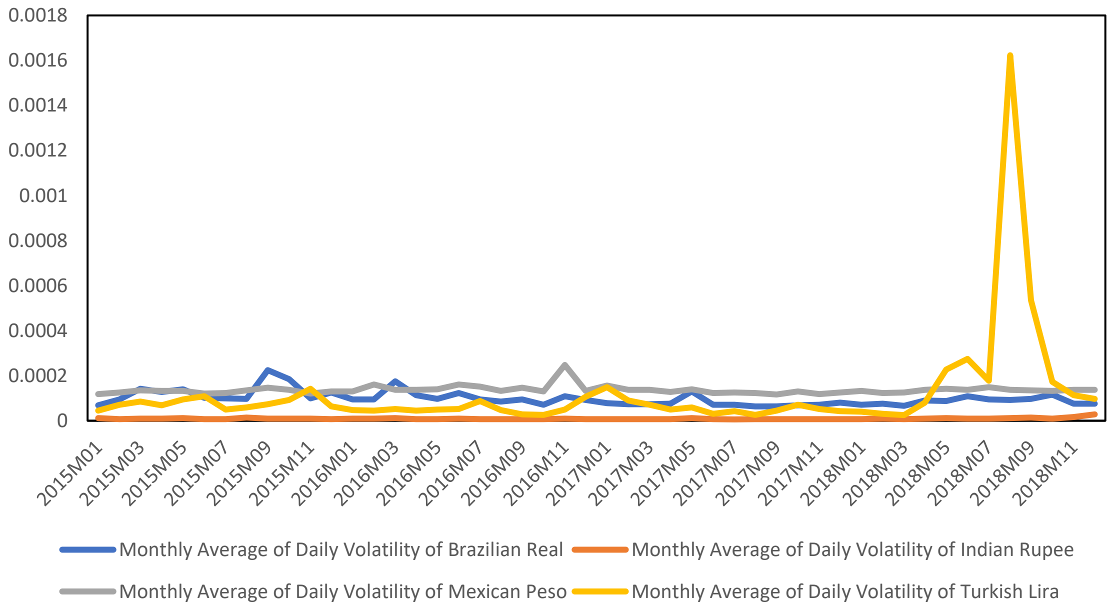


Table 11
Unit Root Tests for The Monthly Average of Daily Volatility

Notes: Automatic lag length selection based on Schwartz Information Criteria. The null hypothesis stands for the existence of unit root.

Method	Statistic	Prob.**
Im, Pesaran and Shin W-stat	-2.3361	0.0097
ADF - Fisher Chi-square	43.2512	0.0000
PP - Fisher Chi-square	56.5430	0.0000