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MACROECONOMIC CONSEQUENCES OF FOREIGN EXCHANGE FUTURES

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Abstract

This paper provides two empirical investigations concerning the macroeconomics of foreign exchange (FX) futures market. We first examine the macroeconomic consequences of FX futures market activities for selected emerging market economies that adopt inflation targeting framework (ITF). This paper then conducts comparative study investigating the effect of futures-based FX intervention on the exchange rate dynamics and exchange rate pass-through effect for the case of Brazil and India. By utilizing the Bayesian Panel VAR, we find initial intention of market squeezing. However, it occurs only in small magnitudes and for short periods and, therefore, the FX futures rate, spot exchange rate, inflation rate, and economic growth would not fluctuate abnormally. For the second investigation, we utilize Autoregressive Distributed Lag model and show that the futures-based FX interventions in Brazil are effective, while it is not the case for India. These findings suggest that specific economic institutional aspects, which leads to the FX futures market deepening and robust financial-economic regulatory structures, are important in mitigating market manipulation and promoting an effective futures-based FX intervention.

Keywords: Foreign Exchange Futures Market; Futures-based FX Intervention; Exchange Rate; Pass-through.

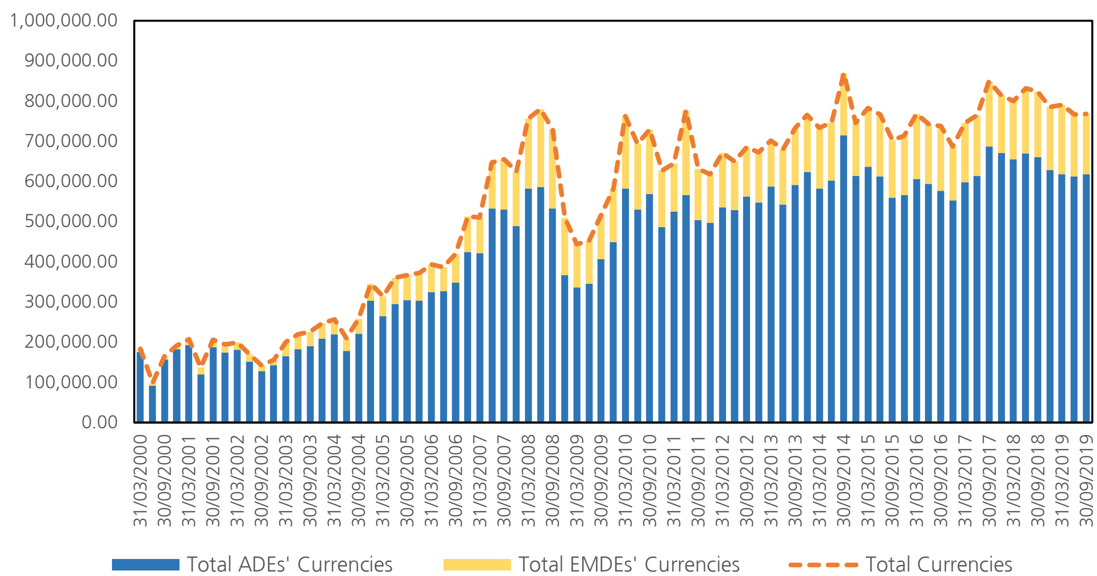
JEL Classifications: E44, E52, E58, G23, G28.

1 Introduction

1.1 Background

Along with the more financially integrated economy in the Emerging Markets and Developing Economies (EMDEs) that inherently associated with higher foreign exchange (FX) volatility, it just like puts their fortunes partly into the hands of others. In this regard, the FX derivates market (i.e., futures and options) as hedging instruments that have an essential role in mitigating the risk given the uncertainty of the FX dynamics in the future, is multiplying.[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 has grown considerably (see Figure 1). The NAOP in EMDEs was approximately seven billion US dollars in 2002 and reached 172,966 million USD in late 2019. Proportionally, it comprised almost 20 percent of the total NAOP in exchange-traded FX futures and options all around the world. Besides, Figure (2) shows that the FX spot and futures rate are approximately equal. It indicates that the spot FX derives the rate for the FX futures (e.g., Reilly and Brown 2012), or the short-run movement of the FX futures market is an unbiased-predictor for the spot FX movement (e.g., Inci and Lu 2007).

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

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

(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).

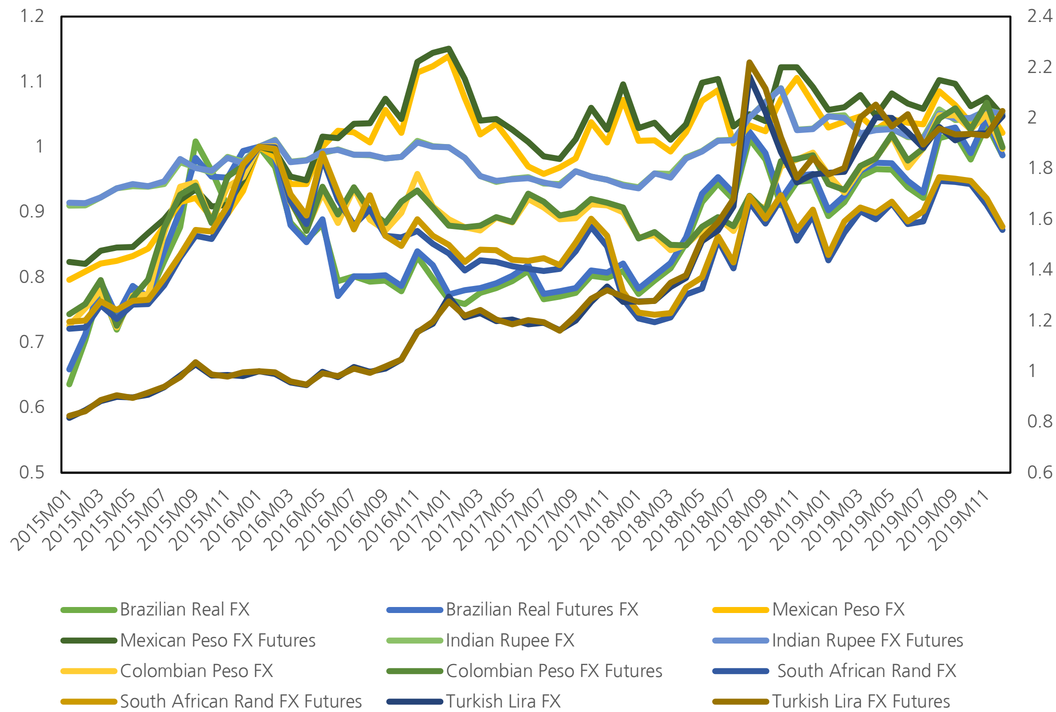
Several works of literature have emphasized that the FX futures provide the risk transferability, which reduces the exchange rate volatility. Classical construction by Grossman and Miller (1988) illustrated that higher liquidity provided by speculators induce the availability of risk transference afforded by the futures market reduces the spot price volatility. Moreover, futures trading activity attracts more traders to spot market, making it more liquid and, therefore, less volatile. Kumar (2015) also found that the spot exchange rate volatility has reduced in the post-futures period in India.

However, although the FX futures market provides risk handover, many researchers have also put much scrutiny on the potential adverse effect on the spot market. Voluminous works of literature have argued that the rising activity in the FX futures market destabilizes the spot FX market. Sharma (2011) indicated that the volatility of spot exchange rate was higher after the introduction of FX futures in India. There is a two-way causality between the volatility in the spot exchange rate and the trading activity in the FX futures market. Niti and Anil (2014) concluded that there was an increase in the volatility of the Indian Rupee exchange to the US Dollar (USD/INR) spot market after the introduction of currency futures in India. Nath and Pacheco (2017) found the presence of volatility clustering in the pre-futures and post-futures period. The underlying FX was relatively more volatile in the post-futures period than the pre-futures period. Biswal and Jain (2019) also suggest that an increase (decrease) in volumes in either market causes a corresponding increase (decrease) in volatility in both markets. Moderately, Jochum and Kodres (1998) have found that the futures market's introduction of derivative contracts (i.e., futures and options) does not destabilize the underlying spot market FX. Guru (2010) also argued that speculative and hedging activities in the futures market for currency do not influence the volatility in the underlying FX spot market. Guru (2010) also found that FX futures trading does not affect underlying spot FX volatility in India.

Furthermore, the FX futures market, just like other financial markets, accommodates speculative motives that may contain market misuse, hence potentially harms the spot exchange market. The seminal paper of Kyle (1992) has demonstrated how the market agent in the futures market interact and how market manipulation occurs. 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 the trade for the sake of squeezing when hedging activity is active. Consequently, it then drives up the FX futures rate to meet the desired rate for the squeezers. Due to the close relationship between the FX futures market and the spot exchange rate market (e.g., see Garcia, Medeiros, and Santos 2015; Inci and Lu 2007), depreciated FX futures rate could then be transmitted to the spot exchange rate.

Given these risks, the growing activity of the FX futures market for several EMDEs' currencies has drawn the attention of central banks in those countries. The rationale is that an impact of FX futures activity on the underlying FX market spot could affect the policy objectives of the central banks, such as exchange rate stability, inflation rates target, and economic growth. For the inflation-targeting (ITF) central bank, especially in the EMDEs, make sure a stable FX is essential since the FX volatility brings an adverse effect on inflation rate via exchange rate pass-through (ERPT) mechanism (Caselli & Roitman, 2016; Céspedes, Chang, & Velasco, 2004a; Menkhoff, 2013).

Figure 2
Spot and Futures FX rate Comparison for Five EMDEs' Currencies



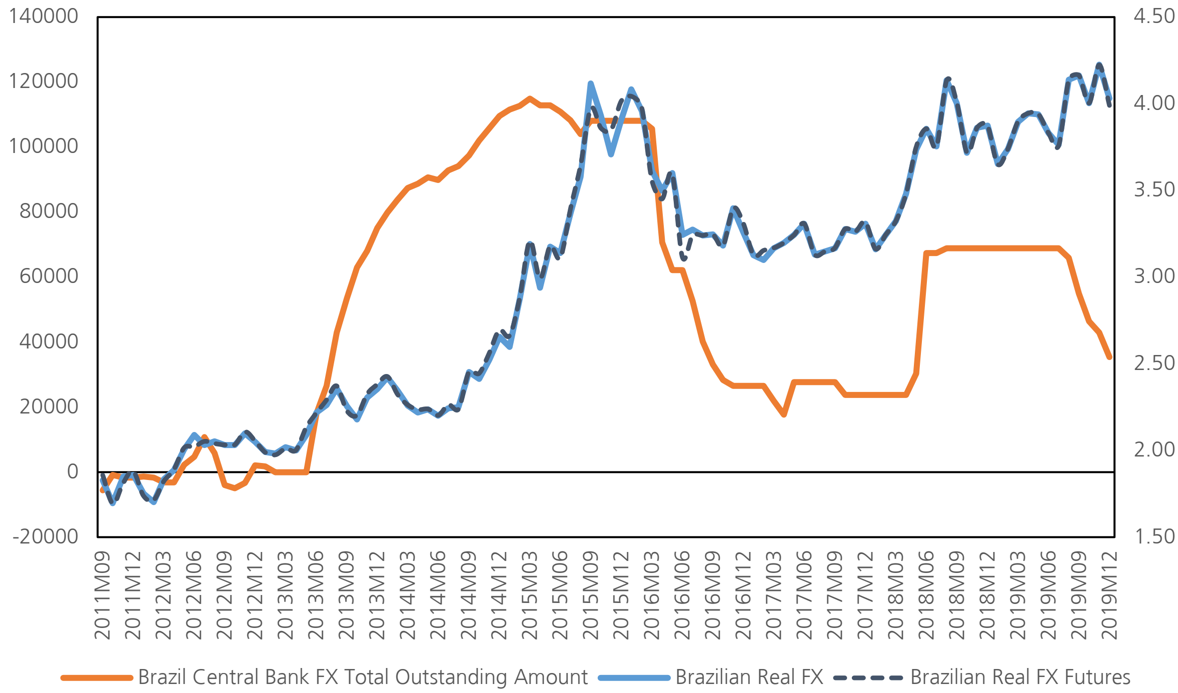
Source: Bloomberg and International Financial Statistics, IMF.
Notes: Value is normalized as the ratio of current value in respect to the value in January 2016. The data comprises five EMDEs' currencies, i.e., BRL (left vertical axis), INR (left vertical axis), ZAR (left vertical axis), TRY (right vertical axis), COL (left vertical axis), and MXN (left vertical axis).

By this concern, some central banks in the ITF-EMDEs countries thus have not only been utilizing the direct FX intervention though the spot market but also through the FX derivatives (i.e., futures and forward) market. Kohlscheen and Andrade (2014) found that even indirect interventions – i.e., through the derivates market – would also have significant effects on the exchange rate. Moreover, the FX intervention via the futures market also provides more liquidity to the economy (Mihaljek, 2005). Besides, the FX intervention via the futures market (e.g., the FX swaps auctions in Brazil) is sterilized, an FX intervention tool without affecting the money supply and stock of FX reserves[2]. In other words, it means that the derivatives-based FX interventions do not disrupt the ITF objectives while also sustaining the FX reserves. For instance, the FX derivatives trading volumes in Brazil's derivatives markets are around four times larger than those in its spot market for foreign exchange (Kang & Saborowski, 2014). The Central Bank of Brazil (CBB) has employed the public FX swap auctions as the FX intervention policy by actively intervening in both the spot and futures markets. The public FX swap auctions are aimed at

[2] Banco Central Do Brazil's (BCB) website (https://www.bcb.gov.br/en/financialstability/fxswap) accessed at February 20, 2020.

ensuring the smooth functioning of the FX market, as well as to ensure that there is a proper supply of hedging instruments in the market (Kohlscheen & Andrade, 2014)[3].

Figure 3
Futures-based FX Intervention by Central Bank of Brazil (CBB)



Source: Bloomberg
Notes: Millions of USD (primary vertical axis) and BRL against USD (secondary vertical axis). A positive value of CBB's FX Total Outstanding Amount means short position (buy) is more extensive than long position (sell) held by CBB (net buy), *vice versa*. The higher value of Real Brazilian FX (BRL/USD) denotes a depreciated BRL/USD.

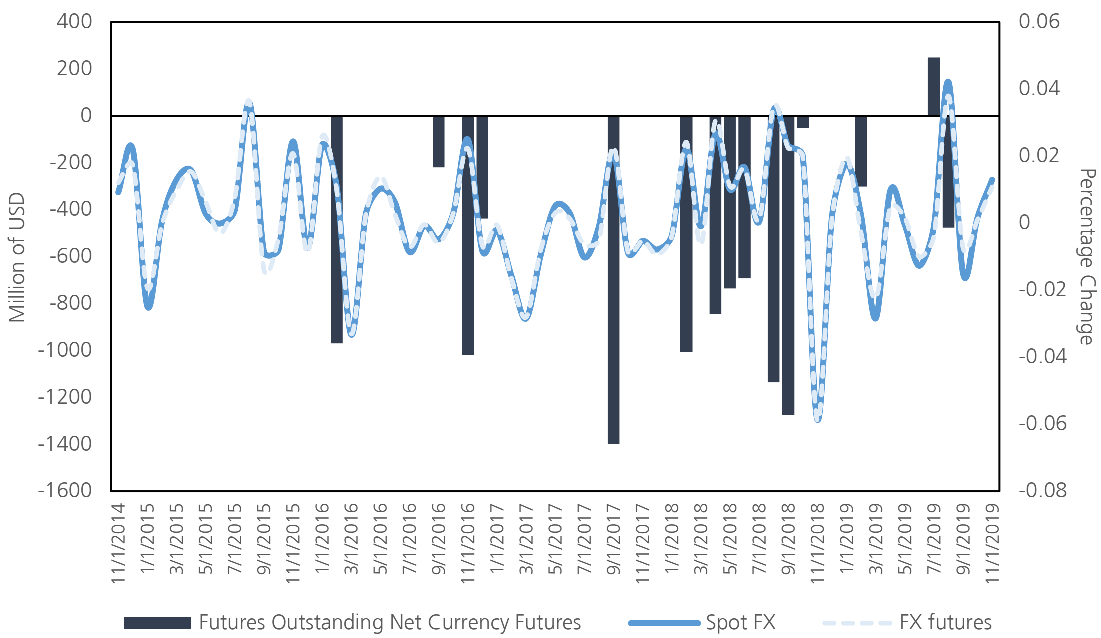
Figure (3) exhibits the Brazilian Real (against USD) and the net outstanding amount of FX futures contract (i.e., short position less long position) issued by Central Bank of Brazil (CBB). The figure illustrates that both FX rates and net outstanding amount of FX futures contract held by the CBB have a positive movement. It indicates that the futures-based FX intervention in Brazil is pervasive in response to the FX rate fluctuation. For instance, in 2013, the taper tantrum shocked the Brazilian economy, and; afterward, the CBB activated the derivatives-based FX intervention in a huge nominal. The futures-based FX intervention is formally utilized, and it adequately sufficient to mitigate the excessive FX depreciation. Specifically, Nedeljkovic and Saborowski (2017) found that the CBB FX intervention of US$1 billion in net spot market intervention changes the real/dollar exchange rate by about one percent, an impact that is statistically indistinguishable from the 0.7 percent change achieved through auctions of non-deliverable futures worth US$1 billion in notional principal. He also argued that one significant advantage of intervening via these instruments is thus that the operation does not directly impact the stock of FX reserves. Moreover,

[3] FX swap auctions is a simultaneous purchase and sale of identical amounts of one currency for another with two different value dates (normally spot to forward or futures) and may use foreign exchange derivatives. It permits companies that have funds in different currencies to manage them efficiently.

it proved that such a policy was able to reduce FX market volatility during the exchange rate turbulence (Mihaljek 2005).

In India, as exhibited in figure (4), the RBI also occasionally intervenes the FX futures market. Biswal and Jain (2019) argued that an increase in trading activity in the futures market is a signal to the RBI to intervene and reduce the uncertainty faced by market participants by its intervention. Participating in the futures market by providing liquidity via increasing order book depth, RBI can effectively reduce the volatility of the futures market, hence lowering futures market trading activity and allowing volumes to recover to normal levels. This action will cause the spot volatility to subside.

Figure 4
Futures-based FX Intervention by the RBI



Source: Bloomberg and IMF.
Notes: Net FX Futures Outstanding Held by the RBI (left axis) is gross purchase minus gross sales of the FX futures contract by the Reserves Bank of India. Spot FX and FX futures (right axis) calculated as the percentage of change in which a positive (negative) value means appreciation (depreciation).

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 et al., 2004a; Menkhoff, 2013). Nevertheless, we documented that the progress of the existing literature was not adequately addressing the role of the FX futures market in the context of the ITF-EMDEs.

First, existing literature put much emphasis on the cross-market linkage between FX spot and futures market (Behera & Swain, 2019; Biswal & Jain, 2019; Grossman & Miller, 1988; Guru, 2010; Jochum & Kodres, 1998; Kumar, 2015; Nath & Pacheco, 2017; Niti & Anil, 2014; Sharma, 2011). We also recognized the interests of previous research that leads to the usage of high-frequency data and disregards real macroeconomic indicators; thus existing literature adopted macroeconomic news rather than real macroeconomic variables (Doukas & Rahman, 1986; Harvey & Huang, 1991; S. J. Kim, 2016; T. Wang, Yang, & Simpson, 2008). Third, it was far from the scholars' scrutiny that previous literature directly connects the FX futures market, monetary policy, and the ITF regime's macroeconomic objectives, while for some strand of literature, they only focus on how macroeconomic affects FX futures price (Bailey & Chan, 1993; Chevallier, 2009; Miffre, 2001).

Furthermore, studies examining the impact of futures-based FX intervention on exchange rate and exchange rate pass-through are still pay little concern in the literature, coupled with the comparative studies that remain unrevealed. Numerous works of literature mainly concentrated on either traditional FX intervention (e.g., Adler et al., 2019; Benes et al., 2015; Ghosh et al., 2016) or interest rate rules (e.g., Caporale, Helmi, Çatık, Menla Ali, & Akdeniz, 2018; Céspedes, Chang, & Velasco, 2004; C. J. Garcia, Restrepo, & Roger, 2011; Mohanty & Klau, 2010), while the investigations on derivatives-based intervention in the ITF-EMDEs, especially futures-based intervention are remaining limited. Although several works of literature have formally examined the effectiveness of futures-based FX intervention in determining the exchange rate movement and volatility in Brazil (Kohlscheen & Andrade, 2014; Nedeljkovic & Saborowski, 2019; Oliveira, 2020), existing literature has not formally addressed the role of futures-based FX intervention in India. Second, existing literature has also not plainly examined the role of futures-based FX intervention in reducing domestic ERPT. This issue is crucial since the central bank also could act as the hedger of the last resort (Gonzalez, Khametshin, Peydró, & Polo, 2019). Third, the comparative studies on this issue between Brazil and India is still unrevealed, especially in addition to the elaboration of economic-institutional features associated with the countries. Gonzalez et al. (2019), Kohlscheen & Andrade (2014), Nedeljkovic & Saborowski (2019), and Oliveira (2020) merely focused on the case of Brazil, while Biswal & Jain (2019) merely minimally examined the case of India.

1.2 Research Objectives

Departing from this backdrop, we thus extend the previous literature in the following ways by specifically discussing two crucial questions:

1. How the ITF-EMDEs' macroeconomic conditions might be impacted by the FX futures market?

Objective 1. This question allows us to trace the role of the FX futures market within the economy. We conduct empirically, a dynamic analysis using the Bayesian Panel VAR (PVAR) approach which comprises four ITF-EMDEs countries with active FX futures marketc, namely, Brazil, Mexico, Turkey, and India. We extend the monetary unifying empirical model proposed by S. Kim (2003) so as to analyze the role FX futures market in the macroeconomic environment while simultaneously controlling the monetary policy framework under an ITF regime.

2. How Indian and Brazilian futures-based FX intervention affect exchange rate movement and exchange rate pass-through?

Objective 2. For this, we will specifically examine the effectiveness of futures-based FX intervention in determining the exchange rate dynamics and exchange rate pass-through effect. We then compare Brazil and India to evaluate and derive lessons from these countries' policy designs and outcomes in utilizing futures-based FX intervention. As these countries are strikingly different in terms of the usage of such interventions, this investigation will allow us to answer the question as to whether the country-specific aspects matter in determining the effectiveness of futures-based FX intervention.

1.3 Research Contributions

A. To the Academics Environment

This paper contributes to the current literature in four crucial ways. First, this study can be scientifically beneficial by adding and enrich current literature in the aspect of the role of the FX futures market at the macroeconomic level, especially in the ITF-EMDEs. It becomes our primary contribution since the existing literature commonly addressed the cross-market linkage between FX spot and futures market (Behera & Swain, 2019; Biswal & Jain, 2019; Grossman & Miller, 1988; Guru, 2010; Jochum & Kodres, 1998; Kumar, 2015; Nath & Pacheco, 2017; Niti & Anil, 2014; Sharma, 2011) and the impact of macroeconomy on FX futures market (Bailey & Chan, 1993; Chevallier, 2009; Miffre, 2001). Second, this paper also provides a systematic comparative studies of the futures-based FX intervention in Brazil and India that has not addressed in previous works of literature (e.g., Biswal & Jain, 2019; Kohlscheen & Andrade, 2014; Nedeljkovic & Saborowski, 2017).

B. For Policymakers

In central bank policy practices, the implementation of derivatives-based FX intervention is still limited – only three out of 22 observed central banks report that they use derivatives regularly for interventions (Mohanty & Berger, 2013). 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 et al., 2004a; Menkhoff, 2013). On the other hand, by providing comparative studies of the futures-based FX interevention, we could offer insights that explain which conditions support the effectiveness of futures-based FX intervention. Therefore, this study can be a reference for the ITF-EMDEs central banks to consider either implement or ignore an alternative monetary policy instrument by using FX futures to maintain the central bank's objectives.

2 Literature Review

2.2 Related Literature on the FX Futures Market

Researchers have placed a lot of emphasis on analyzing the FX futures market. In general, the literature in this field is concentrated on two broad issues, i.e., 'futures-spot market linkage' and 'how the activities of the FX futures market work and are determined.' For the first issue, researchers typically address the transmission mechanism of how FX futures market activities impact the underlying FX market. While for the other, various literature mainly mentions the determinant factors of FX futures market activities.

For the first strand of literature, numerous papers have demonstrated that the impact of the FX futures market on the spot market remains mix and inconclusive – either destabilizing, neutral, or stabilizing the underlying FX spot market (see Behera and Swain 2019). Classical construction by Grossman and Miller (1988) illustrated that higher liquidity provided by speculators induce the availability of risk transference afforded by the futures market reduces spot price volatility. Moreover, futures trading activities attract more traders to the spot market, making it more liquid and, therefore, less volatile. Kumar (2015) also found that spot exchange rate volatility has reduced in the post-futures period in India.

The opponents of the ‘stabilization’ view have argued that the rising activity in the FX futures market destabilizes the spot FX market. Sharma (2011) indicated that the volatility of spot exchange rate was higher after the introduction of FX futures in India. There is a two-way causality between the volatility in the spot exchange rate and trading activity in the FX futures market. Niti and Anil (2014) concluded that there was an increase in the volatility of the Indian Rupee exchange to the US Dollar (USD/INR) spot market after the introduction of currency futures in India. Nath and Pacheco (2017) found the presence of volatility clustering in the pre-futures and post-futures period. The underlying FX was relatively more volatile in the post-futures period than the pre-futures period. Biswal and Jain (2019) also suggested that an increase (decrease) in volumes in either market causes a corresponding increase (decrease) in volatility in both markets. Jochum and Kodres (1998) have found that the futures market’s introduction of derivative contracts (i.e., futures and options) does not destabilize the underlying spot market FX. Guru (2010) also argued that speculative and hedging activities in the futures market for currency do not influence the volatility in the underlying FX spot market.

The FX futures market, just like other financial markets, not only provides a risk handover for hedgers but also accommodates speculative motives. One strand of studies thus goes deeper to investigate the role of the market agent in the FX futures market. The seminal paper of Kyle (1992) has demonstrated how the market agent in the futures market interact and how market manipulation occurs. In the futures market, squeezers and corners (i.e., market manipulators) 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. It, in turn, reduces market effectiveness with the costly and risky hedging in the futures market for the hedgers. The findings of Bhargava and Malhotra (2007) on whether hedgers stabilize or destabilize the market are inconclusive. The results suggest that speculators’ demand for futures goes down in response to increased volatility. While Tornell and Yuan (2012) found that the peaks and troughs of net positions are generally useful predictors to the evolution of spot exchange rates, other trader position measures are less correlated with future market movements. In addition, speculative position measures usually forecast price-continuations in spot rates while hedging position measures forecast price-reversals.

Furthermore, some studies also illustrated that macroeconomic factors which are transmitted through information flows are crucial in determining FX futures market dynamics. In this regard, macro announcements influence traders’ decisions and the value of FX futures absolutely. Doukas and Rahman (1986) examined the impact on FX futures in response to monetary policy announcements. They found that futures market volatility increased when the statements were released. Harvey and Huang (1991) shed light on the role of macroeconomic news in determining FX futures market volatility, and they found that the release of macroeconomic news were more likely to drive volatility. Wang, Yang, and Simpson (2008) scrutinized the asymmetric response of the Euro, Deutsche Mark, Japanese Yen, and British Pound FX futures market due to the fed fund rate shocks. They found that dollar-denominated currency futures prices dropped significantly in response to positive shocks (i.e., unexpected increases) in the target and path factors, but generally had little response to adverse shocks. Kim (2016) investigated the role of macroeconomic news in the carry trade opportunities for major currencies (i.e., Australian Dollar, Euro, and Japanese Yen) against the US dollar in the FX futures market. He found that macroeconomic news could appreciate (depreciate) the AUD (the JPY) and also stimulate the AUD (the JPY) carry trades.

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 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 et al., 2004a; Menkhoff, 2013).

2.2 Related Literature on Conventional and Futures-based FX Intervention

Researchers' scrutiny on FX intervention within the ITF-EMDE central banks has grown exponentially. The primary concern is that conventional wisdom holds that the ITF-central bank should not address the issue of exchange rate variability (Masson, Savastano, and Sharma 1997; Mishkin and Savastano 2001; F.S. Mishkin and K. Schmidt-Hebbel 2001; McCallum 2007). A clear mandate to the central bank with inflation as a single goal is to deliver independence for monetary policy for which a free-floating exchange rate or clean hand away from intervention is required. However, most of the central banks in EMEs appear to have a "fear of floating" and are thus actively involved in interventions in the exchange rate market either via foreign exchange intervention (FXI) or even interest rates (Calvo & Reinhart, 2002). Therefore, some strand of literature have emphasized the role of FX intervention within the FX spot market. In contrast, others addressed the contemporaneous response of interest rates to exacerbated-FX in the ITF-

EMDEs. However, there is another small strand of literature that also scrutinizes the role of futures-based FX intervention.

Most researchers appear to be on the same page that the ITF-sterilized FX intervention combination, the so-called two instruments for two targets (TI-TT), is beneficial for ITF-EMDEs. The TI-TT's proponents argue that exchange rate involvement in policy rate reaction function is misleading and thus recommend sterilized FX interventions alone to ensure exchange rate stabilization. Ghosh, Ostry, and Chamon (2016) explained that the utilization of sterilized FX intervention as a second instrument effectively improves welfare under inflation targeting in EMEs. Benes et al. (2015) also revealed that when the monetary authority leans against the managed float, sterilized FX intervention effectively insulates the economy against external shocks, particularly international financial conditions. Adler, Lama, and Medina (2019) suggested that when the central bank possesses a relatively high degree of credibility, sterilized FX intervention could effectively stifle external shocks (i.e., foreign interest rate and term of trade) on both inflation and output. Montes and Ferreira (2020) also examined the impact of monetary policy credibility (i.e., defined as the central bank's ability to anchor inflation expectations to the target) on the central banks' reaction through the basic interest rate due to the exchange rate fluctuations (i.e., fear of floating). They found that monetary policy credibility can mitigate the fear of floating. However, this effect is weaker after the crisis. Our estimates also reveal that Inflation Targeting developing countries have a stronger fear of floating, which is justified by the fear of inflation in these countries.

Another strand of literature examines some ITF central banks in EMDEs by including the exchange rate in the policy rate reaction function and may have garnered an advantage by doing so. Mohanty and Klau (2010) found that in most EMDEs, interest rate consistently responds to the exchange rate; and in some, it even responds higher than to the fluctuations in output and the inflation rate. Caporale et al. (2018) also revealed that several EMDEs, in reality, augment the exchange rate deviation in their interest rate policy reactions. Moreover, the supporters of this view argue that the inclusion of the exchange rate in the policy rate rule is beneficial for financially-vulnerable emerging economies by effectively managing risk premium shocks (Céspedes, Chang, & Velasco, 2004b; C. J. Garcia et al., 2011)

The last strand of literature investigates the role of futures-based FX intervention. Nedeljkovic and Saborowski (2017) found that CBB FX intervention of every US$1 billion in net spot market intervention changes the real/dollar exchange rate by about one percent. The impact is also statistically indistinguishable from the 0.7 percent change achieved through auctions of non-deliverable futures worth US$1 billion. He also argued that one significant advantage of intervening via these instruments is that the operation does not directly impact the stock of FX reserves. It proved useful that such a policy was able to reduce FX market volatility during the exchange rate turbulence (Mihaljek 2005). The public FX swap auctions were aimed at ensuring the smooth functioning of the FX market, as well as to ensure that there was a proper supply of hedging instruments in the market (Kohlscheen & Andrade, 2014). For the Indian economy, Biswal and Jain (2019) argued that an increase in trading activity in the futures market is a signal to the RBI to intervene and reduce the uncertainty faced by market participants. By participating in the futures market with the provision of liquidity via increasing the order book depth, RBI can effectively reduce the volatility of the futures market. This calming of futures market trading activities allows volumes to recover to normal levels and cause spot volatility to subside. On the other hand, Gonzalez, Khametshin, Peydró, & Polo (2019) emphasized that the central bank has an important role as the hedger of the last resort. They found that futures-based FX intervention significantly reduced the negative effect of the Global Financial Crisis (GFC) and taper tantrum on the balance sheets of highly external resilient banks; therefore, reducing firm-level unemployment in Brazil.

We have looked at the numerous literature related to FX intervention which is mainly concentrated on either sterilized FX intervention or interest rate rules. Numerous works of literature mainly concentrated on either traditional FX intervention (e.g., Adler et al., 2019; Benes et al., 2015; Ghosh et al., 2016) or interest rate rules (e.g., Caporale, Helmi, Çatık, Menla Ali, & Akdeniz, 2018; Céspedes, Chang, & Velasco, 2004; C. J. Garcia, Restrepo, & Roger, 2011; Mohanty & Klau, 2010), while the investigations on derivatives-based intervention in the ITF-EMDEs, especially futures-based intervention are remaining limited. Although several works of literature have formally examined the effectiveness of futures-based FX intervention in determining the exchange rate movement and volatility in Brazil, existing literature has not formally addressed the role of futures-based FX intervention in India. Second, existing literature has also not plainly examined the role of futures-based FX intervention in reducing domestic ERPT. This issue is crucial since the central bank also could act as the hedger of the last resort (Gonzalez et al., 2019). Third, the comparative studies on this issue between Brazil and India is still unrevealed, especially in addition to the elaboration of economic-institutional features associated with the countries. Gonzalez et al. (2019), Kohlscheen & Andrade (2014), Nedeljkovic & Saborowski (2019), and Oliveira (2020) merely focused on the case of Brazil, while Biswal & Jain (2019) merely minimally examined the case of India.

3 The Micro-structure of FX Futures Market in Brazil and India: Progress, Significance, and Regulatory Background

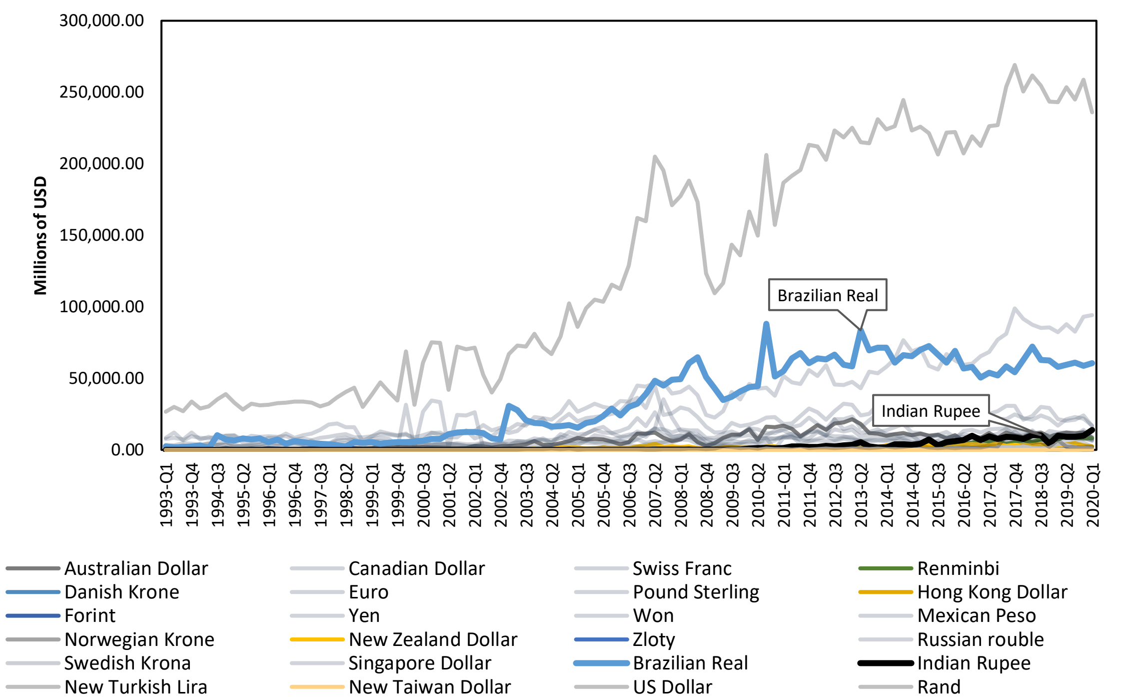
The exchange-traded FX futures have been gradually taking an essential part in FX derivatives activities. In the Emerging Market and Developing Economies (EMDEs), the Notional Amount of Outstanding Positions (NAOP), one of the proxies of FX derivatives activity, has grown considerably (see Figure 5). The NAOP in EMDEs which was only seven billion US dollars in 2002, reached approximately 180 million USD in late 2019. Proportionally, it comprised almost 20 percent of the total NAOP in exchange-traded FX futures globally.

Among the EMDEs, the FX futures activities in Brazilian Real (BRL) and the Indian Rupee (INR) are prevalent. The BRL has the largest NAOP in the FX futures market, and is in fact the third-largest in the world after the US Dollar and Euro, followed by the INR (see Figure 6). In the first quarter of 2020, the BRL's NAOP reached roughly 60 billion US dollars and has grown over 4 percent in the year-over-year calculation. For the INR, the NAOP has grown approximately 40 percent in the first quarter of 2020. However, the size of the NOAP for the INR is still very small compared to the BRL, or about more than 400 percent smaller than the BRL. The FX futures market in Brazil is more extensive than that in India in terms of daily average turnover. In March 2020, the BRL daily average turnover reached almost 40 billion US dollars, while the INR was about more than 350 percent smaller than that. It is obvious that the FX futures market for the BRL is much larger and more developed than for the INR.

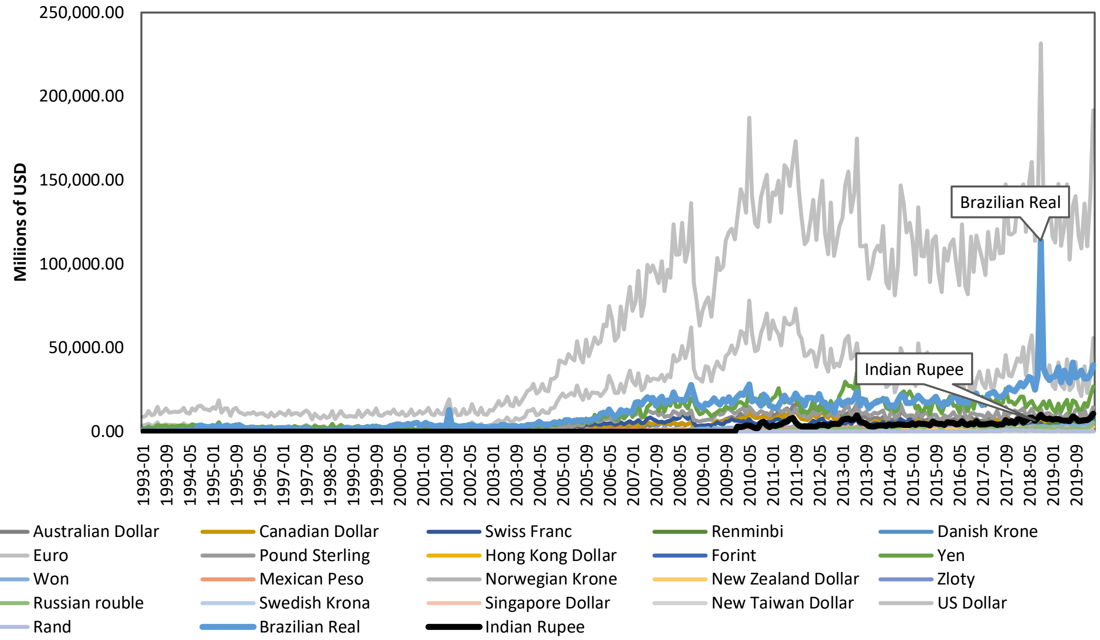
Moreover, the FX market in Brazil and India has a strikingly different structure, although the FX derivatives markets in both countries are more active than the spot markets (see Figure 7). In Brazil, FX derivatives are concentrated in outright forwards, non-deliverable forwards, and futures markets with each market contributing about 30 percent, 25 percent, and 24 percent of the total daily average turnover in 2019, respectively. The FX futures market in Brazil has been continuously expanding throughout 1998 and 2019, although it shrank somewhat in 2013 due to introduction of non-deliverable forwards in the handling of the taper tantrum. In India, the FX derivatives markets are mainly concentrated only in outright forwards and non-deliverable forwards, comprising 36 percent and 29 percent of total share, respectively. Meanwhile, the FX futures market makes up only 4 percent of the total daily average turnover in 2019. Although the FX futures market in Brazil is more extensive than in India, the Over-the-counter (OTC) FX derivatives market in India (i.e., outright forward and non-deliverable forward) is approximately two times bigger than Brazil's in terms of the total daily average turnover, especially in 2019.

Figure 5
The FX Futures Market Activities, 1993-2020

Panel A Quarterly Notional Amount of Outstanding Positions, 1993-2020 (Millions of USD)



Panel B Daily Average Turnover – Notional Amounts, 1993-2020 (Millions of USD)



Source: Exchange-traded Derivatives Statistics, BIS.

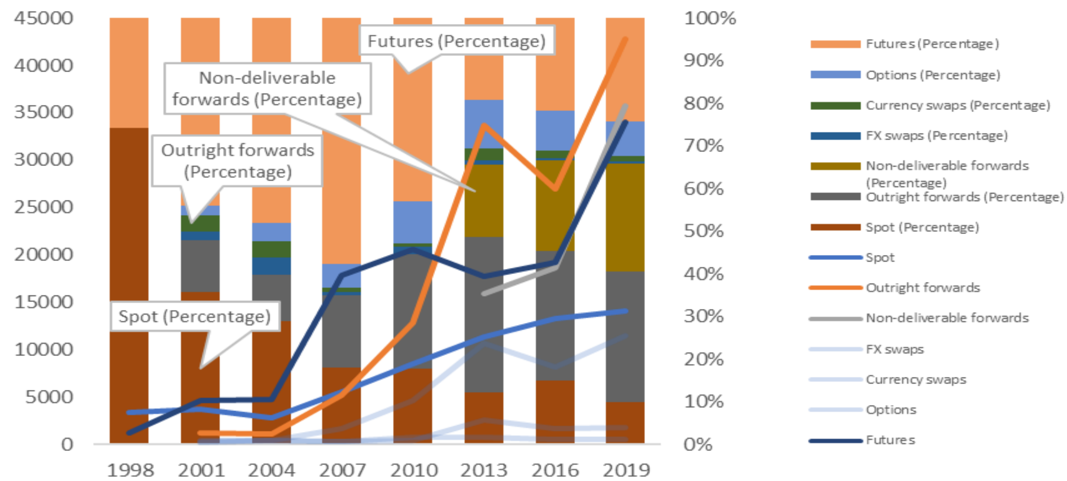
These differences in the development of the FX futures markets and the FX derivatives market structures in Brazil and India are inherently associated with the regulatory frameworks.

The robust and unique structure of the FX markets in Brazil is related to the regulatory framework, including not only financial regulations but also fiscal policies. Its FX futures market has the oldest FX derivatives instrument.[4] The International Monetary Fund (2018) noted that a relatively small spot FX market in Brazil reflects the regulation constraint that allows only a few agents to access the spot FX market directly. Based on the Decree-Law No. 857, for every contract, security, document or obligation to be fulfilled in Brazil, payment cannot be stipulated in gold or foreign currency, or in any other form, except in Brazilian currency. The exceptions to this law are currency exchange operations, import/export contracts, export financing (when a Brazilian bank buys, paying in Reals, in advance, the amount of foreign currency to be received by an exporter in an export operation) or loans or any obligations for which the creditor or debtor is domiciled outside Brazil (International Monetary Fund, 2015). Since the FX futures contract is non-deliverable, the resulting limited internal convertibility provides the incentives for hedging in the FX futures market. The Brazilian legal and regulatory framework also places added constraints with the levying of taxes on revenues and cash flows rather than income or value-added. This therefore encourages the migration of trading to exchanges (Upper & Valli, 2016). These restrictions which are aimed at mitigating the adverse effects from speculations in the spot FX, have also on the side, helped to develop a relatively large and robust FX futures market. In addition to the financial and foreign exchange regulatory framework, the Brazilian regulatory authorities have initiated the Capital Account Regulation along with the FX Derivatives Regulation in 2010, to effectively restrain excessive BRL volatility. This has helped to resolve the economic policy dilemma faced by the Brazilian government of containing inflationary pressures without exacerbating exchange rate misalignment (Prates & de Paula, 2017).

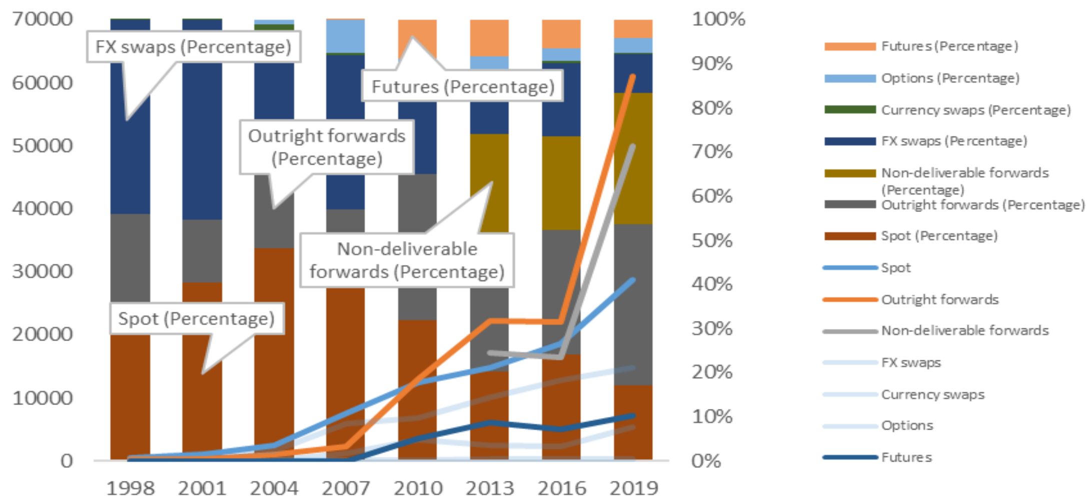
[4] Brazilian Real US dollar futures contracts were launched on August 1, 1991.

Figure 6
The FX Derivatives Market Activities in Brazil and India, 1998-2019

Panel A Brazil



Panel B India



Source: Triennial Central Bank Survey and Exchange-traded Derivatives Statistics, BIS.

The FX futures market has also served a vital role in accommodating hedging in Brazil. After the Brazilian currency crisis in the 1990s, the foreign debt overhang has encouraged the use of FX futures for hedging (Upper & Valli, 2016). The eligibility for the issuance of the main futures contract (DOL) is limited to two groups, i.e., authorized dealers and other companies for which the primary activity is related to the transactions regulated for this market (i.e., exporters/importers, permitted financial services and capital flows).[5] It effectively anticipates the misuse of the FX futures market for hedging activities. Given the well-developed FX futures market in Brazil, the

[5] Brazilian Mercantile & Futures Exchange (BM&F).

price discovery in the Brazilian spot FX market is highly determined by the FX futures market (M. Garcia et al., 2015).

On the contrary, the FX futures market in India is relatively less developed compared to other FX derivatives markets. As discussed earlier, the FX futures market makes up only 4 percent of the total daily average derivatives turnover in 2019. This is even though the RBI has raised the single investment limit to USD 100 million per user compared with a meager USD 15 million per exchange for dollar-rupee pair in February 2018.[6,7] The main reason why the FX futures market in India is far less-developed than OTC FX derivates such as forwards is that it was only introduced recently. When the FX futures was first launched in 2008, the OTC FX markets were already becoming the main instruments for economic agents to manage their risks, subsequent to India's financial reforms to establish a fully convertible currency in 1994 (Shyamala Gopinath, 2010). In contrast to the Brazilian FX futures market, the regulations in India allow resident individuals to hedge their underlying or anticipated exposures in the FX futures market without any limitation pertaining to the underlying motives of agents' economic activities. In this regard, therefore, the FX futures market is unlikely to replicate the discipline of ensuring underlying commercial transactions and it is only in the OTC market that participants are able to fulfill the genuine hedging requirements (Shyamala Gopinath, 2010).

Furthuremore, the FX futures market, as a financial instrument of foreign exchange, is closely related to exchange rate stability and financial stability, so that the central bank has to take a primary role in the FX futures market. In India, according to (Reserve Bank of India, 2008), the Foreign Exchange Management Act (FEMA) gives the RBI the mandate to manage the overall affairs related to foreign exchange and exchange rate as well as maintaining monetary and financial stability. In Brazil, the National Monetary Council (CMN) sets the FX policy to be implemented by the Central Bank of Brazil (BCB). The CMN establishes the guidelines for the financial relationships between the economy and the rest of the world, the FX market operations, the rules for the flow of international capital to the country, and the management of international reserves. At the same time, the BCB is also in charge of assuring the soundness and efficiency of the National Financial System (SFN), pursuant to its institutional mission by regulating and supervising financial institutions and other licensed entities, monitoring their capitalization, regulatory compliance and their conduct towards the financial consumers and users.[8]

Both the RBI and BCB have a crucial role in the provisioning, regulating, and monitoring of the FX futures market. In India, both the FEMA and RBI Act authorize the RBI in the provision of the FX derivatives market and hence it has overall responsibility for the market (Reserve Bank of India, 2008). Furthermore, the RBI, in coordination with the Securities and Exchange Board of India (SEMA), undertake the surveillance of the FX futures market by conducting periodical

[6] Economic Times, India Times. RBI eases limit in exchange traded currency futures market. (Link: https://economictimes.indiatimes.com/markets/forex/rbi-eases-limit-in-exchange-traded-currency-futures-market/articleshow/62820152.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cpps.)

[7] Based on (Reserve Bank of India, 2008; p.47), the role of Reserve Bank of India in FX futures market includes: *"stipulating or modifying the participants and/or fixing participant-wise position limits or any other prudential limits in the interest of financial stability. Such over-riding powers are not without a parallel and are also used by other regulators in their respective jurisdictions. Illustrations of such emergency powers include being empowered to order the Exchange to take actions specified by the regulator. Such actions could include imposing or reducing limits on positions, requiring the liquidation of positions, extending a delivery period or closing a market."*

[8] https://www.bcb.gov.br/en/financialstability/fxpolicy

meetings to sort out issues, if any, arising from overlapping jurisdictions of the currency futures market (RBI & SEMA, 2008). For the case of Brazil, the *Plano Real* in 1994, generally shaped the role of BCB in the FX derivatives market, especially the futures market. More specifically, the BCB ensures the permanence and functionality of the FX market, and may intervene to reduce excessive volatility by offering FX hedge or liquidity to market agents by means of several instruments.

4 FX Intervention in Brazil and India

In contrast to Advanced Economies (AEs), the Emerging Market and Developing Economies (EMDEs) regularly use FX interventions to manage exchange rate movements. The rationale behind these interventions is that exchange rate variability in EMDEs is highly volatile due to external disturbances which can have adverse impacts on the domestic economies. In EMEs, exchange rate volatility can affect the economy via pass-through mechanisms (Zorzi, Hahn, and Sanchez 2007). These pass-through mechanisms can therefore cause exchange rate instability, which in turn would disrupt trade, leading to a rise in the dollar burden, pushing up the prices of imported goods, undermining inflation and economic growth (Menkhoff 2013). Céspedes, Chang, and Velasco (2004) also confirmed that weaker local currencies in financially vulnerable countries could deteriorate debt, leading to service difficulties, and worsening balance sheets of domestic banks and firms.

Given this circumstance, the FX intervention mechanism in EMDEs has been used in various ways. The first mechanism known as sterilized FX intervention, is most often used in the ITF-EMDEs. Ghosh, Ostry, and Chamon (2016) clarified that the utilization of sterilized FXI as a second instrument improves welfare under inflation targeting in EMDEs. Benes et al. (2015) also revealed that when the monetary authority leans against the managed float, sterilized FXI effectively insulates the economy against external shocks, particularly from international financial conditions. Adler, Lama, and Medina (2019) suggested that when the central bank possesses a relatively high degree of credibility, sterilized FXI could effectively stifle external shocks (i.e., foreign interest rate and term of trade) on both inflation and output.

In particular, countries like Brazil and India, which are characterized by developed derivatives FX markets, have not only regularly applied sterilized FX intervention but also derivatives-based FX intervention. The Brazilian central bank has intervened frequently in foreign exchange markets since the adoption of its floating exchange rate regime in January 1999, including the regular use of the FX futures market. Given its high liquidity, the central bank has been encouraged to intervene more frequently and systematically in this market (Upper & Valli, 2016). The futures-based FX intervention[9], to some extent, also replaced domestic government bonds that were linked to the exchange rate (Kohlscheen & Andrade, 2014).[10] The RBI has also intervened through the FX futures market, albiet only occasionally and in a limited amount. Given that Indian derivatives are mostly concentrated in the OTC market (e.g., forwards), the derivatives-based FX intervention is more extensive in the forwards market.

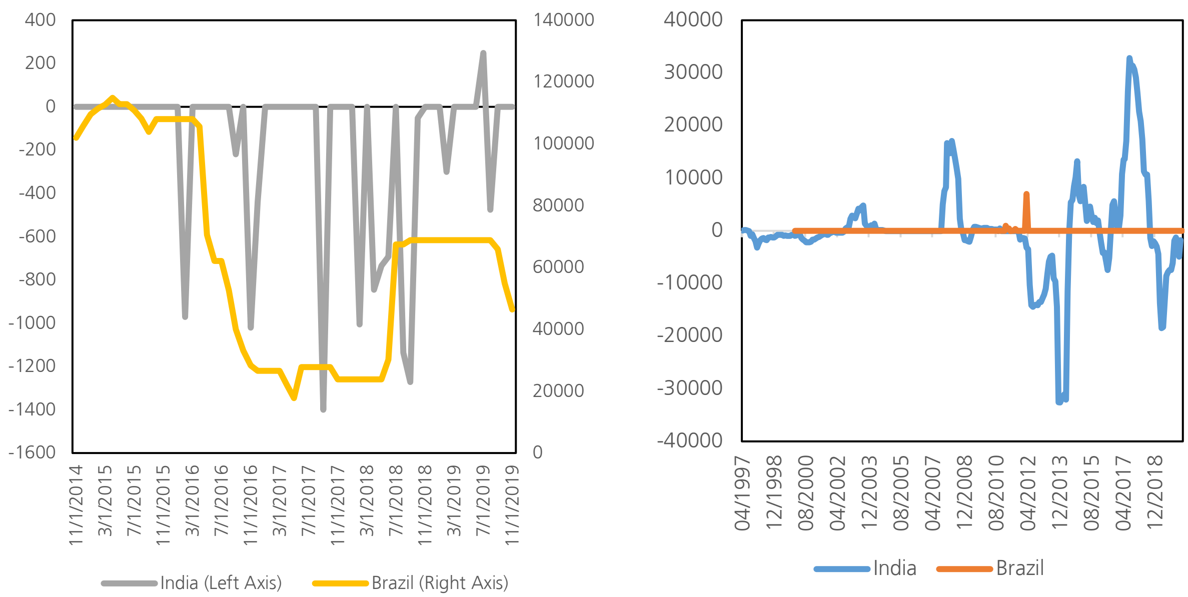
[9] We use the term of futures-based FX intervention rather than Brazilian FX swap because it is somewhat misleading since the instruments are more similar to non-deliverable futures. Unlike conventional cross-currency swaps, they do not involve an exchange of notional principal; the crucial difference to conventional non-deliverable futures is that they are settled in local currency (Nedeljkovic & Saborowski, 2019).

[10] Specific discussions on the futures-based FX intervention in Brazil are provided in Box 1.

Figure 7
Derivatives-based FX Intervention in Brazil and India

Panel A
FX Intervention in Futures Market

Panel B
FX Intervention in the Forwards Market



Source: Bloomberg and CEIC.
Notes: In Millions of USD. The value denotes net purchase/sale in the derivatives market by the Central Bank. A positive value of denotes net purchase, vice versa.

Figure (9) exhibits both futures-based and forwards-based FX intervention in Brazil and India. The figure illustrates that the forwards-based FX intervention in Brazil is strikingly smaller than the futures-based FX intervention, while it is the opposite in India where the FX intervention in the FX futures market is strikingly smaller than that in the forward market. In India, FX operation by the central bank in the FX futures are mostly neutral in terms of the gross purchases offseting the gross sell.[11] The intention of the futures-based FX intervention in India is merely to ensure that the market is well-functioning, while the intervention in the forwards market also comprises the intention to stabilize exchange rate volatility and to avoid a cash crunch in the banking system. (Tripathy, 2013).

[11] See RBI Bulletin, 4. Sale/Purchase of US Dollar by the RBI (https://www.rbi.org.in/scripts/BS_ViewBulletin.aspx)

Box 1

The Mechanism of the Futures-based FX Intervention in Brazil

Futures-based FX intervention by the Central Bank of Brazil is operated through the auction mechanism in registered contracts available at the BM&FBovespa exchange as the SCC *(Contrato de Swap Cambialcom Ajuste Periodico)*. Auctions are always announced through the Central Bank's communication system, establishing the exact time of the auction (typically a few minutes after the announcement), the number of contracts that the Central Bank is offering to buy or sell, as well as the maturities that are on offer. Each participating institution is allowed to place up to five bids, specifying the quantity and price (i.e., the implicit interest rate) for each. After bids are placed, the Central Bank has the discretion to accept any volume of contracts up to the maximum amount that is on offer. If the Central Bank is offering to buy these derivative contracts, the financial institution receives the equivalent of the exchange rate variation over the time of the contract plus a local onshore US$ interest rate, all paid in Brazilian Reals. At the same time, the Central Bank receives the cumulative interbank interest rate. The local market convention has been to label auctions as traditional futures-based FX intervention when the Central Bank is buying contracts (which may have the effect of limiting the depreciation of the Brazilian Real), and as a reverse intervention when the Central Bank is selling these contracts.

Source: Mihaljek (2005)

Voluminous literature have demonstrated the role of futures-based FX intervention in Brazil. (Kohlscheen & Andrade, 2014) found that to the extent that a change in the supply of SCC derivatives alters the supply of hedging instruments that are available in the market, such auctions will affect the relative demand for USD dollars in the marketplace and, as a consequence, the prevailing USDBRL exchange rate. (Nedeljkovic & Saborowski, 2019) found that the CBB FX intervention of every US$1 billion in net spot market intervention changes the real/dollar exchange rate by about one percent. Also, the impact is statistically indistinguishable from the 0.7 percent change achieved through auctions of non-deliverable futures worth US$1 billion. They also argued that one significant advantage of intervening via these instruments is that the operation does not directly impact the stock of FX reserves. It proved useful that such a policy was able to reduce FX market volatility during the exchange rate turbulence (Mihaljek 2005). The public FX swap auctions are aimed at ensuring the smooth functioning of the FX market, as well as to ensure that there is a proper supply of hedging instruments in the market (Kohlscheen & Andrade, 2014). (Gonzalez et al., 2019) emphasized that the central bank has an essential role as the hedger of the last resort. They found that futures-based FX intervention significantly reduced the negative effect of the Global Financial Crisis (GFC) and taper tantrum on the balance sheet of highly external resilient banks; therefore, reducing firm-level unemployment in Brazil.

5 Empirical Strategy

5.1 Data and Variables

5.1.1 First Dataset

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
Variables

Variables	Description	Data Transformation	Unit of Account	Source
Open interest (OP)	The total value of FX futures contracts	First-differenced	Growth	Bloomberg
Trade volume (TV)	The daily average of monthly turnover in the FX futures market.	First-differenced	Growth	Triennial Survey, Bank for International Settlements (BIS)
FX futures contract price (F)	FX futures rate	Log-differenced	Returns	Bloomberg
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

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; M. Garcia et al., 2015; Guru, 2010; Jochum

& Kodres, 1998; T. Wang et al., 2008). For the variables that control the conduct of monetary policy, we follow (S. 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
Descriptive Statistics

	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

5.1.2 Second Dataset

For our analysis, we use two separate time-series data for Brazil and India. Brazil's dataset comprises monthly data from 2011:09 to 2018:12, while India's dataset includes monthly data from 2014:10 to 2018:12. For the observation selection, we take into consideration the following principles: First, we utilize monthly-based time series in order to incorporate them with the macroeconomic data. Second, the observation for India represents the initial intervention of the RBI in the FX futures market (see RBI Bulletin, 2015). More specifically, the period used for India's estimations disregard the Global Financial Crisis. Hence, we have selected observations for Brazil starting from 2011 in order to provide comparability with India, while at the same time, optimizing the small number of observations.[12] By this, our observations may potentially generate a small sample bias. It is thus necessary to check whether our estimations are consistent. In this regard, we utilize robustness strategies to ensure that our estimations are consistent, although the number of observations was relatively small (see in the Robustness Tests section for details).[13]

The details of the variables and descriptive statistics are exhibited in the following two tables (Table 3 and 4):

[12] As discussed by Laeven & Valencia (2013), the GFC ended in 2011.

[13] We also utilize the D-OLS estimation for the robustness test, which is robustly superior in small samples, as well as being able to account for possible simultaneity within regressors (Masih & Masih, 1996).

Table 3
Variable Description

Variables	Description	Data Transformation	Unit of Account	Source
Spot FX intervention (SI)	Changes in the stock of FX reserves		Millions of USD	IMF
Futures-based FX intervention (FI)	Changes in the total outstanding amount of FX futures positions held by the central bank		Millions of USD	Bloomberg
Domestic interest rates $\left(r^d\right)$	Policy rate		Basis Point	IMF and CEIC
Economic growth (y)	Industrial Production Index (IPI)	Log-differenced	Index	IMF
Exchange rates (S)	Nominal FX	Log-differenced and Logarithm	Returns and Log	IMF
Consumer Price Index (CPI)	CPI	Log-differenced	Percentage	BIS
FX futures contract price (F)	FX futures rate	Log-differenced	Percentage Change	Bloomberg
US interest rates (r^{US})	Fed fund rate	Log-differenced	Basis Point	FRED
Economic growth (y^{US})	Industrial Production Index (IPI)	Log-differenced	Index	FRED
Trade Balance (TB)	Net export	-	Millions of USD	DOTS, IMF
Import Price	Commodity Import Price Index	Logarithm	Index	DOTS, IMF

Table 4
Descriptive Statistics

Panel A Brazil

	Mean	Median	Maximum	Minimum	Std. Dev.	Observations
Exchange Rate	-5.00E-16	0.3677	1.8356	-1.5367	1.0057	88
FX Futures Rate	2.47E-16	0.3808	1.8106	-1.6057	1.0057	88
Foreign Exchange Intervention	-0.00135	-0.1187	5.0292	-4.9709	1.0057	88

	Mean	Median	Maximum	Minimum	Std. Dev.	Observations
Futures-based Intervention	3.53E-17	0.0570	3.1159	-3.2352	1.0057	88
Policy Rate	-1.33E-15	0.1094	1.4438	-1.4666	1.0057	88
Industrial Production, Log	-9.42E-15	-0.1443	1.6487	-1.6642	1.0057	88
Consumer Price, Log	-1.34E-14	0.0678	1.4285	-1.6589	1.0057	88
Net Export	1.41E-16	-0.0522	1.9423	-2.0811	1.0057	88
Fed Fund Rate	1.21E-16	-0.5442	3.0447	-0.6907	1.0057	88
US Industrial Production, Log	2.06E-14	-0.1529	2.3952	-2.0770	1.0057	88
Import Price Index, Log	-2.83E-16	-0.0261	1.4993	-1.9001	1.0057	88
Exchange Rate, Log	1.04E-15	0.4669	1.5873	-1.7513	1.0057	88

Panel B India

	Mean	Median	Maximum	Minimum	Std. Dev.	Observations
Exchange Rate	-2.63E-15	-0.020	2.929	-1.821	1.010	51
FX Futures Rate	3.73E-15	0.045	3.061	-1.778	1.010	51
Foreign Exchange Intervention	-0.00707	-0.125	2.615	-2.125	1.010	51
Futures-based Intervention	-5.93E-18	0.000	2.721	-2.721	1.010	51
Policy Rate	1.40E-15	-0.270	2.400	-1.140	1.010	51
Industrial Production, Log	-2.87E-14	-0.093	1.918	-2.081	1.010	51
Consumer Price, Log	2.47E-14	0.014	1.742	-1.866	1.010	51
Net Export	8.34E-16	-0.090	2.082	-2.058	1.010	51
Fed Fund Rate	3.83E-16	-0.581	2.316	-0.990	1.010	51
US Industrial Production, Log	1.58E-14	-0.197	2.223	-1.402	1.010	51
Import Price Index, Log	-2.49E-16	0.042	1.591	-2.626	1.010	51
Exchange Rate, Log	-6.96E-15	0.000	2.817	-1.888	1.010	51

Notes: Panel A and B exhibit the results of descriptive statistics for Brazil and India, respectively. Data is normalized using $\breve{x}_i = \left(\frac{x_i - \bar{x}}{\sigma_i}\right)$. For Brazil's dataset, it comprises monthly data from 2011:09 to 2018:12, while India's dataset includes monthly data from 2014:10 to 2018:12.

5.2 Econometric Approach

5.2.1 Panel VAR

In the previous works of research, the standard VAR frequently is employed to examine the market linkage between the futures market and spot market (e.g., Jochum and Kodres 1998; Bhargava and Malhotra 2007; Guru 2010; Floros and Salvador 2016). In this paper, we extend the investigation, which comprises not only the inter-relationship between FX futures and spot market but also the consequences of the FX futures market activities on macroeconomy in a panel of selected ITF-EMDEs countries.

To accommodate our interests, we utilize the Panel Vector Autoregressive (PVAR). The PVAR is built with the same logic as the standard VAR model (Canova & Ciccarelli, 2013). Suppose we have the following standard unrestricted P-VAR equation:

$$y_{it} = \boldsymbol{\varphi_i} x_{it} + \boldsymbol{\omega_i} w_{it} + \varepsilon_{it} \tag{1}$$

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

From the equation above, we could thus identify three main features of standard P-VAR, which are cross-sectional heterogeneity and static and dynamic interdependencies. However, these features frequently lead to over-parameterization, the curse of dimensionality (Feldkircher, Huber, & Pfarrhofer, 2020). For instance, Canova and Ciccarelli (2009) examined the effects of a US real shock on the G-7 countries' GDP and the consequences of an unexpected oil price change on inflation in euro area countries. By utilizing four dependent variables ($K = 4$) lagged in one period ($P = 1$) for G-7 countries ($N = 7$), an unrestricted P-VAR has 784 VAR coefficients and 406 error variance and covariance to estimate (Koop & Korobilis, 2016)[14].

Cross-sectional Homogeneity. The first restriction refers to cross-sectional heterogeneity (CH). It concerns with the relationship between y_{it} with their lags $x_{it} = \left(y'_{it-1}, y'_{it-2}, \ldots, y'_{it-p}\right)'$. In cross-country case, CH restriction implies that $\boldsymbol{\varphi_i} = \boldsymbol{\varphi_j} = \boldsymbol{\varphi}$ or, in other words, it indicates the parameter homogeneity ($\boldsymbol{\varphi}$) across countries.

Dynamic Interdependencies. The second restriction related to the parameter of lagged relation across units, $\boldsymbol{\omega_i}$**.** The simplest case for this restriction is that $\boldsymbol{\omega_i} = \mathbf{0}$**,** ruling out the dynamic cross-unit spillover. However, in this paper, we are not focusing on investigating the spillover effect among EMDEs' currencies. Instead, we set it later (second model estimate) with exogenous external disturbance.

Static Interdependencies. The last restriction associated with contemporaneous model relations between the shocks across countries in the system, i.e., static interdependencies, $\boldsymbol{\Sigma_{ij}} = \mathbf{0}$. It essentially asks the question of whether shocks are correlated among countries and variable types.

There are numerous ways to estimate P-VAR in which primarily depends on the data structure and research objective. First, based on the size of N and T, some might prefer to using the Generalized Method of Moment (GMM) style PVAR estimation developed by Arellano and Bond (1991). When T is finite and large N, GMM is a consistent estimator. Therefore, in the case of T is finite and N is large, the GMM-style PVAR developed futher by Abrigo and Love (2016) is suitable. However, there are several crucial weaknesses of the GMM estimator. First, when T tends to large, thus, GMM is biased and inconsistent (see Judson and Owen 1999; Bruno 2005).

[14] 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).

On the other hand, the PVAR generates a considerable number of coefficients that are difficult to tackle using frequentist methods. Therefore, it is worth emphasizing that dozens of literature rely on Bayesian-based techniques to estimate PVAR models (e.g., see Canova & Ciccarelli, 2009, 2013; Koop & Korobilis, 2016). Bayesian methods, by contrast, provide a natural way of exploring a vast dimensional model space by using Markov chain Monte Carlo (MCMC) algorithms that entail exploring promising regions of the model space (Feldkircher et al., 2020).

In this paper, we thus primarily employ Bayesian-based estimations developed by (Canova & Ciccarelli, 2009, 2013). Specifically, we perform pooled Bayesian PVAR, which restricts the cross-sectional heterogeneity and dynamic and static interdependencies. The intuition behind it is that our cross-sectional observation is similar in terms of the monetary policy framework and economic status. Second, we assume the absence of dynamic and static interdependencies because our observation is generally not in the same region. For the case of Pooled Bayesian PVAR, the standard normal-Wishart identification is adopted (Dieppe, Legrand, & Van Roye, 2016). It starts with the formulation of the VAR model in the matrix form as follows:

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

$$y = \bar{X}\beta + \varepsilon$$

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) as 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 are respectively defined as 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:

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

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

5.2.2 Autoregressive Distributed Lag (ARDL)

In economics, the role of lapse of time is crucial. The relationship between, for instance, two variables (Y, X) is rarely contemporaneous (Gujarati & Porter, 2009). The response of Y to X frequently takes a lapse of time, so-called lags. On the other hand, value of the current variable also impacts its lagged value. For instance, inflation rates theoretically inertial in which means that the lagged value of inflation shapes the current inflation. In econometrics, the autoregressive form could handle this kind of issue (Baltagi, 2008). Also, in economics, the dependent variable is frequently influenced by its lagged value (i.e., autoregressive form) and lagged regressor (i.e., distributed-lag). In this regard, it thus takes a form of the autoregressive and distributed-lag model (ARDL). Besides, according to (Pesaran & Shin, 1999) modeling the ARDL with the appropriate lags will correct for both serial correlation and endogeneity problems. In general, the ARDL (p, q) model is expressed as follows:

$$Y_t = \alpha + \sum_{i=1}^{p} \beta_i Y_{t-i} + \sum_{i=0}^{q} \beta_i X_{t-i} + \varepsilon_t \tag{8}$$

To illustrate particular features of the ARDL model, we take the simplest ARDL model for the example. Suppose we have ARDL (1,1) with $IID(0, \sigma_\varepsilon)$ and no time trend as follows:

$$Y_t = \alpha + \rho Y_{t-1} + \beta_0 X_t + \beta_1 X_{t-1} + \varepsilon_t \tag{9}$$

Alternatively, by assuming that $|\rho| < 1$, equation (9) can be re-expressed in the long-run equilibrium formation. Under static long-run equilibrium, where $Y_t = Y_{t-1} = Y^*$ and $X_t = X_{t-1} = X^*$, and the disturbance is set equal to zero; thus, we could generate as the following equation:

$$Y^* = \frac{\alpha}{1-\rho} + \frac{\beta_0 + \beta_1}{1-\rho} X^* \tag{10}$$

One of the crucial features of the model (11) is the long-run coefficient (or multiplier) expressed by $\frac{(\beta_0+\beta_1)}{1-\rho}$. It explains the long-run consequences of the changes in regressor upon the dependent variables in which calculated as the sum of β. We then proceed to obtain the short-run formation of equation (9) by replacing Y_t with $Y_{t-1} + \Delta Y_t$ and X_t by $X_{t-1} + \Delta X_t$ in equation (10):

$$\Delta Y_t = \alpha + \beta_0 \Delta X_t - (1-\rho) Y_{t-1} + (\beta_0 + \beta_1) X_{t-1} + \varepsilon_t \tag{11}$$

Alternatively, it can be expressed as follows:

$$\Delta Y_t = \alpha + \beta_0 \Delta X_t - (1-\rho)\left[Y_{t-1} - \frac{\alpha}{1-\rho} - \frac{\beta_0+\beta_1}{1-\rho} X_{t-1}\right] + \varepsilon_t \tag{12}$$

The equation above expresses the *error correction model* (ECM). Besides, the term within the bracket represents the deviation of Y_{t-1} from the long-run equilibrium term corresponding to the X_{t-1}. In other words, the ECM analysis gives us an explanation about how fast model equilibrium deviation is adjusted for each period.

Empirically, many works of research specifically employ the ARDL bounds testing approach in which the most straightforward specification is stated as the following equation:

$$\Delta Y_t = \alpha + \sum_{i=1}^{p} \beta_1 \Delta Y_{t-1} + \sum_{i=0}^{p} \beta_2 \Delta X_t + \delta_1 Y_{t-1} + \delta_2 X_{t-1} + \varepsilon_t \quad (13)$$

From equation (48), we can infer that the cointegration does not exist when $\delta_1 = \delta_2 = 0$ while the cointegration exists when $\delta_1 \neq \delta_2 \neq 0$. The test for the cointegration employs F statistics to investigate the existence of long-run equilibrium. We then compared the F statistics with its critical values developed by Pesaran et al. (2001). Null hypothesis (H_0) stands for no cointegration, $\delta_1 = \delta_2 = 0$, while the alternative hypothesis (H_a) states the existence of cointegration, $\delta_1 \neq \delta_2 \neq 0$. Specifically, when the calculated F statistics are higher than the critical values developed by (Pesaran, Shin, & Smith, 2001); hence, the H_a cannot be rejected, and the underlying variables are cointegrated over time.

5.3 Specifying the Model Estimates

5.3.1 First Model Estimate: Macroeconomic Consequences of the FX Futures Market Activities

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

$$X_{it} = \boldsymbol{\tau} x_{it} + \varepsilon_{it} \quad (14)$$

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), but three more variables as the representation of the FX futures market activity: Open interest (OP) as the representation of hedgers activity, trade volume (TV) for representing of speculators activity, and the FX futures contract price (F). The matrix of lagged endogenous variables, $x_{it} = (X'_{it-1}, X'_{it-2}, \dots, X'_{it-p})'$, while $\boldsymbol{\tau}$ and ε_{it} are a matrix of coefficients associated with x_{it} and a vector of shocks. We use six lags, $p = 6$, in our model.

In estimating Impulse-response Function (IRF), we utilize the Choleski ordering in which the variables are ordered from the least endogenous to the most endogenous. We thus order the variables based on our transmission hypothesis as follows, $X_{it} = \{OP_{it}, TV_{it}, F_{it}, S_{it}, SI_{it}, M_{it}, r_{it}^d, y_{it}, CPI_{it}\}$.

5.3.2 Second Model Estimate: The Futures-based FX Interventions on Exchange Rate Dynamics and Pass-through Effect

For the second objective, we aim to study the experience from Brazil and India in utilizing the FX futures market as one of the FX intervention toolkits to stabilize the exchange rate and reduce the exchange rate pass-through effect (ERPT). Besides, to comprehensively compare the effectiveness, we thus normalize the variables using $\breve{x}_i = \left(\frac{x_i - \bar{x}}{\sigma_i}\right)$.

First, we adopt a generic exchange rate determination model by Richard (2016) in a simple form of autoregressive distributed lag (ARDL). Since there is a bidirectional relationship between FX interventions and exchange rates (Nedeljkovic & Saborowski, 2019), the ARDL model with the appropriate lags could correct both serial correlation and endogeneity problems (Pesaran & Shin, 1999). We thus specify the model estimate as follows:

$$\begin{aligned}\Delta(\log S_t) = \alpha + \sum_{i=1}^{p} \beta_i \Delta(\log S_{t-i}) + \sum_{i=0}^{q} \partial_i \Delta(\log F_{t-i}) + \sum_{i=0}^{v} \gamma_i SI_{t-i} \\ + \sum_{i=0}^{b} \delta_i FI_{t-i} + \boldsymbol{X'\theta} + \varepsilon_t\end{aligned} \tag{15}$$

Where $\Delta(\log S_t), \Delta(\log F_t), SI_t, FI_t$, and $\boldsymbol{X}$ are the spot exchange rate returns, log-differenced of FX futures rate, central bank direct FX intervention via spot market, FX intervention through derivatives market (i.e., futures market), and vector of control variables, respectively. While β_i, ∂_i, γ_i, and δ_i are parameters associated with lagged $\log(\Delta S_t)$, $\log(\Delta F_t), SI_t, FI_t$. The control variables for exchange rate movements follow a generic specification that comprises domestic inflation rate, domestic economic growth, domestic interest rate, trade balance, Fed Fund Rate (FFR), and US economic growth. The length of the lag, p, q, v, and b determined by the Schwartz Criterion (SC).

In addition to the estimation in equation (15), we also address the role of futures-based FX intervention in determining the Brazilian and Indian exchange rate volatility. To accommodate the objective, we conduct the Generalized Autoregressive Condition Heteroskedasticity (GARCH) estimation to calculate the exchange rate volatility. Firstly, we perform Autoregressive Moving Average (ARMA) model and investigate the presence of heteroskedasticity and autocorrelation problems. In this case, we use ARMA (4,4) for Brazil's case estimation and ARMA (3,3) for the case of India since it produces smaller AIC and SIC compared to shorter ARMA orders. Second, we employ GARCH (1,1) to estimate the volatility. The GARCH (1,1) is frequently employed in voluminous works of research to estimate the exchange rate volatility (e.g., Floros & Salvador, 2016; Kohlscheen & Andrade, 2014; Kumar, 2015).

Second, we also specify the standard ERPT model specification using the generic model approach (e.g., Jaffri, 2010; Xu et al., 2019). However, we extend the model by including the interaction term of both spot FX intervention and futures-based FX intervention to analyze the effect of each intervention on the pass-through effect. The empirical model is expressed as the following equation:

$$\ln \tau_t = \varphi + \sum_{i=0}^{p} \omega_i \ln \tau_{t-i} + \sum_{i=0}^{q} \ell_i \ln S_{t-i} + \sum_{i=0}^{v} \varsigma_i (\ln S_{t-i} \times SI_{t-i}) + \sum_{i=0}^{b} \psi_i (\ln S_{t-i} \times FI_{t-i}) + \mu_t \tag{16}$$

Where τ_t, ς_i, and ψ_i respectively denote the import price index, the interaction term coefficient of FX intervention, and the interaction term coefficient of futures-based FX intervention. To illustrate how interaction terms determine the pass-through effect, we transform equation (17) into the long-run equation as follows:

$$\ln \tau_t = \ell \ln S_t + \varsigma(\ln S_t \times SI_t) + \psi(\ln S_{t-i} \times FI_{t-i}) + \mathcal{E}_t \tag{17}$$

By simplifying equation (17), we then obtain the equation as follows:

$$\ln \tau_t = (\ell + \varsigma SI_t + \psi FI_t) \ln S_t + \mathcal{E}_t \tag{18}$$

Where $(\ell + \varsigma SI_t + \psi FI_t) = \lambda$. In this equation, λ denotes the ERPT coefficient in which defines as the percentage change in domestic import prices resulting from changes in the exchange rate (Jaffri, 2010). However, the value of λ is also determined by ς and ψ in which implies that the FX intervention and futures-based FX intervention would affect the impact of changes in exchange rate on imported inflation.

5.4 Robustness Tests

5.4.1 Robustness Tests For First Model Estimate

For the robustness checks, we conduct 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 is performs well in estimating Panel VAR. Lastly, we substitute exchange rate returns with exchange rate volatility, which is estimated using Bayesian PVAR.[15]

5.4.2 Robustness Tests For Second Model Estimate

For the second model, we estimate not only the one model specification but also the five-best ARDL specification based on the Schwartz Information Criterion (SC). This is essential to gauge whether our results are consistent for the various lag specifications. We also estimate the long-run model using two alternative approaches: Fully Modified OLS (FM-OLS) and Dynamic OLS (D-OLS). These two estimators are frequently utilized in estimating long-run models. The FM-OLS is designed to provide the optimal estimates of cointegrating regressions, taking into account the serial correlation effects and the endogeneity in the regressors resulting from the existence of a cointegrating relationship (Phillips, 1995). Meanwhile, the D-OLS is robustly superior for small samples, as well as being able to account for possible simultaneity within the regressors (Masih & Masih, 1996).

[15] See Appendix E for the estimations of exchange rate volatility.

5.5 Empirical Hypotheses

In this section, we present our empirical conjecture as to the following table (5) below:

Table 5
Empirical Hypotheses

Panel A First Model Estimate

The variables in Panel A is defined as follows: FX intervention (SI), money aggregate (M), domestic interest rates (r^d), economic growth (y), exchange rates (S), inflation rates (π), Open interest (OP), trade volume (TV), and the FX futures contract price (F).

		Response of:								
		OP	TV	F	S	SI	M	R	π	y
Shocks from:	OP		−	+	+	−	+	+/−	+	−
	TV	+		−	−	+	−	−/+	−	+
	F	−	+	+	+	−	+	+/−	−	−

Panel B Second Model Estimate

Hypothesis	Explanation
H_1: $\frac{\partial S}{\partial SI} > 0$	**Spot FX intervention (SI) has a positive impact on spot FX rate (S)** Spot FX intervention (sell) appreciates the spot FX rate, *vice versa* (e.g., Kim 2003; Nedeljkovic and Saborowski 2017).
H_2: $\frac{\partial S}{\partial FI} > 0$	**Futures-based FX intervention (FI) has a positive impact on spot FX rate (S)** Participating in the futures market by providing liquidity via increasing order book depth, DI can effectively reduce the volatility of the futures market, hence allowing volumes to recover to normal levels. This action will cause the spot volatility to subside (Nedeljkovic and Saborowski 2017; Biswal and Jain 2019).
H_3: $\frac{\partial ERPT}{\partial DI} > 0$	**Futures-based FX intervention (FI) has a negative impact on exchange rate pass-through (ERPT)** The futures-based FX intervention also aims to ensure the smooth functioning of the FX market, as well as to ensure that there is a proper supply of hedging instruments in the market (Kohlscheen & Andrade, 2014); therefore, in turn, lowers the pass-through effect. In this regard, the central bank has an important role as the hedger of the last resort. For instance, Gonzalez, Khametshin, Peydró, & Polo (2019) found that futures-based FX intervention significantly reduced the negative effect of the Global Financial Crisis (GFC) and Taper tantrum on the balance sheet of highly external resilience banks; therefore, reducing firm-level unemployment in Brazil.

For the estimation of the first model, our hypothesis is dependent on how the shocks from FX futures market activities impact exchange rate movement and in turn, how the exchange rate movements impact other macroeconomic indicators such as the inflation rate and economic growth (see Table 7 Panel A). In the case of the FX futures rate, its depreciation would be corresponded by a depreciation in the spot exchange rate via the covered interest rate parity mechanism. The depreciated spot exchange rate would then be transmitted via the pass-through mechanism, resulting in a rise in foreign currency burden which would drive up import prices and subsequently impact inflation and economic growth (Menkhoff, 2013). Trade volume shocks, which are reflective of speculative motives, could be corresponded by the increase in hedging activities when open interest and trade volumes are hedged against the expectation of future spot FX movements, providing liquidity to the futures market. This induces risk transfer and leads to a stronger and more stable spot exchange rate (Grossman & Miller, 1988). This could in turn be translated into a lower inflation rate and higher economic growth due to a smaller exchange rate risk. However, the FX futures market is also inherently associated with risks, e.g., squeezing mechanism or market manipulation, where the 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 the increasing of open interest in the opposite way. Consequently, it could lead to a higher cost of hedging and exchange rate risk that would be transmitted to inflation and economic growth.

6 Results and Discussion

6.1 Macroeconomic Consequences of the FX Futures Market

6.1.1 Pre-estimation Tests

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 6). Also, all of our unit root tests are consistent across the different methods used, indicating that our variables are robustly stationary.

Table 6
Unit Root Test (Level)

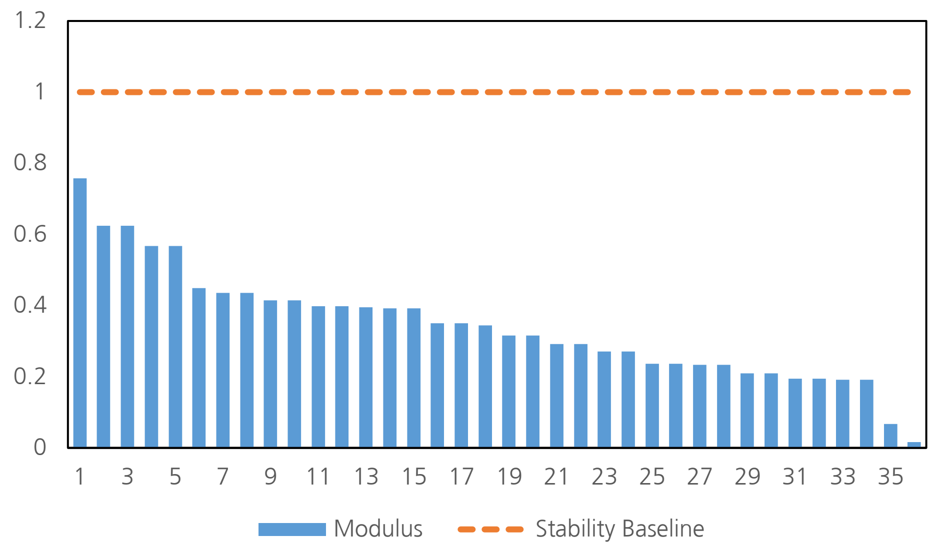
Notes: Automatic lag length selection based on Schwartz Information Criteria. The null hypothesis stands for the existence of unit root.

		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	

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 11. As depicted, the roots of the characteristic polynomial (modulus) lie below one, confirming the validity of the Panel VAR estimation.

Figure 8
Roots of the Characteristic Polynomial (Modulus)

Notes: Figure 8 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.



6.1.2 Estimation Results

Our empirical results for the IRF and Variance Decompositions analysis are displayed in Figure 9 and 10, respectively.

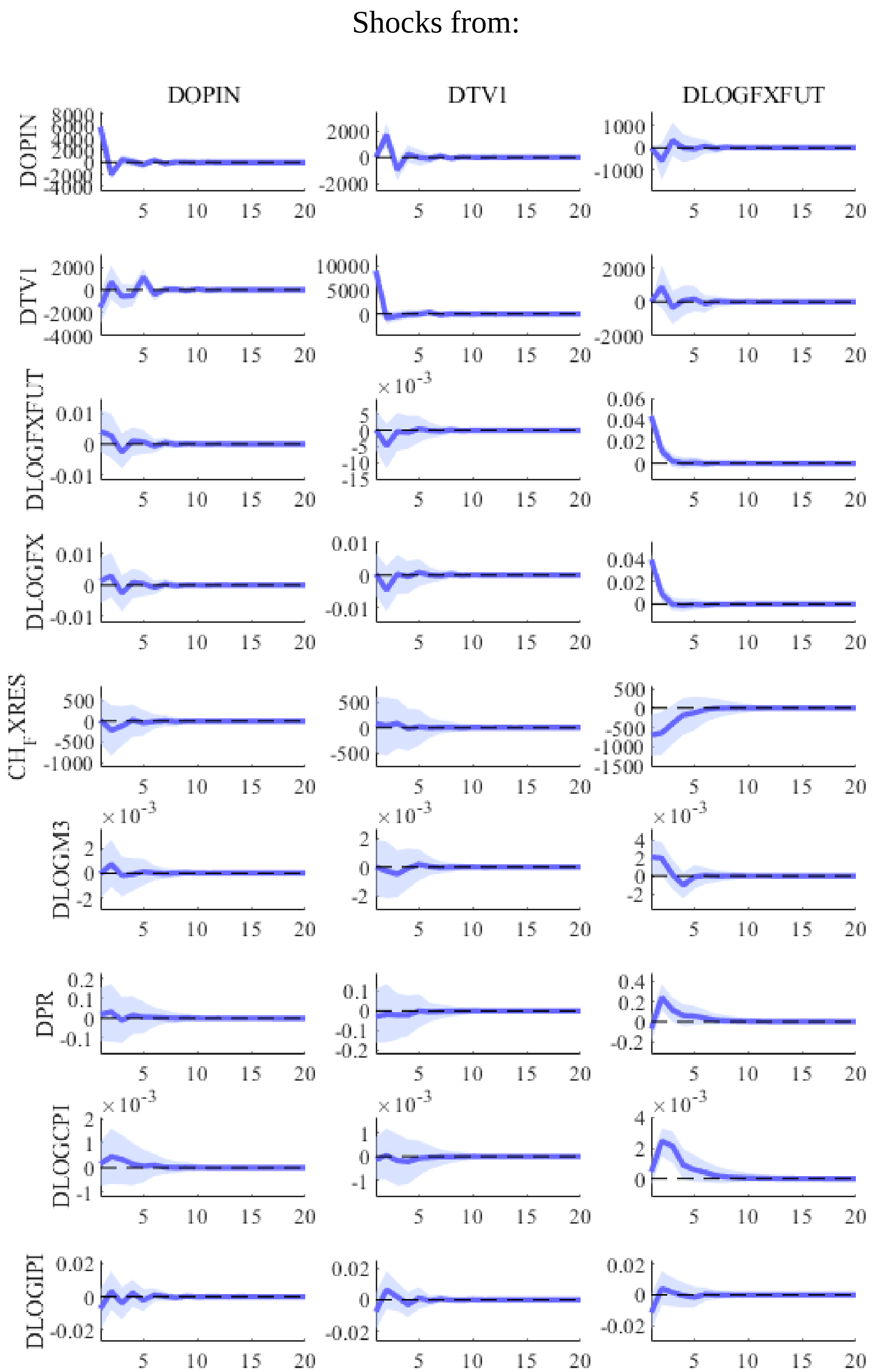
We first scrutinize the impact of the trade volume shock. We observe that the open interest increased significantly in the second period in response to trade volume shocks. This suggests that increasing the volume of trade in the FX futures market would induce activities of the hedgers. The growing transactions 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 (e.g., 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 9
Impulse Response Function (IRF)

Notes: Figure 9 portrays the Impulse Response Function (IRF). The horizontal axis denotes the period. 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 $OP_{it}, TV_{it}, F_{it}, S_{it}, SI_{it}, M_{it}, r_{it}^{d}, CPI_{it}, y_{it}$



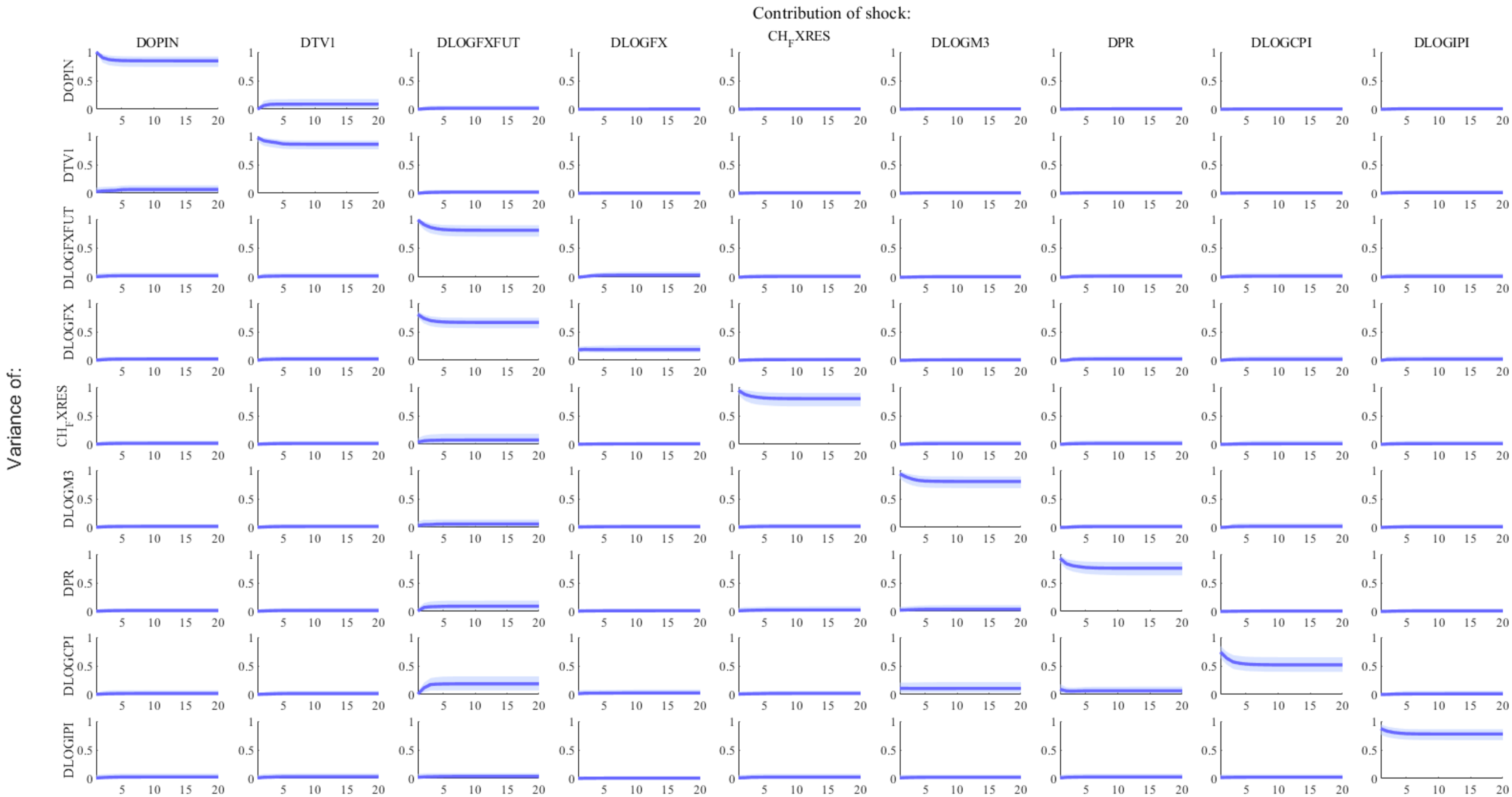
We find that FX futures rate shocks could be sterilized promptly. The spot exchange rate depreciated significantly due to FX futures rate shocks. The significant positive response of the spot exchange rate to FX futures shocks confirms the theory of Covered Interest Rate Parity (CIRP), which is the actualization 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 (e.g., see M. Garcia et al., 2015). 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 10). 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 (e.g., 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 will focus on several crucial evidences. 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 10
Variance Decomposition

Notes: Figure 10 portrays the Forecast Error Variance Decomposition (FEVD). 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 $OP_{it}, TV_{it}, F_{it}, S_{it}, SI_{it}, M_{it}, r_{it}^{d}, CPI_{it}, y_{it}$



6.1.3 Robustness Checks

For the robustness checks, we conduct four robustness strategies as follows: First, we use an alternative variable ordering to estimate the Panel VAR model. In this case, 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 the Bayesian Pooled PVAR with $p = 4$. Second, we conduct a sensitivity test. In this regard, we perform five different lag structures of the Panel VAR estimation using the Pooled Bayesian PVAR and verify whether the estimated IRFs are consistent. This test is essential since the VAR model is sensitive to the lag structure (Hafer & Sheehan, 1989). Third, we perform an iteration of the primary estimation using a Large BVAR developed by (Banbura et al., 2010). As mentioned by (Canova & Ciccarelli, 2013), Large BVAR is similar to the Panel BVAR. The Performance evaluation by (Feldkircher et al., 2020) also illustrate that large scale BVAR performs well in estimating the Panel VAR. Lastly, we substitute the exchange rate returns with exchange rate volatility, which is estimated using the Bayesian PVAR.[16]

Table 7
Panel Granger Causality

Notes: Table 7 portrays the Panel Granger causality test. We utilize the stacked tests (common coefficients) in 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**	

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 7). 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 *DLOGFX* are only explained by the changes of 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 the *DPR*; and (vii) *DLOGM3* is significantly Granger-caused by *DLOGFXFUT*,

[16] See Appendix E for the estimations of exchange rate volatility.

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 A).

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 B). 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 C). 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 D). 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 second robustness test is consistent with our primary results.

6.2 The Futures-based FX Interventions on Exchange Rate Dynamics and ERPT: The Case of Brazil and India

6.2.1 The Futures-based FX Intervention and Exchange Rate Dynamics

6.2.1.1 Pre-estimation Tests

In this section, we perform several crucial pre-estimation tests for the empirical model analyzing the role of futures-based FX intervention on exchange rate dynamics. The tests comprise unit root tests, ARDL bound test, and classical assumptions. For the unit root tests, we employ the Augmented Dickey-Fuller (ADF) test for three different unit root specifications, which include the test with constant, constant and trend, and without constant and trend. For the ARDL bound test, we perform the F-Wald test, which is compared to the tables of Pesaran et al. (2001). The test suggests that the empirical model is not cointegrated if the null hypothesis cannot be rejected. For the last pre-estimation tests, we employ four fundamental classical assumption tests as follows: Normality test assumption, $\mu_i \sim N(0)$, using Jarque-Berra; the absence of heteroscedasticity, $var(\varepsilon_i) = \sigma^2$, estimated using Breusch-Pagan-Godfrey; no autocorrelation, $cov(\varepsilon_t, \varepsilon_k | X_t, X_k) = 0; t \neq k$; and Ramsey Regression Equation Specification Error Test (RESET) (see Gujarati and Porter 2009). Also, when the classical assumption is violated, mainly when the model suffers from heteroscedasticity and autocorrelation problems, the Heteroscedasticity Autocorrelation Condition (HAC) is used to adjust for the standard error to avoid a biased interpretation.

Table (8) exhibits the results of unit root tests for Brazil and India. For Brazil, we generally find that most of the variables are stationary at different levels (see Table 10, Panel A). Specifically, we find that the policy rate, FX intervention, and futures-based FX intervention are consistently stationary at the level. For the rest of the variables, we observe that these variables are stationary at the first difference. For India, we find that FX intervention and futures-based FX intervention are significantly stationary at the level. Other variables such as the exchange rate, FX futures rate, industrial production *(log)*, consumer price *(log)*, and net export, are significantly stationary at the first-difference. Lastly, a set of external economic variables, i.e., Fed Fund Rate (FFR) and US industrial production *(log)* are stationary at the first-difference. Generally speaking, our unit root tests suggest that each variable is stationary at different levels for Brazil, India, as well as the external factors. Therefore, the empirical models estimating the role of futures-based FX intervention on exchange rate dynamics may perhaps cointegrate in the long-run (e.g., see Gujarati & Porter, 2009).

Table 8
Augmented Dickey-Fuller (ADF) Unit Root Test

Panel A Brazil

Variables	Level									First Difference								
	With Constant			With Constant & Trend			Without Constant & Trend			With Constant			With Constant & Trend			Without Constant & Trend		
	t-Statistic	Prob.		t-Statistic	Prob.		t-Statistic	Prob.		t-Statistic	Prob.		t-Statistic	Prob.		t-Statistic	Prob.	
Exchange Rate	-0.9656	0.7623	-	-2.1364	0.5182	-	-0.9767	0.2918	-	-6.7230	0.0000	***	-6.6811	0.0000	***	-6.5241	0.0000	***
FX Futures Rate	-0.8844	0.7889	-	-2.0134	0.5857	-	-0.9030	0.3223	-	-9.9323	0.0000	***	-9.8728	0.0000	***	-9.6761	0.0000	***
Foreign Exchange Intervention	-8.5717	0.0000	***	-8.6056	0.0000	***	-8.6221	0.0000	***	-11.2812	0.0001	***	-11.2110	0.0000	***	-11.3475	0.0000	***
Futures-based Intervention	-6.3187	0.0000	***	-6.3341	0.0000	***	-6.3558	0.0000	***	-10.2976	0.0000	***	-10.2345	0.0000	***	-10.3602	0.0000	***
Policy Rate	-3.0633	0.0333	**	-3.0058	0.1369	-	-3.0751	0.0025	***	-1.5822	0.4872	-	-1.6681	0.7567	-	-1.6313	0.0967	*
Industrial Production, Log	-0.8253	0.8066	-	-1.6326	0.7718	-	-0.8397	0.3493	-	-10.9740	0.0001	***	-10.9069	0.0000	***	-10.8822	0.0000	***
Consumer Price, Log	-1.4438	0.5571	-	-0.2462	0.9910	-	-0.9605	0.2984	-	-4.8456	0.0001	***	-5.0631	0.0004	***	-1.2911	0.1801	-
Net Export	-1.2623	0.6438	-	-4.7040	0.0014	***	-1.2848	0.1820	-	-10.4352	0.0000	***	-10.4106	0.0000	***	-10.4692	0.0000	***
Fed Fund Rate	3.1864	1.0000	-	1.7404	1.0000	-	1.3317	0.9531	-	-2.4581	0.1294	-	-4.3168	0.0048	***	-1.8473	0.0619	*
US Industrial Production, Log	-0.4139	0.9012	-	-0.9996	0.9382	-	-0.4727	0.5081	-	-8.5501	0.0000	***	-8.5301	0.0000	***	-8.0435	0.0000	***

Panel B India

Variables	Level									First Difference								
	With Constant			With Constant & Trend			Without Constant & Trend			With Constant			With Constant & Trend			Without Constant & Trend		
	t-Statistic	Prob.		t-Statistic	Prob.		t-Statistic	Prob.		t-Statistic	Prob.		t-Statistic	Prob.		t-Statistic	Prob.	
Exchange Rate	-1.7698	0.3908	-	-2.057	0.556	-	-1.8232	0.0653	*	-5.2412	0.0001	***	-5.1773	0.0005	***	-5.1061	0.0000	***
FX Futures Rate	-1.8462	0.3545	-	-2.090	0.539	-	-1.8759	0.0584	*	-7.1169	0.0000	***	-7.0411	0.0000	***	-7.0725	0.0000	***
Foreign Exchange Intervention	-4.8291	0.0002	***	-5.062	0.001	***	-4.8795	0.0000	***	-11.2434	0.0000	***	-11.1235	0.0000	***	-11.3618	0.0000	***
Futures-based Intervention	-8.0896	0.0000	***	-8.026	0.000	***	-8.1771	0.0000	***	-7.8761	0.0000	***	-7.8211	0.0000	***	-7.9605	0.0000	***
Policy Rate	-2.6425	0.0914	*	-0.722	0.966	-	-2.5963	0.0104	**	-7.5766	0.0000	***	-9.1271	0.0000	***	-7.2076	0.0000	***
Industrial Production, Log	-0.4746	0.8871	-	-7.127	0.000	***	-0.9405	0.3045	-	-8.3782	0.0000	***	-8.2823	0.0000	***	-12.1510	0.0000	***
Consumer Price, Log	-0.6829	0.8415	-	-2.139	0.512	-	-0.7615	0.3813	-	-6.0957	0.0000	***	-6.0462	0.0000	***	-4.5699	0.0000	***
Net Export	-2.1303	0.2341	-	-3.232	0.090	*	-2.1544	0.0313	**	-8.1280	0.0000	***	-8.1873	0.0000	***	-8.2222	0.0000	***
Fed Fund Rate	2.1103	0.9999	-	-0.788	0.960	-	0.1953	0.7386	-	-2.4171	0.1426	-	-9.1127	0.0000	***	-1.2487	0.1918	-
US Industrial Production, Log	0.7762	0.9927	-	-1.031	0.930	-	0.7212	0.8676	-	-5.9817	0.0000	***	-7.6789	0.0000	***	-5.9662	0.0000	***

Notes: Panel A and B exhibits the stationary tests for Brazil and India, respectively. The null hypothesis stands for the absence of unit root. The asterisk denotes statistical significance *, **, and *** at 10 percent, 5 percent, and 1 percent, respectively.

Table 9
Best Ten ARDL Specification and Bound Test

Panel A Brazil

No	ARDL Model	SC	Log-likelihood	F Wald test	Prob.
1	ARDL (1,1,1,1,1,1,1,1,1,1)	-0.5931	72.27474	2.881644	0.0049
2	ARDL (1,1,1,1,1,1,1,1,1,2)	-0.5691	73.05797	3.07721	0.0030
3	ARDL (1,1,1,1,2,1,1,1,1,1)	-0.5529	72.37022	2.968815	0.0040
4	ARDL (1,1,1,2,1,1,1,1,1,1)	-0.5487	72.19148	3.002017	0.0037
5	ARDL (1,1,1,2,1,1,1,1,1,2)	-0.5422	74.13763	3.214488	0.0022
6	ARDL (1,2,1,1,1,1,1,1,1,1)	-0.5407	71.85089	2.594056	0.0106
7	ARDL (1,1,1,1,2,1,1,1,1,2)	-0.5383	73.96852	3.156396	0.0025
8	ARDL (2,1,1,1,1,1,1,1,1,1)	-0.5321	71.48701	2.861392	0.0053
9	ARDL (1,1,1,1,1,1,2,1,1,1)	-0.5315	71.45775	2.818667	0.0059
10	ARDL (1,1,1,1,1,1,1,1,1,3)	-0.5314	73.27522	3.309091	0.0018

Panel B India

No	ARDL Model	SC	Log-likelihood	F Wald test	Prob.
1	ARDL (1,2,2,3,1,3,3,3,3,3)	1.12205	41.00941	3.373922	0.025
2	ARDL (1,2,2,3,1,3,1,3,2,3)	1.125124	35.16196	3.376046	0.0168
3	ARDL (2,1,2,3,1,3,1,3,2,3)	1.126129	35.13834	3.769811	0.0104
4	ARDL (1,2,2,3,1,3,3,3,2,3)	1.126741	38.9741	3.550693	0.0178
5	ARDL (2,1,3,3,1,3,1,3,3,3)	1.129486	38.90958	3.722957	0.0148
6	ARDL (1,2,2,2,1,3,3,3,2,3)	1.137797	36.78921	3.933995	0.0101
7	ARDL (2,1,2,3,1,3,1,3,3,3)	1.141735	36.69667	3.540433	0.0157
8	ARDL (2,1,2,3,1,3,3,3,2,3)	1.144848	38.54857	3.892744	0.0124
9	ARDL (2,1,2,3,1,3,3,3,3,3)	1.149247	40.37027	3.617784	0.0194
10	ARDL (2,1,3,3,1,3,3,3,3,3)	1.153981	42.18411	3.639889	0.0224

Notes: Panel A and B exhibits the best ten ARDL specifications and bound test for Brazil and India, respectively. F Wald test is compared to the tables of Pesaran et al. (2001). The null hypothesis stands for the absence of cointegration. Variables ordering: Exchange Rate, FX Futures Rate, Foreign Exchange Intervention, Futures-based Intervention, Policy Rate, Industrial Production (Log), Consumer Price (Log), Net Export, Fed Fund Rate, and US Industrial Production (Log).

We next analyze the ARDL bound tests presented in Table (9). For this, we employ ten ARDL specifications based on the Schwartz Criterion (SC). For the model estimate of the Brazilian case, we find that all specifications produce statistically significant F-Wald tests, which suggest that these specifications are significantly cointegrated. For the empirical model estimating the case of India, we also find that the entire ARDL specifications are significantly cointegrated at five percent confidence level. Based on these tests, the implication is that we should include not only a long-run estimation but also a short-run estimation analyzing the error correction mechanism in Brazil and India.

Table 10
Classical Assumptions

Panel A Brazil

	1	2	3	4	5
Jarque-Bera Test	6.1296**	6.1895**	5.1924*	0.4189	0.6391

Breusch-Pagan-Godfrey Test (F-Stat)	1.4182	1.3611	1.3009	2.3236***	2.2468***
Durbin-Watson Stat	1.9630	1.9557	1.9767	1.8923	1.8890

Panel B India

	1	2	3	4	5
Jarque-Bera Test	1.6360	2.1107	1.6630	1.9229	1.8708
Breusch-Pagan-Godfrey Test (F-Stat)	0.8625	1.0993	1.6139	1.0402	0.8639
Durbin-Watson Stat	1.5926	1.5387	1.7430	1.5896	1.8087

Notes: Panel A and B exhibit the results of classical assumptions for Brazil and India, respectively. The asterisk denotes statistical significance *, **, and *** at 10 percent, 5 percent, and 1 percent, respectively.

Lastly, we perform three tests to examine whether the model estimates contain the violation of the classical assumptions. For this, we investigate the classical assumption tests for the five-best ARDL specifications. For Brazil, we find that the first three specifications are not normally distributed, while the last two specifications suffer significantly from heteroskedastic problems. However, all of the five-best specifications are free from autocorrelation. Furthermore, the classical assumption tests for India indicate that all of the five-best specifications are normally distributed with a homoscedastic error. Based on these tests of classical assumptions violation, we perform the HAC robust standard error for all the regressions of India since they contain autocorrelation problems, and for the last two model specifications for Brazil since they contain heteroskedastic error distribution.

6.2.1.2 Estimation Results

Our main empirical results are displayed in Table (11) and (12), which portray both long-run and short-run estimations analyzing the role of futures-based FX intervention on exchange rate dynamics in Brazil and India.

For the long-run effect of futures-based FX intervention on exchange rate dynamics in Brazil (see Table 11, Panel A), our estimations consistently indicate that traditional futures-based FX intervention (net purchase) causes the Brazilian Real to appreciate, although it is only statistically significant in the column (4) and (5) estimations. This finding is consistent with several strands of research analyzing the role of futures-based FX intervention in Brazil. (Nedeljkovic & Saborowski, 2019) found that the CBB FX intervention of every US$1 billion in the FX futures market appreciates the real/dollar exchange rate by about 0.7 percent. (Kohlscheen & Andrade, 2014; Oliveira, 2020) illustrated that to the extent that an intervention in the supply of SCC derivatives alters the supply of hedging instruments that are available in the market; such intervention will affect the relative demand for US dollars in the market and subsequently, the prevailing USD/BRL exchange rate.

For the case of India, we find no evidence of a long-run effect of futures-based FX intervention on exchange rate dynamics, although the estimations consistently generate negative coefficients. In this instance, we conjecture that several factors account for the difference in effectiveness of futures-based FX intervention between India and Brazil. The FX derivatives market structure in India is dominated by the OTC market, while the FX futures market comprise only 4 percent of the total daily average derivatives turnover. Moreover, the Indian OTC FX markets have already become the main mechanisms for the economic agents to manage their risks, starting from the time of India's financial reforms to a fully convertible currency in 1994 (Shyamala Gopinath, 2010). (Shyamala Gopinath, 2010) also postulates that the FX futures market is also unlikely to replicate the discipline of ensuring underlying commercial transactions and fulfill the genuine hedging requirements of the participants, possible only currently in the OTC market. Given the structure of the Indian FX derivatives market, FX operations by the central bank in FX futures are mostly neutral in terms of the gross purchases in the FX futures market. These typically offset the gross sell, and are intended merely to ensure that the market is functioning smoothly (Tripathy, 2013).

Table 11
Long-run Estimations

	Panel A: Brazil				
	1	2	3	4	5
FX Futures Rate	0.980464*** (0.020725)	0.983947*** (0.021339)	0.984568*** (0.022237)	1.001813*** [0.019171]	1.002998*** [0.018905]
Foreign Exchange Intervention	0.0029 (0.010546)	0.003071 (0.01071)	0.002153 (0.011216)	0.009235 [0.008507]	0.008877 [0.008299]
Futures-based Intervention	-0.010051 (0.009494)	-0.011113 (0.00967)	-0.010389 (0.00973)	-0.031957** [0.012421]	-0.03242*** [0.012205]
Policy Rate	0.014818 (0.015845)	0.012977 (0.016948)	0.013922 (0.017592)	0.013169 [0.013163]	0.013796 [0.013853]
Industrial Production, *Log*	0.002731 (0.026536)	0.005383 (0.02721)	0.005312 (0.028199)	0.031513 [0.026835]	0.033628 [0.027679]
Consumer Price, *Log*	0.033983 (0.029584)	0.038402 (0.030188)	0.03500 (0.030302)	0.041397 [0.030833]	0.043718 [0.032014]
Net Export	-0.025068 (0.015285)	-0.026373* (0.015495)	-0.02696* (0.016078)	-0.031013** [0.012532]	-0.031753** [0.012703]
Fed Fund Rate	0.028581 (0.023946)	0.025233 (0.025421)	0.025352 (0.025785)	0.033098* [0.018054]	0.033371* [0.018698]
US Industrial Production, *Log*	-0.020559 (0.016426)	-0.022381 (0.017068)	-0.019098 (0.016955)	-0.022418 [0.013813]	-0.024385* [0.014553]
	Panel B: India				
	1	2	3	4	5
FX Futures Rate	1.014112*** [0.087640]	0.987549*** [0.056016]	0.960179*** [0.065635]	1.003212*** [0.07289]	0.972976*** [0.07556]
Foreign Exchange Intervention	-0.012773 [0.035681]	-0.01677 [0.029029]	-0.035598 [0.036905]	-0.012246 [0.034735]	-0.017589 [0.041587]
Futures-based Intervention	-0.027513 [0.132959]	-0.062291 [0.122035]	0.028247 [0.178115]	-0.061026 [0.140413]	0.04828 [0.171291]
Policy Rate	-0.039465 [0.133462]	-0.010294 [0.08858]	0.017354 [0.11557]	-0.033081 [0.119013]	0.038538 [0.116939]
Industrial Production, *Log*	-0.35332*** [0.117652]	-0.45919*** [0.06869]	-0.47075*** [0.106314]	-0.43235*** [0.076134]	-0.389462** [0.139682]
Consumer Price, *Log*	0.166832 [0.294691]	0.367696*** [0.122431]	0.361987** [0.157508]	0.299269 [0.187873]	0.297731 [0.187863]
Net Export	0.100616 [0.062928]	0.135205** [0.052406]	0.150235* [0.074629]	0.135757** [0.059402]	0.091212 [0.091781]

Panel A: Brazil					
	1	2	3	4	5
Fed Fund Rate	0.288054* [0.150370]	0.18048 [0.11358]	0.290499** [0.128261]	0.198581 [0.120126]	0.314339** [0.140218]
US Industrial Production, *Log*	0.011484 [0.110241]	0.072658 [0.097961]	0.016437 [0.137699]	0.075951 [0.110948]	-0.052393 [0.138092]

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

For the rest of the variables, the long-run effect estimations find the following results: First, the FX futures rate is positively and statistically significant in determining the exchange rate movements in the long-run, either in Brazil or India. For Brazil, (M. Garcia et al., 2015) have revealed that the FX futures market profoundly influences the price discovery in the Brazilian spot FX market. It is also consistently aligned with the Covered Interest Rate Parity (CIRP) theory, which is the actualization of the law of one price between two countries' interest rates adjusted to the FX hedge value. For the domestic factors, our estimations find that the Indian exchange rate is significantly affected by domestic economic growth, the inflation rate, and net export, while the Brazilian exchange rate is dominantly driven by net export. Furthermore, we find that external factors have no long-run effect on the Real's exchange rate, while the FFR significantly influences the Indian Rupee in the long-run. These findings are reasonable since both countries have different institutional settings on currency convertibility restrictions. In Brazil, the *Plano Real* (1994) led to the restricted direct access to the spot market and lower internal convertibility. Only a few agents could directly access the spot market, and the BRL is strictly domestic inconvertible, thus limiting excessive jumps in the exchange rate market (Upper & Valli, 2016). Meanwhile, the Indian Rupee INR became fully convertible with India's financial reforms (Shyamala Gopinath, 2010).

Table 12
Short-run Estimations

Panel A Brazil

	1	2	3	4	5
Δ FX Futures Rate	0.545117*** (0.027932)	0.548805*** (0.028406)	0.547651*** (0.028462)	0.590163*** [0.026598]	0.590946*** [0.026779]
Δ Foreign Exchange Intervention	0.003361 (0.00438)	0.003451 (0.004456)	0.003146 (0.004528)	0.006495 [0.004009]	0.006552 [0.004035]
Δ Futures-based Intervention	-0.014081** (0.005466)	-0.014804*** (0.005541)	-0.013914** (0.005553)	-0.013605** [0.005497]	-0.013882** [0.005525]
Δ Futures-based Intervention (Lagged)				0.028455*** [0.005272]	0.028176*** [0.005326]
Δ Policy Rate	0.032996 (0.043149)	0.028517 (0.043873)	0.032667 (0.0503)	0.010098 [0.039436]	0.008394 [0.039844]
Δ Policy Rate (Lagged)			-0.030637 (0.048537)		
Δ Industrial Production, Log	0.009063 (0.01333)	0.011745 (0.013459)	0.009971 (0.013827)	0.020388 [0.012491]	0.021971* [0.012573]
Δ Consumer Price, Log	0.389639*** (0.138512)	0.462421*** (0.140046)	0.372541*** (0.14027)	0.397639*** [0.126195]	0.454850*** [0.126930]

	1	2	3	4	5
Δ Net Export	-0.013824 (0.008669)	-0.014604* (0.008729)	-0.014762* (0.008763)	-0.010687 [0.008003]	-0.011241 [0.008037]
Δ Fed Fund Rate	0.022058 (0.047823)	0.022822 (0.048177)	0.023305 (0.048282)	-0.008960 [0.044012]	-0.005501 [0.044186]
Δ US Industrial Production, Log	0.044195 (0.032975)	0.042229 (0.033725)	0.044993 (0.033651)	0.040861 [0.030260]	0.040641 [0.030556]
Δ US Industrial Production (Lagged), Log		0.031002 (0.031801)			0.021255 [0.029018]
ECM_{t-1}	-1.050313*** (0.05582)	-1.050338*** (0.056868)	-1.03958*** (0.056465)	-1.000247*** [0.052416]	-1.004127*** [0.052986]
R-squared	0.903922	0.905057	0.904529	0.922788	0.923180
Adjusted R-squared	0.892692	0.892398	0.891799	0.912493	0.911761

Panel B India

	1	2	3	4	5
Δ Exchange Rate (Lagged)			-0.046627 [0.054149]		-0.040393 [0.056442]
Δ FX Futures Rate	0.58028*** [0.037796]	0.56796*** [0.033546]	0.594233*** [0.035945]	0.572832*** [0.036764]	0.601518*** [0.037596]
Δ FX Futures Rate (Lagged)	-0.16834** [0.066512]	-0.18940** [0.06657]		-0.194281** [0.069235]	
Δ Foreign Exchange Intervention	-0.025242 [0.017235]	-0.028046* [0.015124]	-0.021223 [0.015564]	-0.027613 [0.016845]	-0.016752 [0.016484]
Δ Foreign Exchange Intervention (Second Lagged)					-0.015353 [0.014033]
Δ Foreign Exchange Intervention (First Lagged)	-0.033327* [0.016474]	-0.03989** [0.01589]	-0.02247 [0.015191	-0.041345** [0.01666]	-0.029127 [0.017856]
Δ Futures-based Intervention	0.016098 [0.014242]	0.005614 [0.011814]	0.023756* [0.012168]	0.008728 [0.014138]	0.022193 [0.012799]
Δ Futures-based Intervention (Second Lagged)	-0.0077 [0.012288]	-0.01061 [0.011539]	-0.023476* [0.012456]	-0.008646 [0.012187]	-0.020912 [0.012626]
Δ Futures-based Intervention (First Lagged)	0.016107 [0.017128]	0.029297* [0.015798]	-0.010844 [0.017389]	0.032282* [0.017401]	-0.022331 [0.01792]
Δ Policy Rate	-0.3388*** [0.064666]	-0.2926*** [0.058846]	-0.28742*** [0.062791]	-0.31193*** [0.063937]	-0.27103*** [0.064162]
Δ Industrial Production, Log	-0.1461*** [0.039384]	-0.1657*** [0.035855]	-0.17581*** [0.038409]	-0.16076*** [0.038261]	-0.16205*** [0.040535]
Δ Industrial Production, Log (Second Lagged)	-0.027674 [0.044522]	-0.016753 [0.043301]	-0.036102 [0.04437]	-0.018832 [0.044673]	-0.048189 [0.044958]
Δ Industrial Production, Log (First Lagged)	0.077781 [0.056598]	0.153807** [0.05928]	0.068935 [0.050176	0.134772** [0.060404]	0.027464 [0.049633]
Δ Consumer Price, Log	0.170851 [0.140176]	0.44260*** [0.126298]	0.269331* [0.130294	0.387159** [0.144291]	0.224844 [0.135064]
Δ Consumer Price, Log (Second Lagged)	0.152315 [0.121973]			0.094374 [0.121211]	

	1	2	3	4	5
Δ Consumer Price, Log (First Lagged)	0.134414 [0.12017]			0.047714 [0.116616]	
Δ Net Export	-0.017987 [0.023138]	-0.006906 [0.021672]	0.007092 [0.024245]	-0.010155 [0.022342]	-0.007524 [0.02517]
Δ Net Export (Second Lagged)	-0.0747*** [0.024039]	-0.0802*** [0.022851]	-0.059021** [0.021186]	-0.08495*** [0.024381]	-0.042995* [0.021494]
Δ Net Export (First Lagged)	-0.1001*** [0.025012]	-0.1041*** [0.024431]	-0.084*** [0.024]	-0.10876*** [0.025461]	-0.056604** [0.024908]
Δ Fed Fund Rate	0.179173 [0.106803]	0.30855*** [0.091131]	0.36992*** [0.094994	0.290023** [0.10305]	0.256085** [0.098244]
Δ Fed Fund Rate (Second Lagged)	-0.225438* [0.107337]				-0.165325 [0.107864]
Δ Fed Fund Rate (First Lagged)	-0.160697 [0.100659]	-0.023362 [0.095201]	-0.093141 [0.10404]	-0.028916 [0.100066]	-0.208989* {0.10491]
Δ US Industrial Production, Log	-0.027048 0.064426]	0.017946 [0.061298]	-0.031043 [0.065311]	0.019194 [0.064797]	-0.070756 [0.068522]
Δ US Industrial Production, Log (Second Lagged)	0.126986* [0.068781]	0.165312** [0.064401]	0.090731 [0.065744	0.159647** [0.06715]	0.078847 [0.070392]
Δ US Industrial Production, Log (First Lagged)	0.078588 [0.063822]	0.098027 [0.060222]	0.105224 [0.066259]	0.082864 [0.063298]	0.126144* [0.067573]
ECM_{t-1}	-1.0969*** [0.122995]	-1.1140*** [0.12114]	-0.86995*** [0.080461]	-1.10676*** [0.124326]	-0.90109*** [0.085837]
R-squared	0.979578	0.978406	0.975292	0.978737	0.97664
Adjusted R-squared	0.960007	0.96241	0.95699	0.960026	0.956083

Notes: Panel A and B exhibit the short-run estimations for Brazil and India, respectively. The asterisk denotes statistical significance *, **, and *** at 10 percent, 5 percent, and 1 percent, respectively. Numbers in the parentheses ( ), represent the standard error. Numbers in the square brackets [ ], represent the HAC-corrected standard error.

For the short-run estimations, depicted in Table (11), we find that futures-based FX intervention in Brazil significantly affects exchange rate movements in the short-run, where increasing net purchase by the central bank would appreciate the exchange rate and *vice versa*. For India, we find no evidence of the effect of futures-based FX intervention on the Indian Rupee exchange rate. However, our short-run estimations suggest that traditional FX intervention in the previous month significantly drives the current movements of the Indian Rupee exchange rate. Furthermore, we find that both domestic and external factors, such as the policy rate, domestic economic growth, inflation rate, and US economic growth have significant influence on the Indian Rupee exchange rate in the short-run. On the contrary, our estimations show that the Brazilian exchange rate is driven predominantly by the internal factor of the inflation rate in the short run. Moreover, we find that the coefficients of error correction (ECM) are statistically significant at any conventional level, for both Brazil and India. Specifically, our estimations show that the magnitude of ECM for both countries are generally below one, which indicates that a deviation from the equilibrium level of the exchange rate in the current period will be corrected by more than 100 percent. This suggests that every deviation in Indian and Brazilian exchange rate equilibrium will be corrected in a fluctuating manner.

6.2.2 The Futures-based FX Intervention and ERPT

6.2.2.1 Pre-estimation Tests

In this section, we discuss three main pre-estimation tests for the empirical model analyzing the role of futures-based FX intervention on exchange rate pass-through in Brazil and India. First, we perform the Augmented Dickey-Fuller (ADF) test for three different unit root specifications, which include the test with constant, constant and trend, and without constant and trend. Second, we utilize the ARDL bound test by calculating the F-Wald and comparing the results with the tables of Pesaran et al. (2001). The test suggests that the empirical model is not cointegrated if the null hypothesis cannot be rejected. For the last pre-estimation tests, we employ four fundamental classical assumption tests as follows: Normality test assumption, $\mu_i \sim N(0)$, using Jarque-Berra; the absence of heteroscedasticity, $var(\varepsilon_i) = \sigma^2$, estimated using Breusch-Pagan-Godfrey; no autocorrelation, $cov(\varepsilon_t, \varepsilon_k | X_t, X_k) = 0; t \neq k$ (see Gujarati and Porter 2009). In addition, when the classical assumption is violated, mainly when the model suffers from heteroscedasticity and autocorrelation problems, the Heteroscedasticity Autocorrelation Condition (HAC) is used to adjust the standard error to avoid biased interpretation.

Table 13
Augmented Dickey-Fuller (ADF) Unit Root Test

Panel A Brazil

		Import Price, *Log*	Exchange Rate, *Log*	Exchange Rate, *Log* × Foreign Exchange Intervention	Exchange Rate, *Log* × Futures-based Intervention
At Level					
With Constant	t-Statistic	-1.3081	-1.1021	-9.5042	-6.7268
	Prob.	0.6227	0.7119	0.0000	0.0000
		-	-	***	***
With Constant & Trend	t-Statistic	-1.6985	-2.0371	-9.4556	-6.7004
	Prob.	0.7437	0.5727	0.0000	0.0000
		-	-	***	***
Without Constant & Trend	t-Statistic	-1.3099	-1.0864	-9.5604	-6.7663
	Prob.	0.1746	0.2493	0.0000	0.0000
		-	-	***	***
At First Difference					
With Constant	t-Statistic	-6.2397	-6.4197	-8.9802	-10.6759
	Prob.	0.0000	0.0000	0.0000	0.0001
		***	***	***	***
With Constant & Trend	t-Statistic	-6.1853	-6.3868	-8.9240	-10.6106
	Prob.	0.0000	0.0000	0.0000	0.0000
		***	***	***	***
Without Constant & Trend	t-Statistic	-6.2140	-6.1571	-9.0330	-10.7408
	Prob.	0.0000	0.0000	0.0000	0.0000
		***	***	***	***

Panel B India

		Import Price, *Log*	Exchange Rate, *Log*	Exchange Rate, *Log* × Foreign Exchange Intervention	Exchange Rate, *Log* × Futures-based Intervention
At Level					
With Constant	t-Statistic	-2.0515	-1.6224	-4.8478	-8.0846
	Prob.	0.2647	0.4637	0.0002	0.0000
		-	-	***	***
With Constant & Trend	t-Statistic	-3.4698	-1.9673	-5.0812	-8.0241
	Prob.	0.0540	0.6042	0.0007	0.0000
		*	-	***	***
Without Constant & Trend	t-Statistic	-2.0676	-1.6809	-4.8985	-8.1720
	Prob.	0.0382	0.0874	0.0000	0.0000
		**	*	***	***
At First Difference					
With Constant	t-Statistic	-5.7891	-5.1947	-11.2691	-7.8591
	Prob.	0.0000	0.0001	0.0000	0.0000
		***	***	***	***
With Constant & Trend	t-Statistic	-5.7640	-5.1323	-11.1489	-7.8064
	Prob.	0.0001	0.0006	0.0000	0.0000
		***	***	***	***
Without Constant & Trend	t-Statistic	-5.8439	-5.0817	-11.3878	-7.9426
	Prob.	0.0000	0.0000	0.0000	0.0000
		***	***	***	***

Notes: Panel A and B exhibits the stationary tests for Brazil and India, respectively. The null hypothesis stands for the absence of unit root. The asterisk denotes statistical significance *, **, and *** at 10 percent, 5 percent, and 1 percent, respectively

In our unit root tests, presented in Table (13), we find that Brazil's variables of import price *(log)* and exchange rate *(log)* are not stationary at level, while the interaction term variables are already stationary at level for any conventional confidence level. At the first difference, we find that all Brazil's variables are statistically stationary. For India's variables, the results of the ADF unit root tests indicate that import price *(log)* and exchange rate *(log)* are significantly non-stationary at level but statistically stationary at the first-difference, while the interaction term variables are stationary at level. In summary, the variables for Brazil and India are commonly stationary at different levels wherein import price *(log)* and exchange rate *(log)* are non-stationary at level while the interaction term variables are stationary. Therefore, the empirical models estimating the role of futures-based FX intervention on exchange rate dynamics could cointegrate in the long-run (e.g., see Gujarati & Porter, 2009).

Table 14
Best Ten ARDL Specification and Bound Test

Panel A Brazil

No	ARDL Model	SC	Log-likelihood	F Wald test	Prob.
1	ARDL (1,1,1,1)	-0.32689	34.10088	1.715224	0.1552
2	ARDL (1,1,1,2)	-0.28712	34.41588	1.898346	0.1195
3	ARDL (1,2,1,1)	-0.28121	34.16458	1.82242	0.1334
4	ARDL (1,1,1,3)	-0.22095	33.64933	1.83913	0.1305
5	ARDL (1,1,1,4)	-0.19634	34.66123	1.809627	0.1365
6	ARDL (1,1,3,2)	-0.19148	34.62683	1.22083	0.3096
7	ARDL (1,3,1,2)	-0.18815	34.48712	2.180602	0.0797

8	ARDL (1,1,2,3)	-0.1868	34.43067	1.379765	0.2495
9	ARDL (1,2,1,3)	-0.18027	34.15642	1.964321	0.1091
10	ARDL (2,2,2,1)	-0.17997	34.30449	1.229391	0.3059

Panel B India

No	ARDL Model	SC	Log-likelihood	F Wald test	Prob.
1	ARDL (1,4,1,1)	1.689807	-15.8937	1.058896	0.3918
2	ARDL (2,4,1,1)	1.753283	-15.4393	0.729567	0.5782
3	ARDL (1,4,1,2)	1.771795	-15.8651	0.92525	0.4611
4	ARDL (1,4,2,1)	1.773033	-15.8936	0.987512	0.4279
5	ARDL (1,1,4,1)	1.798062	-18.3836	1.34689	0.2728
6	ARDL (3,1,1,1)	1.804959	-21.2407	0.8494	0.5034
7	ARDL (4,1,1,1)	1.80705	-18.5903	0.880832	0.4857
8	ARDL (1,1,1,4)	1.809675	-18.6507	1.267858	0.3017
9	ARDL (1,3,1,1)	1.818871	-21.5677	1.680186	0.1759
10	ARDL (1,1,1,3)	1.820645	-21.6094	1.472138	0.2310

Notes: Panel A and B exhibits the best ten ARDL specifications and bound test for Brazil and India, respectively. F Wald test is compared to the tables of Pesaran et al. (2001). The null hypothesis stands for the absence of cointegration. Variables ordering: Import price index (log), the exchange rate (log), the interaction variable of FX intervention, and the interaction variable of futures-based FX intervention.

For the ARDL bound tests, the results are displayed in Table (14). We employ ten ARDL specifications based on the Schwartz Criterion (SC). For the model estimate of Brazil, we find that all specifications produce statistically insignificant F-Wald results, suggesting that these specifications are significantly cointegrated at any confidence level. For the empirical model estimating the case of India, we also find that all the ARDL specifications are statistically not cointegrated at any confidence level. Based on these tests, it implies that our empirical models do not generate error correction terms. We next focus our analysis on the long-run empirical estimations.

Table 15
Classical Assumptions

Panel A Brazil

	1	2	3	4	5
Jarque-Bera Test	4.3242	4.3986	3.8504	6.5572**	6.6073**
Breusch-Pagan-Godfrey Test (F-Stat)	2.0470*	1.7964*	1.9381*	2.1470**	1.9196*
Durbin-Watson Stat	1.3207	1.3253	1.3076	1.2862	1.2982

Panel B India

	1	2	3	4	5
Jarque-Bera Test	48.0707***	51.1584***	34.5647***	44.0119***	43.0153
Breusch-Pagan-Godfrey Test (F-Stat)	1.0582	1.1392	0.9714	1.0040	1.1667
Durbin-Watson Stat	1.2791	1.4750	1.3148	1.2694	1.3868

Notes: Panel A and B exhibit the results of classical assumptions for Brazil and India, respectively. The asterisk denotes statistical significance *, **, and *** at 10 percent, 5 percent, and 1 percent, respectively.

For the last pre-estimation tests, we investigate the classical assumption tests for the five-best ARDL specifications. For Brazil, we find that the last two specifications are not normally distributed, while the first three specifications are normally distributed. However, all of the five-best specifications are prone to autocorrelation and heteroskedasticity regression problems. Furthermore, the classical assumption tests for India indicate that four out of five model specifications are normally distributed. However, we find that the empirical models for India suffer from heteroskedastic error and autocorrelation problems. Based on these tests of classical assumptions violation, we thus perform the HAC robust standard error for all empirical models for both Brazil and India.

6.2.2.2 Estimation Results

Our main empirical results are displayed in Table (16), which portray the long-run estimations analyzing the role of futures-based FX intervention on exchange rate pass-through in Brazil and India.

For Brazil, we find that the elasticity coefficients of exchange rate on import price are statistically significant in the (4) and (5) column estimations at ten percent confidence level. Specifically, this suggests that the depreciated exchange rate is inelastic, leading to a less efficient import price. For India, we find an approximately similar situation where the depreciated exchange rate would reduce the efficiency of import prices. However, the exchange rate pass-through in India seems to be higher than in Brazil where the estimated elasticity coefficients approximate unitary. While admittedly the magnitudes are different, these findings confirm the theory that pass-through mechanisms for which exchange rate instability are effectively transmitted could disrupt trade, leading to a rise in the dollar burden and placing upward pressure on prices of imported goods. (Menkhoff 2013). Céspedes, Chang, and Velasco (2004) also confirm that weaker local currency in financially vulnerable countries could worsen debt and difficulties in its servcing as well as impair balance sheets of domestic banks and firms.

Table 16
Long-run Estimations

Panel A Brazil

	1	2	3	4	5
Exchange Rate, *Log*	-0.601711 [0.524557]	-0.609509 [0.505476]	-0.604392 [0.568317]	-0.66349* [0.357252]	-0.659848* [0.373177]
Exchange Rate, *Log* × Foreign Exchange Intervention	0.472435 [0.911303]	0.448922 [0.904038]	0.567737 [0.99851]	0.33746 [0.668023]	0.339855 [0.690969]
Exchange Rate, *Log* × Futures-based Intervention	0.286458 [0.320522]	0.337931 [0.295381]	0.151283 [0.419237]	0.590862** [0.261142]	0.573631** [0.261968]

Panel B India

	1	2	3	4	5
Exchange Rate, *Log*	-1.005255* [0.578235]	-0.909794** [0.444131]	-1.015378 [0.631472]	-0.872523* [0.499091]	-0.857554 [0.697313]

	1	2	3	4	5
Exchange Rate, *Log*					
× Foreign Exchange	0.001416	0.001195	0.001628	0.003499	-0.003369
Intervention	[0.003719]	[0.003228]	[0.004153]	[0.004393]	[0.006680]
Exchange Rate, *Log*					
× Futures-based	-0.005154	-0.00507	-0.012369	-0.004786	-0.004286
Intervention	[0.005784]	[0.004992]	[0.015234]	[0.005753	[0.007831]

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

We now proceed to investigate the long-run impact of FX intervention and futures-based FX intervention on the exchange rate pass-through in Brazil and India. For the FX intervention, we find no evidence, either for Brazil or India, of an exchange rate pass-through effect. For the role of futures-based FX intervention, we find that that it effectively reduces the exchange rate pass-through in Brazil. Our empirical results also suggest that the reducing-effect of futures-based FX intervention (i.e., when the central bank holds net purchases) is approximately perfect, indicated by the interaction term coefficients of futures-based FX intervention nearly offsetting the elasticity coefficients of exchange rate on import price (see Panel A, column 4 and 5 estimations). This finding, in general, is aligned with Gonzalez, Khametshin, Peydró, & Polo (2019), who found that futures-based FX intervention significantly reduced the negative effect of a depreciated exchange rate during the Global Financial Crisis (GFC) and taper tantrum on the balance sheets of highly external resilient banks. Specifically, they showed that a large futures-based FX intervention program supplying derivatives against FX risks halved the adverse effects from exchange rate depreciations. For India, our empirical results find no evidence of any impact of futures-based FX intervention on the exchange rate pass-through.

Our findings demonstrate that the role of futures-based FX intervention is more extensive in Brazil than in India. There are several factors support this finding. Generally, derivatives-based FX intervention would be concentrated in the more developed market. In the case of Brazil, the FX derivatives are more developed in the futures market, and the forwards market in turn, is more developed than the futures market. Second, the Brazilian central bank has intervened regularly in foreign exchange market since the adoption of a floating exchange rate regime in January 1999. These interventions have included the regular use of the FX futures market. Given its high liquidity, the central bank has been able to intervene more frequently and systematically in this market (Upper & Valli, 2016). The RBI has also intervened through the FX futures market, but only occasionally and in a limited amount. Because Indian derivatives are mostly concentrated in the OTC market (e.g., forwards), derivatives-based FX intervention is more extensive in the forwards market. In Brazil, the eligibility to issue the main futures contract (DOL) is limited so as to ensure smooth and efficient hedging in the FX futures market. At the same time, however, hedging activities in the FX futures market are vulnerable to misuse. In view of this, we find that the Indian FX futures market is unlikely to fulfill the genuine hedging requirements of participants, which is only possible presently in the OTC market (Shyamala Gopinath, 2010).

6.2.3 Robustness Checks

For the robustness checks, we estimate the long-run model using two alternative approaches: Fully Modified OLS (FM-OLS) and Dynamic OLS (D-OLS). These two estimators are frequently utilized in estimating long-run models. The FM-OLS is designed to provide optimal estimates for cointegrating regressions that include serial correlation effects and endogeneity in the regressors (Phillips, 1995). On the other hand, the D-OLS is robustly superior for small samples, as well as being able to account for possible simultaneity within regressors (Masih & Masih, 1996).

Table 17
Robustness Checks: The Futures-based FX Intervention and Exchange Rate Dynamics

	Brazil		India	
	FM-OLS	D-OLS	FM-OLS	D-OLS
FX Futures Rate	0.939447*** (0.017589)	1.009969*** [0.032954]	0.88071*** (19.65022)	0.936694*** [0.074072]
Foreign Exchange Intervention	0.006828 (0.007275)	0.021012 [0.020650]	0.014476 (0.027839)	-0.039444 [0.037300]
Futures-based Intervention	-0.011791 (0.007475)	-0.041075** [0.017615]	0.072232*** (0.018613)	-0.219135 [0.147324]
Policy Rate	0.025863 (0.0156450	0.022601 [0.021305]	0.242423*** (0.0778230	0.051428 [0.139567]
Industrial Production, *Log*	0.001811 (0.019859)	0.061112 [0.042951]	-0.229508*** (0.0711)	-0.597354*** [0.189201]
Consumer Price, *Log*	0.070682*** (0.025122)	0.057759 [0.041678]	0.570222*** (0.123322)	0.823698** [0.290959]
Net Export	-0.036164*** (0.012444)	-0.035371 [0.025871]	-0.018847 (0.035901)	0.148331 [0.084038]
Fed Fund Rate	0.059323*** (0.022352)	0.045881 [0.030719]	0.098845 (0.119622)	-0.229844 [0.201081]
US Industrial Production, *Log*	-0.042758*** (0.014456)	-0.028946 [0.018852]	-0.187841** (0.083039)	0.246035 [0.180018]
R-squared	0.990508	0.998592	0.971433	0.99846
Adjusted R-squared	0.989399	0.997536	0.965005	0.993421

Notes: The asterisk denotes statistical significance *, **, and *** at 10 percent, 5 percent, and 1 percent, respectively. Numbers in the parentheses ( ), represent the standard error. Numbers in the square brackets [ ], represent the HAC-corrected standard error. Schwartz Criterion is performed to determine both lags and lead in D-OLS estimations.

First, we address the robustness estimations for the empirical relationship between the exchange rate and FX intervention and futures-based FX intervention, which are presented in Table (17). The empirical results from the FM-OLS and D-OLS confirm our proposition that the FX futures rate significantly drives the actual exchange rate. Second, Brazilian futures-based FX intervention is statistically significant and confirm our primary estimations in the D-OLS, while it is statistically insignificant in the FM-OLS. Although the FM-OLS generates insignificant parameters, these are consistently positive, which support our primary estimation. For India, futures-based FX intervention is significantly positive at one percent confidence level in the FM-OLS estimation. This suggests that futures-based FX intervention in India depreciates the exchange rate. However, the estimated parameter from the FM-OLS estimation seems to be biased due to the small sample size, while the D-OLS is superior against the small sample bias (Masih & Masih, 1996). We can, therefore, conclude that futures-based FX intervention in India has no effect on exchange rate dynamics, thus confirming our primary estimations.

Table 18
Robustness Checks: The Futures-based FX Intervention and ERPT

	Brazil		India	
	FM-OLS	D-OLS	FM-OLS	D-OLS
Exchange Rate, *Log*	-0.817983*** (0.089768)	-0.804225*** [0.078408]	-0.693714*** [0.223577]	-0.64245** [0.282573]
Exchange Rate, *Log* × Foreign Exchange Intervention	0.110132 (0.094962)	0.089998 [0.165375]	-0.003080* [0.001718]	-0.002696 [0.001815]
Exchange Rate, *Log* × Futures-based Intervention	0.386724*** (0.095124)	0.625128*** [0.134135]	0.001747 [0.001471]	0.002682* [0.001568]
R-squared	0.772897	0.860889	0.496787	0.563145
Adjusted R-squared	0.764688	0.837703	0.452056	0.490336

Notes: The asterisk denotes statistical significance *, **, and *** at 10 percent, 5 percent, and 1 percent, respectively. Numbers in the parentheses ( ), represent the standard error. Numbers in the square brackets [ ], represent the HAC-corrected standard error. For India's estimations, we use linear trend specification since it generates higher R-squared. Schwartz Criterion is performed to determine both lags and lead in D-OLS estimation. We also estimate the Indian case with the inclusion of forward-based FX intervention (see Appendix E) which consistent with this estimation.

From our robustness estimations, we see that Brazilian futures-based FX intervention is effective in weakening the exchange rate pass-through effect. This is indicated by statistically significant coefficients at any conventional level. Based on the FM-OLS and D-OLS estimations, we find specifically that futures-based FX intervention could reduce the exchange rate pass-through effect by about 47 percent to 77 percent. However, futures-based FX intervention has relatively no effect in reducing exchange rate pass-through in India. Although it is statistically significant at ten percent confidence level in the D-OLS, we cannot conclude that Indian futures-based FX intervention significantly affects the exchange rate pass-through since it is statistically weak, with near zero parameters, as well as being inconsistent in comparison to the majority of other estimations.

6.3 Discussion on Policy Implications

In this section, we will look at policy implications that can be derived from our empirical findings. Our panel VAR results illustrate the squeezing mechanism in the FX futures market, albeit occurring in small magnitudes and for short periods and therefore unlikely to cause volatility in the FX future rate. This indicates that authorities could effectively mitigate extensive market misuse in the FX futures market by setting up an effective surveillance system comprising price monitoring, positions monitoring, and market abuse mitigation and investigation (e.g., see Reserve Bank of India, 2008). For instance,the Central Bank of Brazil (CBB) and Reserves Bank of India (RBI) have conducted currency operations in the FX futures market to ensure its well-functioning (S. Gopinath, 2010; Kohlscheen & Andrade, 2014; Prates & de Paula, 2017).[17] Intuitively, such operations could prevent trade volumes from sudden stops with the immediate offsetting of the volume decreases. The domino effect of the squeezing mechanism on the FX futures rate and macroeconomy can thus be anticipated effectively.

Furthermore, we examine the utilization of futures-based FX intervention as a policy instrument for exchange rate management. We compare the implementation of futures-based

[17] Also see RBI Bulletin *(continuously updated)*, Chapter 4 Sale/Purchase of U.S. Dollar by the RBI.

FX intervention in India and Brazil and our empirical results show that the futures-based FX interventions in Brazil are effective in determining exchange rate movement and exchange rate pass-through, while it is the opposite in the case of India.

This finding sheds light on several crucial features that differentiate Brazil from India, the first of which are the different paths of economic transformation taken by them. In Brazil, the *Plano Real* (1994) led to the restricted direct access of agents to the spot market as well as the lower internal convertibility. Both the restriction on the spot FX market and limited internal convertibility helped to induce transactions in the derivatives market, especially in the FX futures market (Upper & Valli, 2016). While financial reforms transformed the INR to be fully convertible (Shyamala Gopinath, 2010), the non-deliverable contracts in the FX futures market have not given adequate incentives for hedging in the FX futures market under fully convertible currency in India. Second, the FX futures market in Brazil is more mature than that in India in terms of the establishment date. While the FX futures market is one of the oldest derivatives markets in Brazil (1991), the Indian FX futures market was only introduced in 2008. In India, the OTC FX market was already established even before the launching of the FX futures market. It makes the FX futures market in India is likely to subordinated by the OTC markets. Third, the eligibility for issuance of the main futures contract (DOL) in Brazil is limited to ensure smooth hedging in the FX futures market. On the contrary, hedging activities in the Indian FX futures market are vulnerable. The FX futures market is unlikely to fulfill the genuine hedging requirements of the participants, which is only possible in the OTC market (Shyamala Gopinath, 2010).

Given these situations, the FX futures market in Brazil is relatively more extensive than India's and thus, it is intuitive that derivatives-based FX intervention would be more productive and concentrated in the more developed market. In Brazil, the FX derivatives market is more developed than the futures market, while the Indian forwards market is more advanced than the futures market. The Brazilian central bank has intervened frequently in foreign exchange markets since the adoption of the floating exchange rate regime in January 1999. These have included the regular use of the FX futures market. Due to its high liquidity, the central bank has been encouraged to intervene more frequently and systematically in this market (Upper & Valli, 2016). Futures-based FX intervention, to some extent, has also replaced domestic government bonds that were linked to the exchange rate (Kohlscheen & Andrade, 2014). The RBI has also intervened through the FX futures market, but only occasionally and in a limited quantity. As we have seen, Indian derivatives are mostly concentrated in the OTC market (e.g., forwards) and thus, FX intervention is more extensive in the forwards market (see Sub-section 2.2.5).

Table 19
Summary of Policy Implications

	Description	Factors that minimize the risks and maximize the benefits
Risks	Market manipulations	1. Price monitoring, positions monitoring, and market abuse mitigation and investigation; 2. Central Bank's currency operation in the FX futures market.
Benefits[a]	As an effective policy subject in managing exchange rate stability (i.e., futures-based FX intervention)	1. FX futures market deepening; 2. Strong and suitable financial-economic regulatory background;

	3. Frequent intervention in the FX futures market.

[a] In policy perspectives

Based on our results and rationalizations, we formulate several policy implications as follows (see Table 19 for the summary): First, from our empirical results, it can be seen that micro-prudential authorities and the central bank have critical roles to play in ensuring the smooth functioning of the FX futures market, which is inherently associated with risks such as market manipulations. With regard to micro-prudential issues, the authorities have to develop a robust surveillance system that monitors and mitigates abnormal behavior in the market. The typical standard surveillance system generally comprises price monitoring, positions monitoring, and market abuse mitigation and investigation. The regulatory framework in Brazil is particularly unique and robust for safeguarding the FX futures market against market abuses. Specifically as described in earlier sections, the *Plano Real* which was initiated in 1994, was effective in thwarting market manipulation or circular trading.

Moreover, the central bank plays an important role in ensuring a well-functioning FX futures market through its currency operation. The CBB and the RBI have both conducted currency operations in their respective FX futures markets to ensure their effective function. Such operations serve to prevent sudden drops in trade volume, with the immediate offsetting of declining trade volumes by the central banks, thus restoring market value.

Furthermore, the central bank could also utilize the FX futures market not only to prevent market misuse but also as a policy option for exchange rate management under particular conditions. From our analysis, we find that futures-based FX interventions in Brazil are used more regularly than in India since its FX futures market is more developed. The empirical findings show that futures-based FX interventions in Brazil are able to effectively control exchange rate movements and reduce the exchange rate pass-through effect. However, the development of the futures market is dependent on several essential aspects such as the historical background of the economic transformation, establishment of the FX futures market, and the tradeoff between the futures and OTC market development. Hence, we can surmise that the effectiveness of futures-based FX intervention is contingent on specific conditions in Brazil. On the other hand, we find no evidence for the effectiveness of futures-based FX intervention in India. The occasional interventions in the futures market by authorities could be interpreted as the appropriate policies for India. In contrast to (Biswal & Jain, 2019) who argued that the RBI should formally intervene in the FX futures market for managing the exchange rate, we on the other hand, is of the view that it is unwarranted to regularly use futures-based FX interventions for exchange rate management since the size of the futures market is relatively smaller than other derivatives markets such as the OTC market.

7 Concluding Remarks

This paper provides analysis related to two research areas of the FX futures market in ITF-EMDEs. First, we examine how the FX futures market might impact the macroeconomic conditions of the ITF-EMDEs. For the empirical investigation, we use a dynamic analysis via the Bayesian Pooled PVAR approach comprising of four ITF-EMDEs countries with active FX futures market, namely, Brazil, Mexico, Turkey, and India for the period of January 2015 to December 2018. In our specification of the empirical model, the unifying monetary framework developed by S. Kim (2003) is extended to capture the role of FX futures market activities while simultaneously controlling for regular sterilized FX interventions in ITF monetary regimes (Ghosh et al., 2016b). Second, we examine the effectiveness of futures-based FX interventions in determining the exchange rate dynamics and exchange rate pass-through in India and Brazil. As mentioned earlier, the operations of these interventions are strikingly different. In Brazil, regular futures-based FX interventions have occurred since March 2002, while in India, they have been sparsely used. The analysis has allowed us to evaluate and glean lessons from these countries' policy designs on futures-based FX interventions and their outcomes. Specifically, we are able to establish whether the magnitude and frequency of interventions and the fundamental aspects of the economic background matter in determining the effectiveness of futures-based FX interventions.

There are several crucial findings from our empirical analysis. The first is that FX futures rate shocks have an essential role in the macroeconomic environment and the conduct of monetary policy due to their roles in the price discovery of the spot exchange rate. Second, trade volumes would normally respond negatively to open interest shocks, meaning that when hedging is active, speculators tend to hold their transactions and *vice versa,* which is indicative of a market squeezing mechanism (e.g., see Kyle, 1992). However, in our study, both the spot exchange rate and the FX futures rate are insignificant. This means that there are early indications of market squeezing but which are not realized due possibly to regulatory contraints. We thus do not find that market squeezing has significant impact on 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 essential in describing the variance in economic growth compared to other variables. Furthermore, we also perform robustness strategies to investigate whether our empirical results are robust. After conducting these robustness tests, the results confirm our primary results.

For our second research enquiry, the empirical results show that futures-based FX interventions in Brazil are effective in determining exchange rate movement and the exchange rate pass-through, while it is the opposite for India. These are confirmed in the robustness checks estimations and they substantiate the differentials for Brazil and India.

Our empirical results has several implications for policy options. First is the critical role of micro-prudential policies in safeguarding the stability of the FX futures market. It is imperative that authorities develop a robust surveillance system which can monitor, mitigate and enforce regulations when there are indications of abnormal behavior in the market. At the same time, the central bank also has an essential role in ensuring the stability of the FX futures market through its currency operations. Central Bank of Brazil (CBB) and Reserves Bank of India (RBI) have conducted the currency operation in the FX futures market to ensure the well-functioning futures market (see e.g., Kohlscheen and Andrade 2014; Nedeljkovic and Saborowski 2019; Oliveira 2020). Such operations would act to shore up sudden disruptions in trade volumes and help restore market activities. Furthermore, our investigation also implies that the effectiveness of futures-based FX intervention is related to several essential aspects such as the historical background of the economic transformation, the establishment of the FX futures market, and the tradeoff between futures and OTC market development. On the other hand, it suggests that an effective futures-based FX intervention occurs only in particular conditions.

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Appendix A
Robustness I: Alternative Variables Ordering

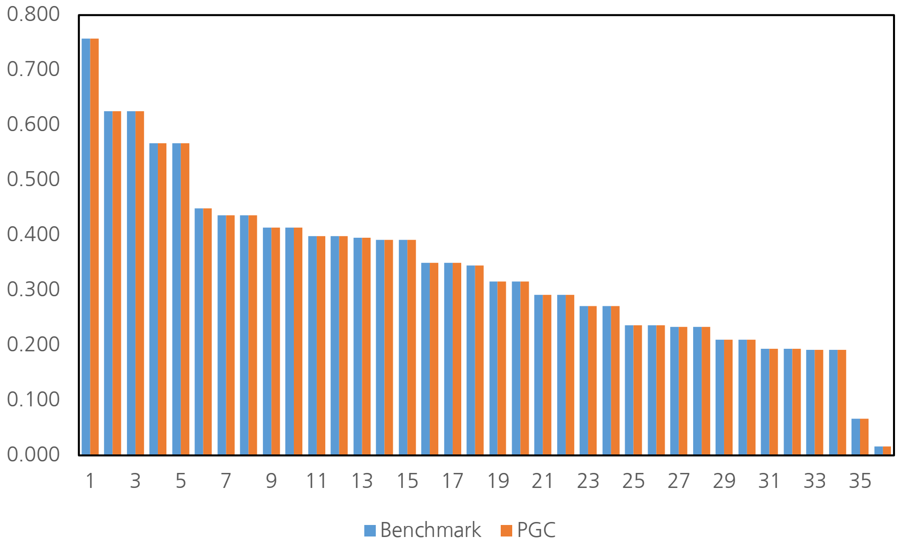
Table 20
Comparative IRF Output Between Benchmark Ordering and PGC Ordering

Notes: Table 22 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 11
Modulus Values For Benchmark and PGC-based Ordering of PVAR

Notes: Figure 14 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 denote the number of endogenous variables.



Appendix B
Robustness II: Sensitivity Test

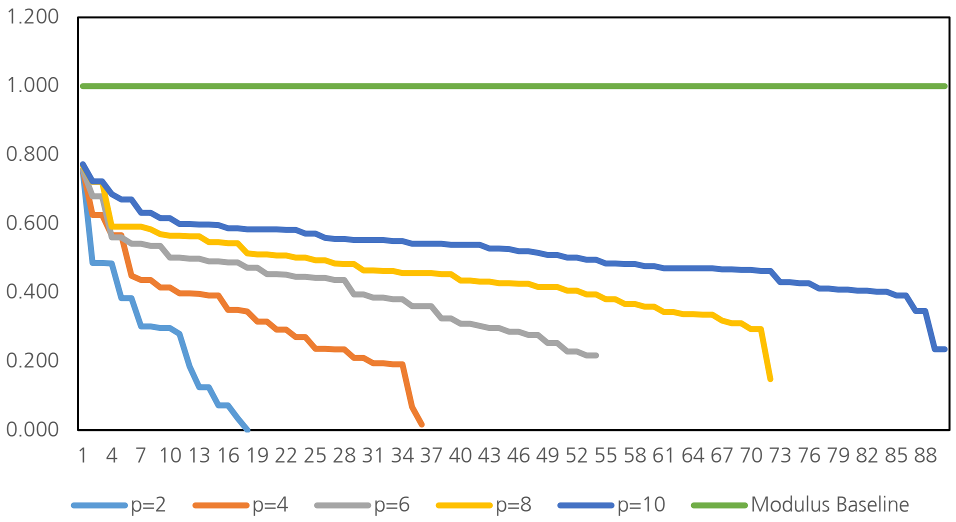
Table 21
Estimated IRF for Sensitivity Test

Notes: Table 21 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 12
Modulus Values For Five Different Lag Structures of PVAR

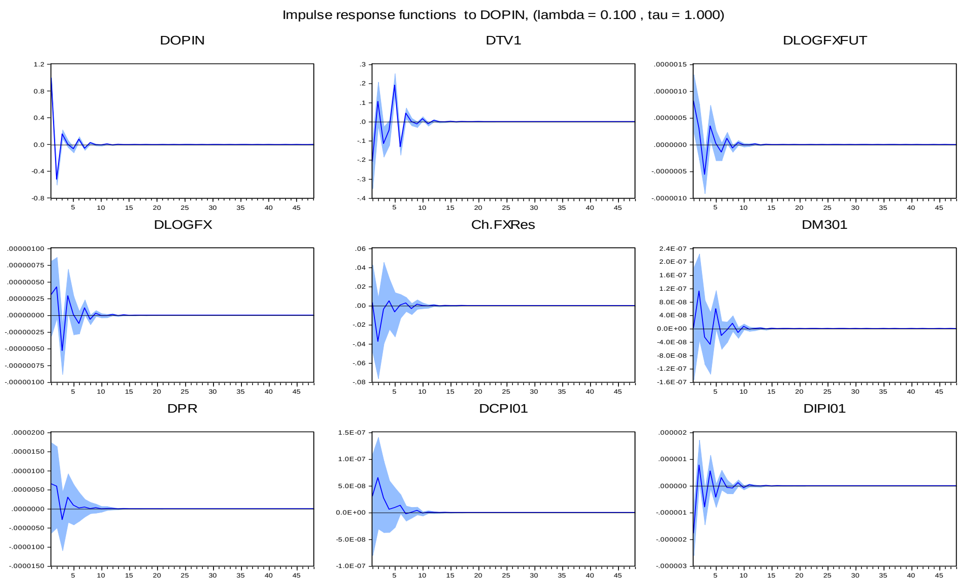
Notes: Figure 12 depicts the roots of the characteristic polynomial (modulus) utilized to identify the stability condition of five different lag structure (p) of Panel VAR estimations estimated using Pooled Bayesian PVAR. We investigate the following lag structures: $p = \{2, 4, 6, 8, 10\}$. The vertical 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.

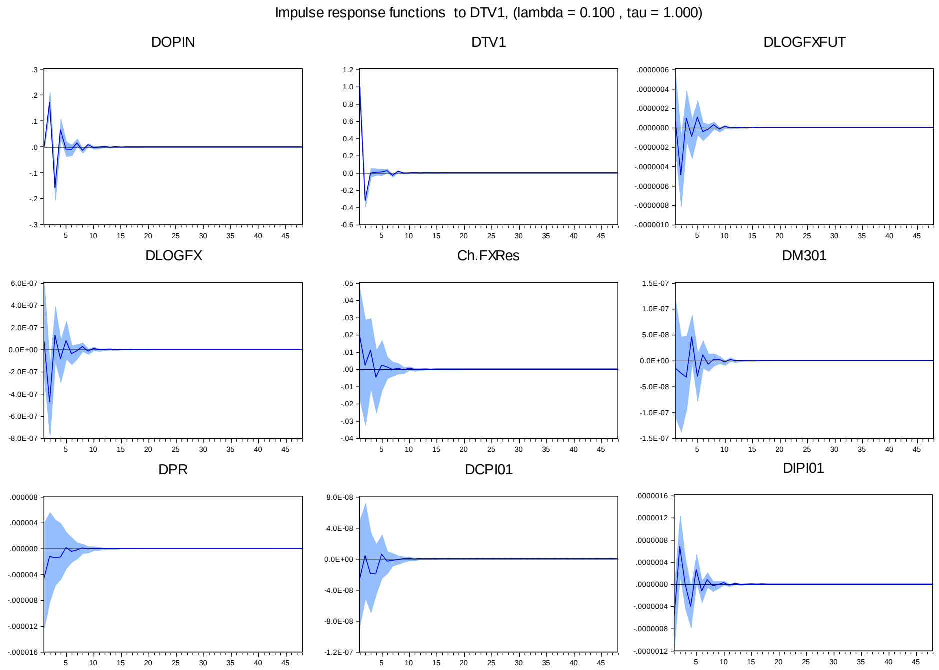


Appendix C
Robustness Test III: Large Bayesian VAR Estimation

Figure 13
Impulse Response Function (IRF)

Notes: Figure 14 portrays the Impulse Response Function (IRF) obtained from the PVAR estimated using Large Bayesian VAR. The horizontal axis denotes the period. 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 $OP_{it}, TV_{it}, F_{it}, EV_{it}, SI_{it}, M_{it}, r_{it}^{d}, CPI_{it}, y_{it}$





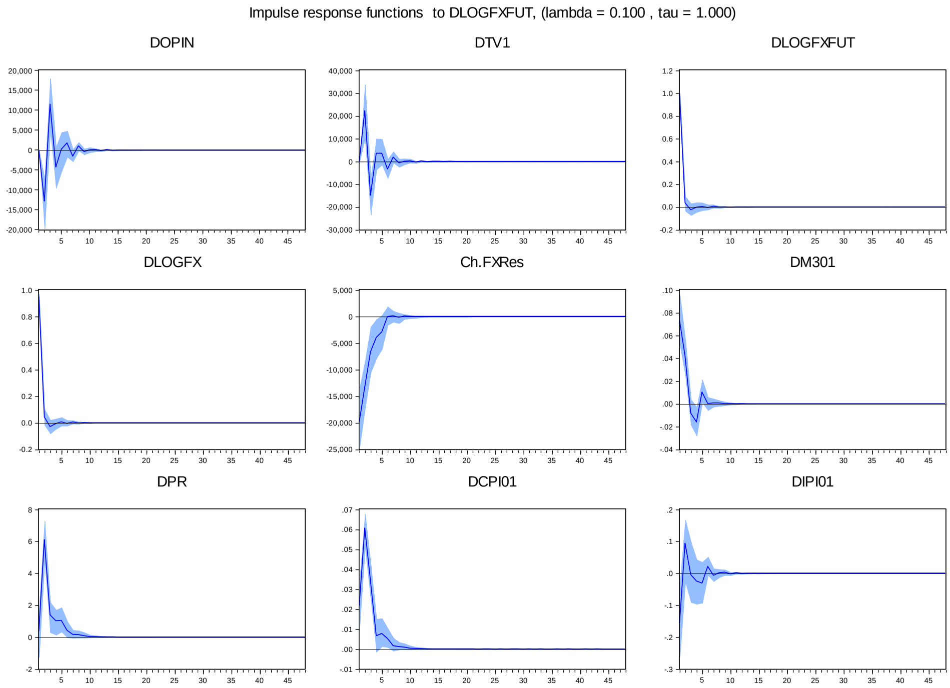


Table 22
Variance Decomposition

Notes: Table 22 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 are denoting 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

Exchange Rate (DLOGFX)									
	DOPIN	DTV1	DLOGFXFUT	DLOGFX	CH_FXRES	DLOGM3	DPR	DLOGCPI	DLOGIPI
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 C
Robustness Test IV: Bayesian PVAR with Exchange Rate Volatility

Figure 14
Impulse Response Function

Notes: Figure 14 portrays the Impulse Response Function (IRF) obtained from the PVAR model specification with exchange rate volatility (ERVOL). The horizontal axis denotes the period. 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 $OP_{it}, TV_{it}, F_{it}, EV_{it}, SI_{it}, M_{it}, r^d_{it}, CPI_{it}, y_{it}$.

Shocks from:

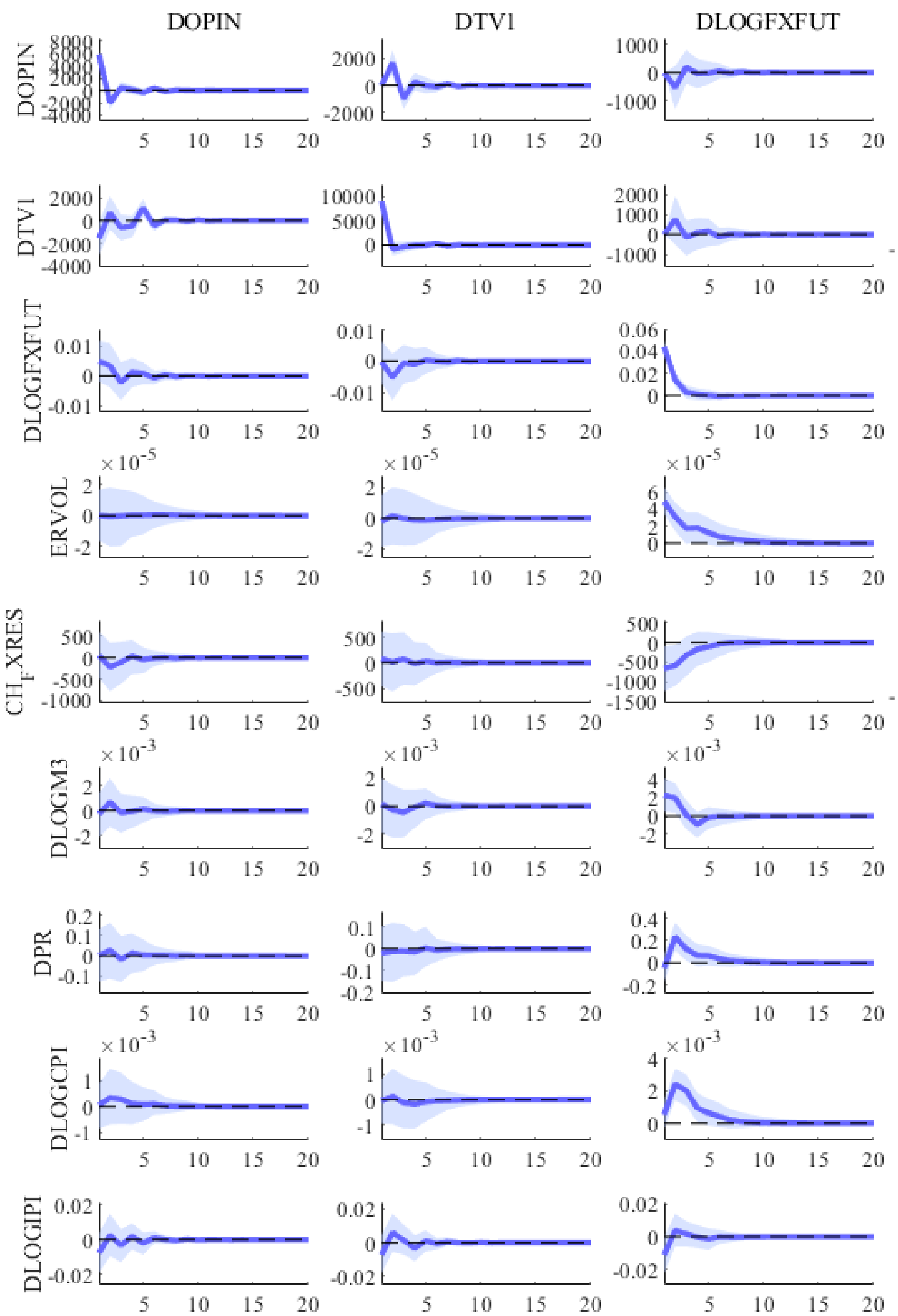
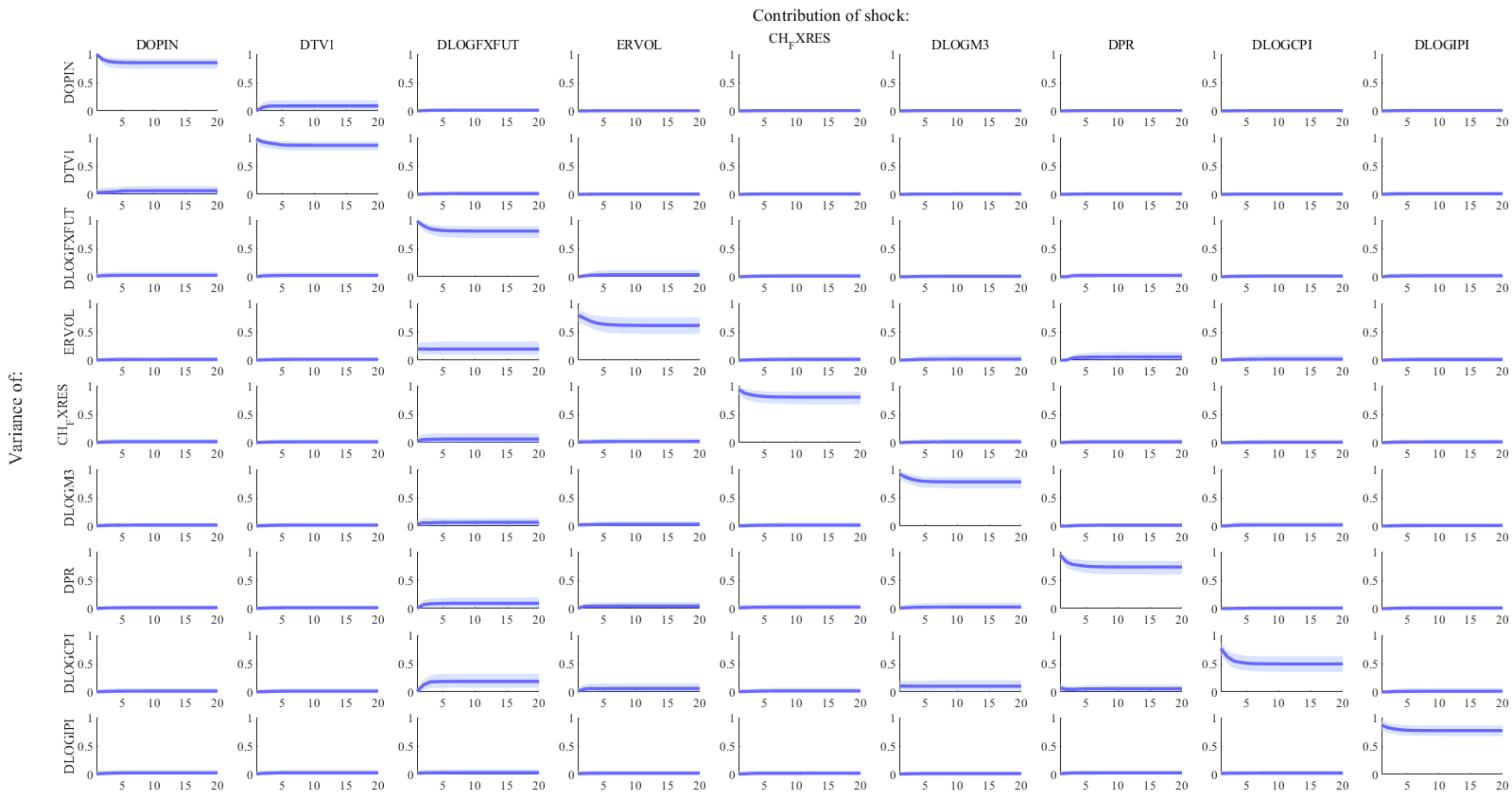


Figure 15
Variance Decomposition

Notes: Figure 15 portrays the Forecast Error Variance Decomposition (FEVD) derived from the estimated PVAR model, which is 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 D
Exchange Rate Volatility Estimations

Table 23
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 24
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 25
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 16
The Monthly Average of Daily Volatility

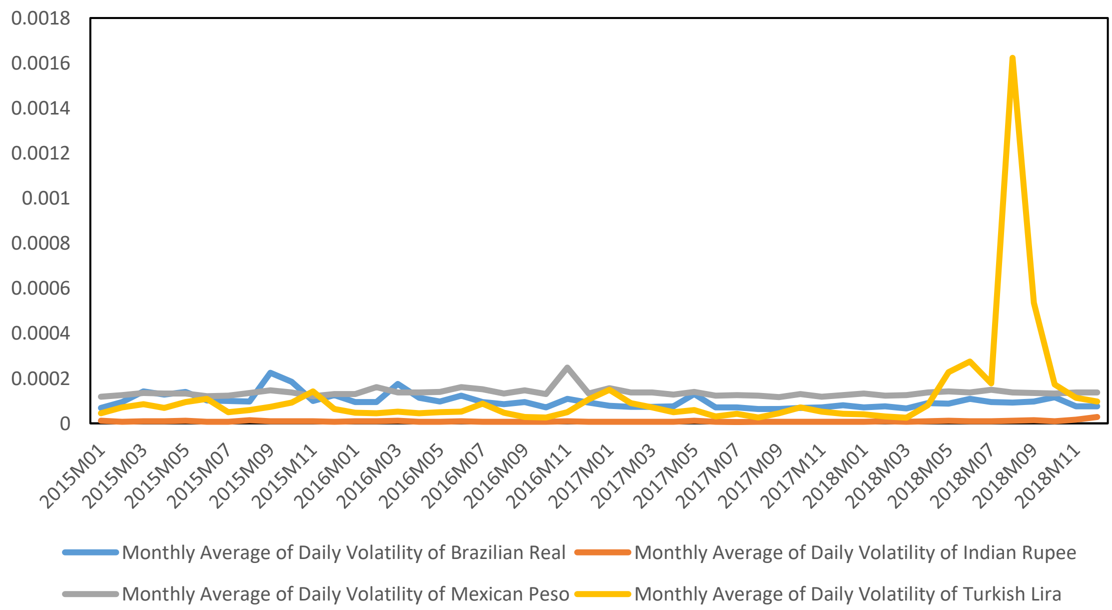


Table 26
Unit Root Tests for The Monthly Average of Daily Volatility

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

Appendix E
The Futures-based and Forward-based FX Intervention and ERPT (Indian Case)

	FM-OLS	D-OLS
Exchange Rate, *Log*	-0.710236*** (0.243667)	-0.711272** [0.283937]
Exchange Rate, *Log* × Foreign Exchange Intervention	-0.003382* (0.001851)	-0.003380 [0.002164]
Exchange Rate, *Log* × Futures-based Intervention	0.001721 (0.001484)	0.002657* [0.001567]
Exchange Rate, *Log* × Forward-based Intervention	-0.154788 (0.302210)	-0.159073 [0.282374]
R-squared	0.496806	0.569104
Adjusted R-squared	0.439625	0.472152

Notes: The asterisk denotes statistical significance *, **, and *** at 10 percent, 5 percent, and 1 percent, respectively. Numbers in the parentheses ( ), represent the standard error. Numbers in the square brackets [ ], represent the HAC-corrected standard error. For India's estimations, we use linear trend specification. Schwartz Criterion is performed to determine both lags and lead in D-OLS estimation.