The Effectiveness of Futures-based Foreign Exchange Intervention: Comparative Studies of Brazil and India

Syarifuddin, Ferry and Izzulhaq, Syahid

Bank Indonesia Institute

1 December 2020

The Effectiveness of Futures-based Foreign Exchange Intervention: Comparative Studies of Brazil and India[1]

Ferry Syarifuddin[2]
Deputy Director, Bank Indonesia Institute

Syahid Izzulhaq
Research Assistant, Bank Indonesia Institute

Abstract

This paper examines the effectiveness of futures-based foreign exchange (FX) intervention in determining the exchange rate dynamics and exchange rate pass-through effect. We specifically compare the case of Brazil and India to evaluate and take a lesson learned from those countries' policy designs and outcomes in utilizing the futures-based FX intervention. By utilizing autoregressive and distributed lag estimations, our empirical results show that the futures-based FX interventions in Brazil are effective in determining the exchange rate movement and reducing exchange rate pass-through, while the futures-based intervention in India is neutral. The results are also confirmed in the robustness checks estimations. The finding implies that the effectiveness of futures-based FX intervention is related to the economic-institutional aspects within these countries, which also suggests that an effective futures-based FX intervention occurs only under specific circumstances.

Keywords: Foreign Exchange Intervention; Futures-based FX Intervention; Brazil; India.
JEL Classifications: E44, E58, G28.

---

[1] The views expressed in this Working Papers are those of the author(s) and necessarily represent no formal views of the Bank Indonesia and its Executive Board.

[2] Corresponding author. Email: ferry.s@bi.go.id. Bank Indonesia, Jl. MH Thamrin No. 2, Jakarta 10350, Indonesia.

I Introduction

Discourses on the FX intervention under the Inflation Targeting Framework in Emerging and Developing Economies (ITF-EMDEs) 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 suggests that independence for the monetary policy requires a free-floating exchange rate. However, most of the central banks in ITF-EMDEs appear to "fear of floating" and, thus, they actively involve such intervention in the exchange rate market either via foreign exchange intervention (FXI) or even interest rates (Calvo & Reinhart, 2002).

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

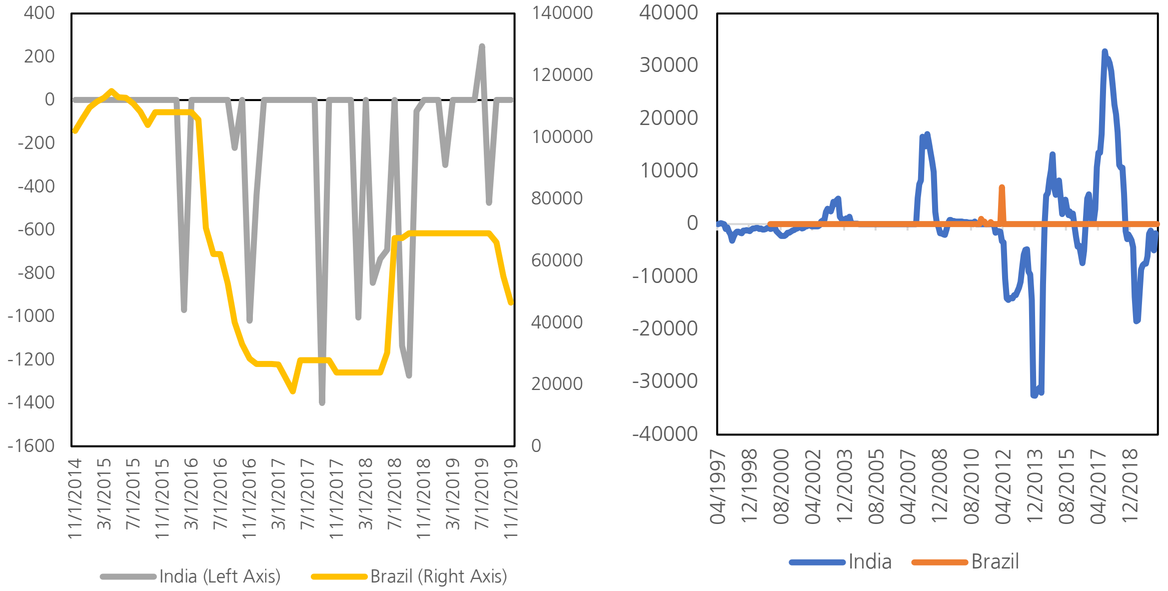
However, countries like Brazil and India, which are characterized by developed derivatives FX markets, have operated not only the sterilized FX intervention but also derivatives-based FX intervention. Figure (1) exhibits both futures-based and forwards-based FX intervention in Brazil and India. The figure illustrates that the Central Bank of Brazil (CBB) has intervened, formally and extensively, in 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[3], to some extent, also replaced domestic government bonds that were linked to the exchange rate (Kohlscheen & Andrade, 2014). For the case of India, the RBI has also intervened through the FX futures market, but occasionally and in a limited amount. Given the Indian derivatives market mostly concentrated in the OTC market (e.g., forwards), the derivatives-based FX intervention is more extensive in the forwards market. The intension of the futures-based FX intervention is merely to ensure that the market is well-functioning. On the contrary, the intervention in the forwards market comprises the intention to stabilize the exchange rate volatility and to avoid a cash crunch in the banking system and the adverse effects from international trade (Bhaumik & Mukopadhyay, 2000; Tripathy, 2013).

[3] We use the term of futures-based FX intervention rather than Brazilian FX swap because (Nedeljkovic & Saborowski, 2019) argues that the intervention are more similar to non-deliverable futures.

Figure 1
Derivatives-based FX Intervention in Brazil and India

Panel A
FX Intervention in
the Futures Market

Panel B
FX Intervention in
the Outright 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*.

Several works of literature have emphasized an essential role of futures-based FX intervention in exchange rate management in Brazil. Nedeljkovic and Saborowski (2017) found that the futures-based FX intervention in Brazil effectively manages the exchange rate movement. Mihaljek (2005) proved that such a policy was able to moderate the FX market volatility during the exchange rate turbulence. Kohlscheen & Andrade (2014) and Oliveira (2020) also found that futures-based FX intervention in Brazil effectively influences both the volatility and nominal movements of the spot exchange rate. Intuitively, an effective futures-based FX intervention ensures 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, Khametshin, Peydró, & Polo (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 adverse effect of the Global Financial Crisis (GFC) and Taper tantrum on highly-external-resilience banks' balance sheets; therefore, reducing firm-level unemployment in Brazil.

For the case of India, the RBI involvement in the FX futures market is mostly neutral, in which the gross purchases frequently offset the gross sell.[4] However, Biswal and Jain (2019) argued that an increase in trading activity in the FX futures market could be interpreted as a signal for the RBI to intervene through the FX futures market formally. They then argued that

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

intervention by the RBI in providing liquidity in the FX futures market could effectively reduce the volatility in both the futures market and spot market. Nevertheless, this argument needs to be thoroughly scrutinized since Biswal & Jain (2019) only mentioned it but not demonstrated this issue.

In this paper, 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 the case of Brazil and India to evaluate and take a lesson learned from those countries' policy designs and outcomes in utilizing the futures-based FX intervention. As we mentioned earlier, they are strikingly different in terms of operating such intervention. This investigation thus allows us to answer whether the country-specific aspects of the intervention are matter in determining the effectiveness of futures-based FX intervention. To precisely address the country-specific aspects, we will also be discussing some key economic-institutional features in Brazil and India to address the role of the fundamental aspects of economic background in determining the outcomes of the futures-based FX intervention.

Based on our research purposes, this paper thus contributes to the literature by fulfilling the following gaps. First, 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.

For the statistical investigations, we conduct two steps of empirical investigation comprise the examinations on the role of futures-based FX intervention on exchange rate dynamics and exchange rate pass-through effect, respectively. We specifically utilize the Autoregressive Distributed Lag (ARDL) to accommodate these objectives. Furthermore, we also perform robustness investigations to test whether our empirical results are consistent and robust. In this case, we estimate not only one model specification but also the five-best ARDL specification based on Schwartz Information Criterion (SC). This strategy is essential to see whether our results are consistent in various lag specifications. Second, we estimate the long-run model using two alternative approaches: Fully Modified OLS (FM-OLS) and Dynamic OLS (D-OLS). Those two estimators are frequently utilized in estimating the long-run model. The FM-OLS is designed to provide optimal estimates of cointegrating regressions that counting the serial correlation effects and the endogeneity in the regressors that results from the existence of a cointegrating relationship (Phillips, 1995). On the other hand, the D-OLS is robustly superior in small samples, as well as being able to account for possible simultaneity within regressors (Masih & Masih, 1996).

Our empirical results show that the futures-based FX interventions in Brazil are effective in determining the exchange rate movement and reducing exchange rate pass-through, while the futures-based intervention in India is neutral. The results are also confirmed in the robustness checks estimations. For the case of Brazil, the results support the works conducted by Gonzalez et al. (2019), Kohlscheen & Andrade (2014), Nedeljkovic & Saborowski (2019), and Oliveira (2020). Furthermore, this finding implies that the effectiveness of futures-based FX intervention is associated with 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. It suggests that the effectiveness of futures-based FX intervention occurs only in particular conditions. In this case, therefore, the choice of the RBI for the occasional intervention in the futures market could be interpreted as the right choice. In contrast to Biswal & Jain (2019), who argued that the RBI should formally intervene in the FX futures market for exchange rate management, we argue that it is unnecessary to regularly operate the futures-based FX intervention for the objective of exchange rate management.

This paper is organized as follows. Section II discusses the economic-institution features associated with the FX futures market in Brazil and India. Section III elaborates on the empirical strategy conducted in this paper. Section IV accommodates the empirical results. Section V discusses the concluding remarks.

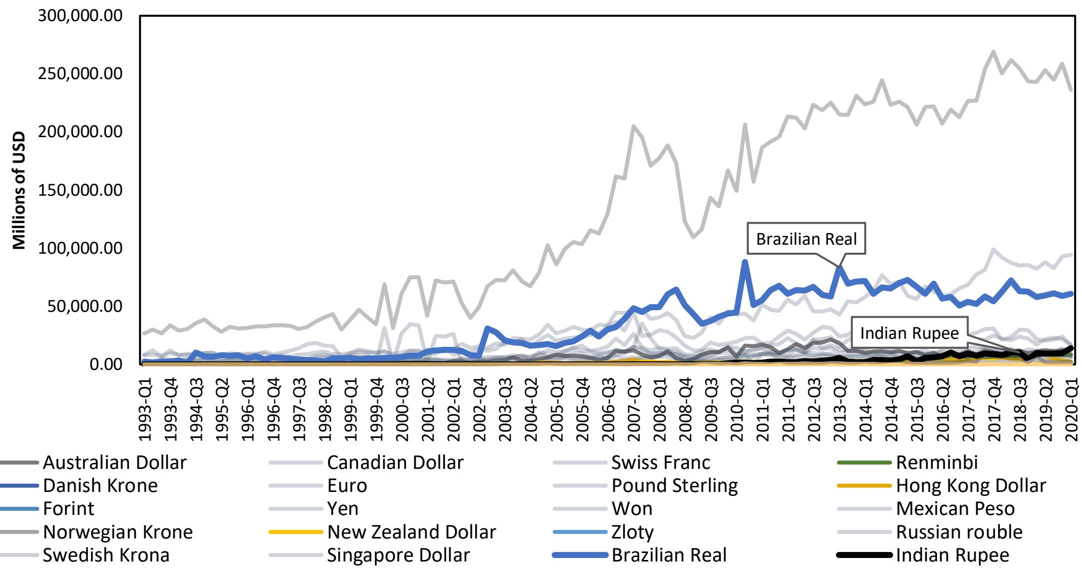
II The Economic-institutional Features Associated with the FX Futures Market in Brazil and India

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, even the third-largest in the world after the US Dollar and Euro, and followed by the INR (see Figure 2). In the first quarter of 2020, the BRL's NAOP reached roughly 60 billion US dollars and 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 far too small compared to BRL, or about more than 400 percent smaller than BRL. It is also the case that the FX futures market in Brazil is more extensive than 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 implies that the FX futures market for the BRL is larger and more developed than the INR's FX futures market.

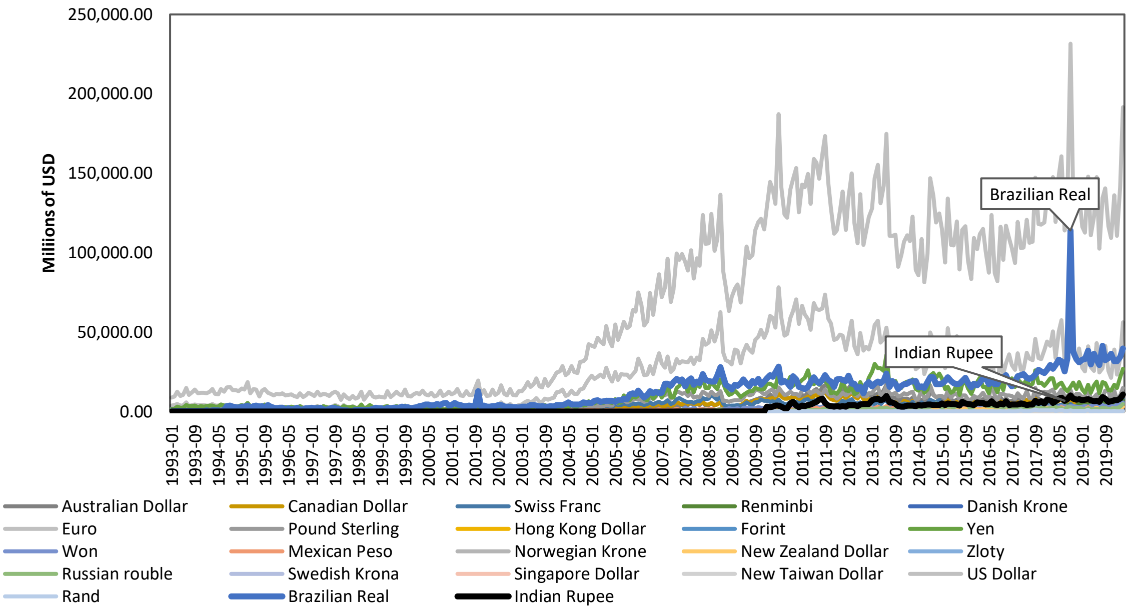
However, the FX market in Brazil and India has a strikingly different structure, although the FX derivatives market in both countries is more active than the spot market (see Figure 3). In Brazil, the FX derivatives markets are concentrated in outright forwards, non-deliverable forwards, and futures markets with each market contribution about 30 percent, 25 percent, and 24 percent of the total daily average turnover in 2019, respectively. The FX futures market in Brazil is continuously expanding throughout 1998 and 2019, although it was reduced in 2013 due to the non-deliverable forwards introduction to handling the taper tantrum. In India, the FX derivatives markets are mainly concentrated only in outright forwards and non-deliverable forwards by 36 percent and 29 percent, respectively. Meanwhile, the FX futures market has 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 in terms of the total daily average turnover, especially in 2019.

Figure 2
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)



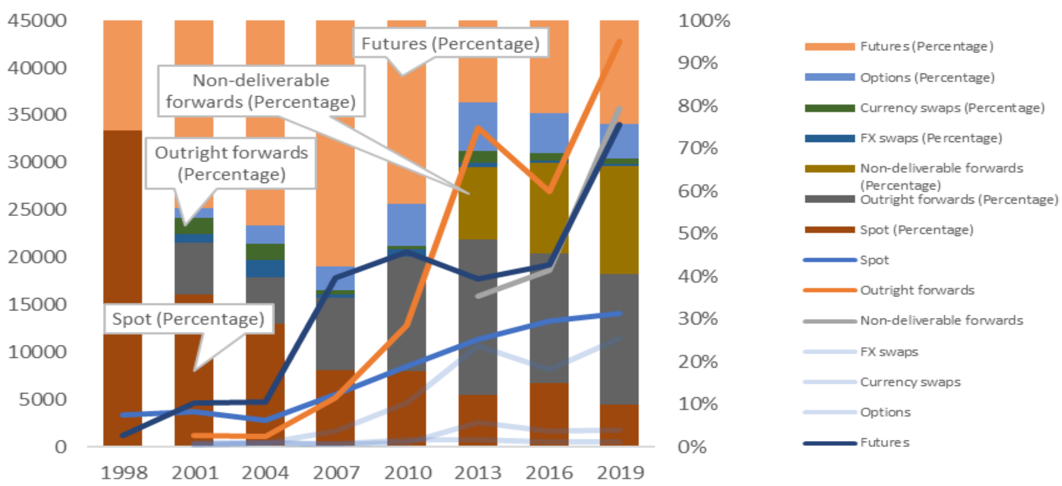
Source: Exchange-traded Derivatives Statistics, BIS.

These differences in both the development of the FX futures market and the FX derivatives market structure in Brazil and India are inherently associated with regulatory backgrounds.

The robust and unique structure of the FX markets in Brazil is related to several regulatory backgrounds – including not only financial regulation but also fiscal policy – and the existence of the FX futures market as the oldest FX derivatives instrument.[5] International Monetary Fund (2018) noted that a relatively small spot FX market in Brazil reflects the regulation constraint that allows only several agents to access the spot FX market directly. Based on the Decree-Law no. 857, every contract, security, document or obligation, in order to be fulfilled in Brazil, cannot stipulate payment in gold or foreign currency, or, in any form, restrict or refuse fulfillment in the Brazilian currency. The exceptions to that 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 in which the creditor or debtor is domiciled outside Brazil (International Monetary Fund, 2015). Since the FX futures contract is non-deliverable; therefore, the resulting of limited internal convertibility gives incentives to hedge in the FX futures market. The Brazilian legal and regulatory framework also puts constraints by levying tax on revenues and cash flows rather than income or value-added; hence, encouraging the migration of trading to exchanges (Upper & Valli, 2016). These restrictions aim to anticipate the adverse-effect of speculation in the spot FX and, on the one hand, it also develops a relatively large and robust FX futures market.

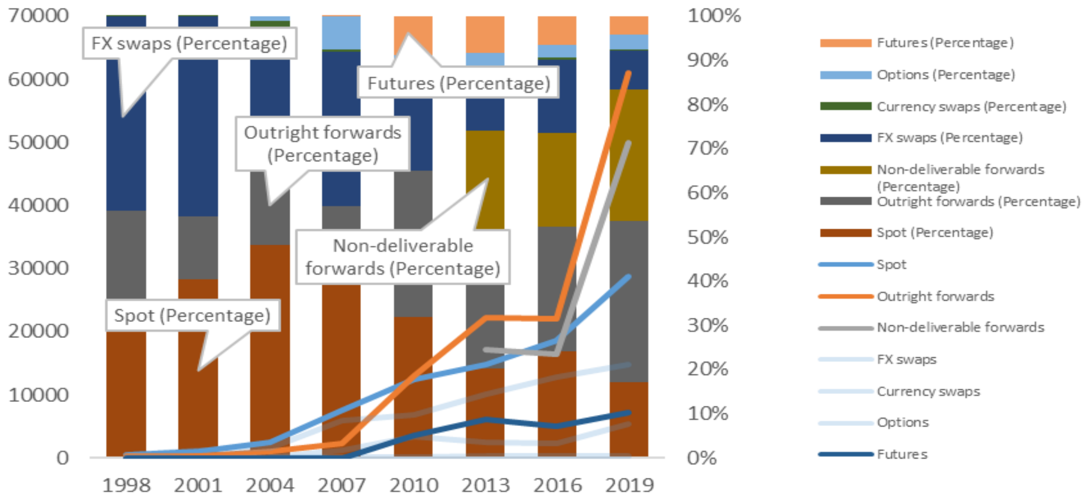
Figure 3
The FX Derivatives Market Activities in Brazil and India, 1998-2019

Panel A Brazil



Panel B India

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



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

The FX futures market also has been serving a vital role in accommodating hedging in Brazil. After the Brazilian currency crisis in the 1990s, the over-burdened foreign debt has encouraged the use of FX futures for hedging (Upper & Valli, 2016). Also, the eligibility to issue the main futures contract (DOL) limited on two groups, i.e., authorized dealers and other companies whose primary activity is related to the transactions regulated for this market (i.e., exporters/importers, permitted financial services and capital flows).[6] It effectively anticipates the misuse of the FX futures market as a hedging market. Given the well-developed FX futures market in Brazil, the price discovery in the Brazilian spot FX market is even highly determined by the FX futures market (M. Garcia, Medeiros, & Santos, 2015).

On the contrary, the FX futures market in India is one of the less developed FX derivatives markets. As we discussed earlier, the FX futures market has only 4 percent of the total daily average derivatives turnover in 2019, although 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.[7,8] The first reason why the FX futures market in India is far less-developed than OTC FX derivates such as forward is that it was introduced lately. While the FX futures was firstly launched in 2008, the OTC FX markets were already becoming the main instrument of the economic agent to manage their risks since India's financial reforms to fully convertible currency in 1994 (Gopinath, 2010). Also, in contrast to the Brazilian FX Futures market, the regulation allows resident individuals to hedge their

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

[7] 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.

[8] 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."*

underlying or anticipated exposures in the FX futures market without any limitation on the background of agents' economic activities. In this regard, therefore, the FX futures market is unlikely to replicate the discipline of ensuring underlying commercial transactions and fulfill the genuine hedging requirements of the participants, which is possible in the OTC market (Gopinath, 2010).

Table 1
Economic-Institutional Differences Between Brazil and India

Aspects	Brazil	India
Economic Transformation	The *Plano Real* (1994)	Financial Reforms (1993)
Introduction of the FX Futures Market	1991	2008
Agent's Eligibility in The FX Futures Market	Restricted	Unrestricted
Development of the FX Futures Market	Well-developed	Least-developed

Let us now summarize the central aspects that differentiate the FX futures market in Brazil and India. The first aspect is the different path of economic transformation between Brazil and India. In Brazil, the *Plano Real* (1994) leads to restricted direct access to the spot market and lower internal convertibility. Only a few agents could directly access the spot market, and BRL is strictly domestic inconvertible. Both restriction on the spot FX market and limited internal convertibility induce the transaction in the derivatives market, and especially in the FX futures market (Upper & Valli, 2016). While Indian financial reforms transformed the INR to be fully convertible (Gopinath, 2010), the non-deliverable contract in the FX futures market inadequately gives incentives to hedge 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 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, In Brazil, the eligibility to issue the main futures contract (DOL) is limited to ensure the well-functioning hedging in the FX futures market. On the contrary, hedging activities in the FX futures market are vulnerable to be misused. Therefore, the FX futures market is unlikely to fulfill the genuine hedging requirements of the participants, which is possible in the OTC market (Gopinath, 2010).

III Empirical Strategy

A. Data and Variables

In this paper, we use two separated time-series data from Brazil and India. 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. For the observation selection, this paper considers the following reasons: First, we utilize the monthly-based data for the estimations in order to incorporate 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 included in India's estimations disregard the Global Financial Crisis; therefore, we select the observation for Brazil from 2011 in order to prevent incomparable observation with India, while minimizing the small observation.[9] By this, our observations 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 with relatively small observations (see in the Robustness Tests section for details).[10]

The details of the description of the variable and descriptive statistics are exhibited in the following two tables (Table 2 and 3):

Table 2
Variable Description

Notes: We operate seasonal adjustment on our variables to avoid seasonal bias in monthly-base data. We also standardize the variables to accommodate the comparative analysis within and between countries using $\breve{x}_i = \left(\frac{x_i - \bar{x}}{\sigma_i}\right)$.

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 (r^d)	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
		Log-differenced	Index	FRED

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

[10] 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).

Variables	Description	Data Transformation	Unit of Account	Source
Economic growth (y^{US})	Industrial Production Index (IPI)			
Trade Balance (TB)	Net export	-	Millions of USD	DOTS, IMF
Import Price	Commodity Import Price Index	Logarithm	Index	DOTS, IMF

Table 3
Descriptive Statistics

Notes: Panel A and B exhibit the results of descriptive statistics for Brazil and India, respectively. Data is normalized using $\tilde{x}_i = \left(\frac{x_i - \bar{x}}{\sigma_i}\right)$. 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.

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
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

	Mean	Median	Maximum	Minimum	Std. Dev.	Observations
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

B. Econometric Method

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:

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

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:

$$Y_t = \alpha + \rho Y_{t-1} + \beta_0 X_t + \beta_1 X_{t-1} + \varepsilon_t \quad (2)$$

Alternatively, by assuming that $|\rho| < 1$, equation (2) 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:

$$Y^* = \frac{\alpha}{1-\rho} + \frac{\beta_0 + \beta_1}{1-\rho} X^* \quad (3)$$

One of the crucial features of the model (3) 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 are calculated as the sum of β. We then proceed to obtain the short-run formation of equation (2) by replacing Y_t with $Y_{t-1} + \Delta Y_t$ and X_t by $X_{t-1} + \Delta X_t$:

$$\Delta Y_t = \alpha + \beta_0 \Delta X_t - (1-\rho) Y_{t-1} + (\beta_0 + \beta_1) X_{t-1} + \varepsilon_t \quad (4)$$

Alternatively, it can be expressed as follows:

$$\Delta Y_t = \alpha + \beta_0 \Delta X_t - (1-\rho)\left[Y_{t-1} - \frac{\alpha}{1-\rho} - \frac{\beta_0 + \beta_1}{1-\rho} X_{t-1}\right] + \varepsilon_t \tag{5}$$

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 employ the ARDL bounds testing approach in which the most straightforward specification is stated as the following equation:

$$\Delta Y_t = \alpha + \sum_{i=1}^{p} \beta_1 \Delta Y_{t-1} + \sum_{i=0}^{p} \beta_2 \Delta X_t + \delta_1 Y_{t-1} + \delta_2 X_{t-1} + \varepsilon_t \tag{6}$$

From equation (6), 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, Shin, & Smith (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 et al. (2001); hence, the H_a cannot be rejected, and the underlying variables are cointegrated over time.

C. The Model Estimates

We aim to study the experience from Brazil and India in utilizing the FX futures market as one of the FX intervention toolkits to manage the exchange rate movements and reduce the exchange rate pass-through effect (ERPT).

For the first model estimate, we adopt a generic exchange rate specification in a simple form of autoregressive distributed lag (e.g., see Richard, 2016). 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:

$$\begin{aligned}\Delta(\log S_t) = \alpha + \sum_{i=1}^{p} \beta_i \Delta(\log S_{t-i}) + \sum_{i=0}^{q} \partial_i \Delta(\log F_{t-i}) + \sum_{i=0}^{v} \gamma_i SI_{t-i} \\ + \sum_{i=0}^{b} \delta_i FI_{t-i} + \boldsymbol{X'\theta} + \varepsilon_t\end{aligned} \tag{7}$$

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).

For the second model estimate, we utilize the standard ERPT model specification (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:

$$\ln \tau_t = \varphi + \sum_{i=0}^{p} \omega_i \ln \tau_{t-i} + \sum_{i=0}^{q} \ell_i \ln S_{t-i} + \sum_{i=0}^{v} \varsigma_i (\ln S_{t-i} \times SI_{t-i}) + \sum_{i=0}^{b} \psi_i (\ln S_{t-i} \times FI_{t-i}) + \mu_t \qquad (8)$$

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 (8) into the long-run equation as follows:

$$\ln \tau_t = \ell \ln S_t + \varsigma(\ln S_t \times SI_t) + \psi(\ln S_{t-i} \times FI_{t-i}) + \mathcal{E}_t \qquad (9)$$

By simplifying equation (9), we then obtain the equation as follows:

$$\ln \tau_t = (\ell + \varsigma SI_t + \psi FI_t) \ln S_t + \mathcal{E}_t$$
$$\ln \tau_t = \lambda \ln S_t + \mathcal{E}_t \qquad (10)$$

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.

D. Unit Root Tests, ARDL Bound Test, and Classical Assumptions

In this section, we perform three crucial pre-estimation tests for the empirical models. 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 fundamental classical assumption tests as follows: Normality test assumption, $\mu_i \sim N(0)$, using Jarque-Berra test; the absence of heteroscedasticity, $var(\varepsilon_i) = \sigma^2$, estimated using Breusch-Pagan-Godfrey; and no autocorrelation, $cov(\varepsilon_t, \varepsilon_k | X_t, X_k) = 0; t \neq k$ (see Gujarati and Porter 2009).

D1. The First Model Estimate

We now begin by discussing the unit root tests. Table (9) exhibits the results of unit root tests for Brazil and India. For Brazil's variables, we generally find that most of the variables are stationary at a different level (see Table 9, Panel A). Specifically, we find that 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's variables, we find that FX intervention and futures-based FX intervention are significantly stationary at the level. For other variables, including 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 a different level, either variable for Brazil, India, or external factors. Therefore, the empirical models estimating the role of futures-based FX intervention on exchange rate dynamics perhaps cointegrate in the long-run (e.g., see Gujarati & Porter, 2009).

Table 4
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 5
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	0.0250
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	38.97410	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).

Let us now proceed by analyzing the ARDL bound tests, which displayed in Table (10). In this case, we specifically employ ten ARDL specifications based on 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 a five percent confidence level. Based on these tests, it thus implies that we should include not only a long-run estimation but also short-run estimation analyzing the error correction mechanism in the empirical model for the case of Brazil and India.

Table 6
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. In this case, we investigate the classical assumption tests for the five-best ARDL specifications. For the case of Brazil, we find that the first three specifications are not normally distributed, while the last two specifications are significantly suffering from heteroskedastic problems. However, all of the five-best specifications are freed from autocorrelation. Furthermore, classical assumption tests for the case of 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 HAC robust standard error for all Indian case regressions, since it contains autocorrelation problems, and for the last two model specifications for the Brazilian case regression as it suffers from heteroskedastic error distribution.

D2. The Second Model Estimate

Let us now begin by discussing the unit root tests, which are displayed in Table (14). For Brazil's variables, we find that import price *(log)* and exchange rate *(log)* are not stationary in level, while the interaction terms variables are already stationary at level for any conventional confidence level. In the first difference, we find that all of 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-different. In contrast, the interaction terms variables are stationary at level. In summary, the variables for Brazil and India are commonly stationary at a different level where import price *(log)* and exchange rate *(log)* are non-stationary at level while the interaction terms variables are stationary. Therefore, the empirical models estimating the role of futures-based FX intervention on exchange rate dynamics perhaps cointegrate in the long-run (e.g., see Gujarati & Porter, 2009).

Table 7
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
		**	*	***	***

		Import Price, *Log*	Exchange Rate, *Log*	Exchange Rate, *Log* × Foreign Exchange Intervention	Exchange Rate, *Log* × Futures-based Intervention
At Level					
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

Table 8
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	1.220830	0.3096
7	ARDL (1,3,1,2)	-0.18815	34.48712	2.180602	0.0797
8	ARDL (1,1,2,3)	-0.18680	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	1.346890	0.2728
6	ARDL (3,1,1,1)	1.804959	-21.2407	0.849400	0.5034
7	ARDL (4,1,1,1)	1.807050	-18.5903	0.880832	0.4857
8	ARDL (1,1,1,4)	1.809675	-18.6507	1.267858	0.3017

No	ARDL Model	SC	Log-likelihood	F Wald test	Prob.
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 (8). In this case, we specifically employ ten ARDL specifications based on Schwartz Criterion (SC). For the model estimate of the Brazilian case, we find that all specifications produce statistically insignificant F-Wald tests, which suggest that these specifications are significantly cointegrated at any confidence level. For the empirical model estimating the case of India, we also find that the entire ARDL specifications are statistically not cointegrated at any confidence level. Based on these tests, it thus implies that our empirical models commonly generate no error correction terms. In this regard, therefore, we focus our empirical estimations on the long-run analysis.

Table 9
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 examine the classical assumptions. In this case, we investigate the classical assumption tests for the five-best ARDL specifications. For the case of 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 prone to autocorrelation and heteroskedasticity regression problems. Furthermore, classical assumption tests for the case of India indicate that four out of five model specifications are normally distributed. However, we find that the empirical models for the Indian case statistically suffer from heteroskedastic error and autocorrelation problems. Based on these tests of classical assumptions violation, we thus perform HAC robust standard error for all empirical models, either the case of Brazil or India.

IV Results and Discussion

A. The Futures-based FX Intervention and Exchange Rate Dynamics

Our main empirical results are displayed in Table (12) and (13), 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.

First, we shed light on the long-run effect of futures-based FX intervention on exchange rate dynamics in Brazil (see Table 12, Panel A). Our long-run estimations consistently indicate that traditional futures-based FX intervention (net purchase) appreciates the Brazilian Reals currency, although it is only statistically significant in column (4) and (5) estimations. This finding is consistent with several works 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; hence, such intervention will affect the relative demand for USD dollars in the market and, as a consequence, the prevailing USDBRL exchange rate.

For the case of India, we find no evidence concerning the long-run effect of the futures-based FX intervention on exchange rate dynamics, although the estimations consistently generate negative coefficients. In this case, we conjecture that several causes distinguish the effectiveness of futures-based FX intervention in India from the case of Brazil. The FX derivatives market structure in India is dominated in the OTC market, while the FX futures market has only 4 percent of the total daily average derivatives turnover. In India, the OTC FX markets were already becoming the main instrument of the economic agent to manage their risks since India's financial reforms to fully convertible currency in 1994 (Gopinath, 2010). 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, which is possible in the OTC market (Gopinath, 2010). Given the structure of the Indian FX derivatives market, the FX operation by the Central Bank in the FX futures mostly neutral in terms of the gross purchases in the FX futures market typically offset the gross sell, which intended merely to ensure that the market is well-functioning (Tripathy, 2013).

Table 10
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]

Panel A: Brazil					
	1	2	3	4	5
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]
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, we find that 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 the case of Brazil, (M. Garcia et al., 2015) have revealed that the FX futures market profoundly influences the price discovery in the Brazilian spot FX market. Besides, it also consistently aligns 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 dominantly driven by net export. Furthermore, we find that external factors have no long-run effect on Real's exchange rate, while the FFR significantly influences Indian Rupee in the long-run. These findings are reasonable since both countries have different institutional settings concerning currency convertibility restrictions. In Brazil, the Plano Real (1994) leads to restricted direct access to the spot market and lower internal convertibility. Only a few agents could directly access the spot market, and BRL is strictly domestic inconvertible, which limits excessive jumps in the exchange rate market (Upper & Valli, 2016), while Indian financial reforms transformed the INR to be fully convertible (Gopinath, 2010).

Table 11
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]
Δ Net Export	-0.013824 (0.008669)	-0.014604* (0.008729)	-0.014762* (0.008763)	-0.010687 [0.008003]	-0.011241 [0.008037]

	1	2	3	4	5
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]

	1	2	3	4	5
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]	
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.

Let us now proceed by discussing the short-run estimations, which are depicted in Table (13). First, we find that futures-based FX intervention in Brazil significantly affects the exchange rate movements in the short-run, where increasing net purchase by the central bank would appreciate the exchange rate, *vice versa*. For the case of 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 policy rate, domestic economic growth, inflation rate, and US economic growth necessarily influence the Indian Rupee exchange rate in the short run. On the contrary, our estimations show that the Brazilian exchange rate dominantly is driven by the internal factor, i.e., inflation rate, in the short run. Moreover, we find that the coefficients of error correction (ECM) are statistically significant at any conventional level, either for the case of Brazil or India. Specifically, our estimations show that the magnitude of ECM for both cases 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, suggesting that both every deviation in Indian and Brazilian exchange rate equilibrium will be corrected in a fluctuating manner.

B. The Futures-based FX Intervention and Exchange Rate Pass-through Effect

Our main empirical results are displayed in Table (17), which portray the long-run estimations analyzing the role of futures-based FX intervention on exchange rate pass-through in Brazil and India.

Let us now begin the empirical investigations on the long-run effect of exchange rate pass-through. For the case of Brazil, we find that elasticity coefficients of exchange rate on import price are statistically significant in the (4) and (5) column estimations at a ten percent confidence level. Specifically, it suggests that the depreciated exchange rate inelastically leads to less efficient import prices. For the case of India, we find an approximately similar case where the depreciated exchange rate would decrease the efficiency of import price. However, the exchange rate pass-through in India is seemingly higher than in Brazil, where the estimated elasticity coefficients approximate the unitary elasticity. Although with different magnitude, these findings confirm the exchange rate pass-through theory where the pass-through mechanisms effectively transmitted by tenacious structures of exchange rate instability that would disrupt trade, leading to a rise in the dollar burden, pushes the price of imported goods. (Menkhoff 2013). Céspedes, Chang, and Velasco (2004) also confirm that weaker local currency in financially vulnerable countries could deteriorate debt to service difficulties, and the balance sheet of domestic banks and firms get worst afterward.

Table 12
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]
Exchange Rate, *Log* × Foreign Exchange Intervention	0.001416 [0.003719]	0.001195 [0.003228]	0.001628 [0.004153]	0.003499 [0.004393]	-0.003369 [0.006680]
Exchange Rate, *Log* × Futures-based Intervention	-0.005154 [0.005784]	-0.00507 [0.004992]	-0.012369 [0.015234]	-0.004786 [0.005753	-0.004286 [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 by investigating 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 evidences, either for the case of Brazil or India, concerning its effect on exchange rate pass-through. For the role of futures-based FX intervention, we find 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 takes net purchases) is approximately perfect, which indicated by the interaction term coefficients of futures-based FX intervention nearly offset the elasticity coefficients of exchange rate on import price (see Panel A, column 4 and 5 estimations). This finding, in general, aligns with Gonzalez, Khametshin, Peydró, & Polo (2019), which found that futures-based FX intervention significantly reduced the negative effect of the depreciated exchange rate during the Global Financial Crisis (GFC) and Taper tantrum on the balance sheet of highly external resilience banks. Specifically, they show that a large futures-based FX intervention program supplying derivatives against FX risks halves the adverse effects of exchange rate depreciation. For the case of India, our empirical results find no evidence regarding the impact of futures-based FX intervention on exchange rate pass-through.

Our findings demonstrate that the role of futures-based FX intervention is more extensive in Brazil than in India. Several factors support the finding. Principally, the derivatives-based FX intervention would be concentrated in the more developed market. In the case of Brazil, the FX derivatives market is more developed in the futures market, while the forwards market is more developed than the futures market. Second, the Brazilian central bank has intervened regularly in foreign exchange markets since the adoption of its floating exchange rate regime in January 1999, including through 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 RBI has also intervened through the FX futures market, but occasionally and in a limited amount. Given the Indian derivatives market mostly concentrated in the OTC market (e.g., forwards), the derivatives-based FX intervention is more extensive in the forwards market. Third, in Brazil, the eligibility to issue the main futures contract (DOL) is limited to ensure the well-functioning hedging in the FX futures market. On the contrary, hedging activities in the FX futures market are vulnerable to be misused. Therefore, the Indian FX futures market is unlikely to fulfill the genuine hedging requirements of the participants, which is possible in the OTC market (Gopinath, 2010).

V Robustness Tests

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

Table 13
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 exchange rate and FX intervention and futures-based FX intervention, which are displayed in Table (18). The empirical results from FM-OLS and D-OLS confirm our empirical results, which states that the FX futures rate significantly drives the actual exchange rate. Second, we find that Brazilian futures-based FX intervention is statistically significant and confirm our primary estimations in D-OLS estimation, while it is statistically insignificant in FM-OLS estimation.

Although FM-OLS generates insignificant parameters, these estimations consistently generate positive parameters, which support our primary estimation. For the case of India, we find that the futures-based FX intervention is significantly positive at one percent confidence level in FM-OLS estimation. It suggests that futures-based FX intervention in India depreciates the exchange rate. However, the estimated parameter from the FM-OLS estimation seemingly biases due to the small sample, while D-OLS is superior against small sample bias (Masih & Masih, 1996). In this case, therefore, we can conclude that futures-based FX intervention in India does not affect exchange rate dynamics, which confirm our primary estimations.

Table 14
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.

For the second robustness checks, we examine the consistency of our empirical findings concerning the role of futures-based FX intervention on exchange rate pass-through in Brazil and India. Based on our robustness estimations, Brazilian futures-based FX intervention is effective in weakening the exchange rate pass-through effect, which is indicated by statistically significant coefficients at any conventional level. Based on the FM-OLS and D-OLS estimations, we specifically find that futures-based FX intervention could reduce the exchange rate pass-through effect by about 47 percent to 77 percent. For the case of India, we find that futures-based FX intervention has relatively no effect in reducing exchange rate pass-through. Although we find that it is statistically significant at a ten percent confidence level in D-OLS, we cannot conclude that the Indian futures-based FX intervention significantly affects the exchange rate pass-through since it is statistically weak, resulting in near-zero parameters, and generally inconsistent compared to the majority of estimations.

VI Concluding Remarks

In this paper, we examine the effectiveness of futures-based FX intervention in determining the exchange rate dynamics and exchange rate pass-through in India and Brazil. As we mentioned earlier, they are strikingly different in terms of operating such intervention. In general, the

Brazilian Central Bank (BCC) regularly operates the futures-based FX intervention from March 2002, while the Reserves Bank of India (RBI) still use it occasionally and in a limited way. This investigation allows us to evaluate and take a lesson learned from those countries' policy designs and outcomes in utilizing the futures-based FX intervention. Specifically, this investigation also could answer whether the magnitude and frequency of the intervention and the fundamental aspects of economic background are matter in determining the effectiveness of futures-based FX intervention

Our empirical results show that the futures-based FX interventions in Brazil are effective in determining the exchange rate movement and exchange rate pass-through, while it is the opposite of the case of India. The results are also confirmed in the robustness checks estimations. This finding sheds light on several crucial features that differentiate the case of Brazil and India. Specifically, it 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.

References

Adler, G., Lama, R., & Medina, J. P. (2019). Foreign exchange intervention and inflation targeting: The role of credibility. *Journal of Economic Dynamics and Control*, *106*. https://doi.org/10.1016/j.jedc.2019.07.002

Baltagi, B. H. (2008). *Econometrics*. Verlag Berlin Heidelberg: Springer. https://doi.org/10.1007/978-3-540-76516-5

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

Bhaumik, S. K., & Mukopadhyay, H. (2000). RBI' s in Foreign Intervention Exchange Market. *Economic and Political Weekly*, *35*(5), 373–376.

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

Calvo, G. A., & Reinhart, C. M. (2002). Quarterly Journal of Economics, 2004- . *Quarterly Journal of Economics*, *CXII*(August), 1998–2006.

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

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

Clarida, R., Galí, J., & Gertler, M. (2001). Optimal monetary policy in open versus closed economies: An integrated approach. *American Economic Review*, *91*(2), 248–252. https://doi.org/10.1257/aer.91.2.248

F.S. Mishkin, & K. Schmidt-Hebbel. (2001). One Decade of Inflation Targeting in the World What Do We Know and What Do We Need to Know. *NBER Working Paper Series 8397, National Bureau of Economic Research, Cambridge*, *3*.

Garcia, C. J., Restrepo, J. E., & Roger, S. (2011). How much should inflation targeters care about the exchange rate? *Journal of International Money and Finance*, *30*(7), 1590–1617. https://doi.org/10.1016/j.jimonfin.2011.06.017

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

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

Gonzalez, R., Khametshin, D., Peydró, J.-, & Polo, A. (2019). Hedger of last resort: evidence from Brazilian FX interventions, local credit, and global financial cycles. *Economics Working Papers*, (83).

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

Gujarati, D. N., & Porter, D. C. (2009). *Basic Econometrics*. (A. E. Hilbert, Ed.) (Fifth Edit). 1221 Avenue of the Americas, New York, NY, 10020: McGraw-Hill/Irwin.

India, R. B. of. (2008). *Report of the Internal Working Group on Currency Futures*. Mumbai.

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

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

Jaffri, A. A. (2010). Exchange rate pass-through to consumer prices in Pakistan: Does misalignment matter? *Pakistan Development Review*, *49*(1), 19–35. https://doi.org/10.30541/v49i1pp.19-35

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

Laeven, L., & Valencia, F. (2013). Systemic banking crises database. *IMF Economic Review*, *61*(2), 225–270. https://doi.org/10.1057/imfer.2013.12

Masih, R., & Masih, A. M. M. (1996). Stock-Watson dynamic OLS (DOLS) and error-correction modelling approaches to estimating long- and short-run elasticities in a demand function: New evidence and methodological implications from an application to the demand for coal in mainland China. *Energy Economics*, *18*(4), 315–334. https://doi.org/10.1016/S0140-9883(96)00016-3

Masson, P. R., Savastano, M. A., & Sharma, S. (1997). *The Scope for Inflation Targeting in Developing Countries* (IMF Working Paper No. WP/97/130).

McCallum, B. T. (2007). INFLATION TARGETING FOR THE UNITED STATES? *Cato Journal*, *27*(2), 261–271.

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

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

Mishkin, F. S., & Savastano, M. A. (2001). Monetary policy strategies for Latin America. *Journal of Development Economics*, *66*(2), 415–444. https://doi.org/10.1016/S0304-3878(01)00169-9

Mohanty, M. S., & Klau, M. (2010). *Monetary Policy Rules in Emerging Market Economies : Issues and Evidence*. (L. R.J. & de S. L.V., Eds.), *Monetary Policy and Macroeconomic Stabilization in Latin America*. Berlin, Heidelberg: Springer. https://doi.org/10.1007/3-540-28201-7_13

Nedeljkovic, M., & Saborowski, C. (2017). The Relative Effectiveness of Spot and Derivatives Based Intervention: The Case of Brazil. *IMF Working Papers*, *17*(11), 1. https://doi.org/10.5089/9781475571035.001

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

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

Pesaran, M. H., & Shin, Y. (1999). An Autoregressive Distributed-Lag Modelling Approach to Cointegration Analysis. In S. Strom (Ed.), *Econometrics and Economic Theory in the 20th Century* (pp. 371–413). Cambridge: Cambridge University Press. https://doi.org/10.1017/CCOL521633230.011

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, *16*(3), 289–326. https://doi.org/10.1002/jae.616

Phillips, P. C. B. (1995). Fully Modified Least Squares and Vector Autoregression. *Econometrica*, *63*(5), 1023–1078.

Richard, F. (2016). Econometric modeling of exchange rate determinants by market classification: an empirical analysis of japan and south Korea using the sticky-price monetary theory. *Economic Policy*, (October), 0–33. https://doi.org/10.1227/01.NEU.0000349921.14519.2A

Taylor, J. B. (2001). The role of the exchange rate in monetary-policy rules. *American Economic Review*, *91*(2), 263–267. https://doi.org/10.1257/aer.91.2.263

Tripathy, R. (2013). Intervention in foreign exchange markets: the approach of the Reserve Bank of India. *BIS Paper*, (73), 169–176.

Upper, C., & Valli, M. (2016). Emerging derivatives markets? *BIS Quarterly Review*, (December), 67–80.

Xu, J., Du, Q., & Wang, Y. (2019). Two-sided heterogeneity and exchange rate pass-through. *Economics Letters*, *183*, 108534. https://doi.org/10.1016/j.econlet.2019.108534