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Central Bank Intervention and Exchange Rate Volatility in the Inflation-Targeting Regime

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Abstract
This paper examines the impact of central bank intervention on the exchange rate fluctuations within the framework of inflation-targeting. Focusing on Indonesia, the Philippines, and Thailand from 2005(7) to 2022(12), empirical analysis using quantile regression demonstrates that the central bank intervention mitigates real exchange rate volatility. However, there is a discernible upward linear trend in the coefficient related to market intervention. While overall behavior tends to be symmetrical, selling intervention and interventions during depreciation periods differently affect real exchange rate volatility across quantiles. Those results underline the importance for monetary authorities to consider shifts in exchange rate expectations over the medium term. Accordingly, the selective implementation of market intervention, tailored to the dynamics of real exchange rate volatility, is essential for upholding the credibility of inflation-targeting monetary policy.

Keywords: Foreign reserves, Central bank intervention, Exchange rate volatility, Quantile regression

JEL classification: E52, E58, F31, G15

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1. Introduction

The inflation targeting (IT) adoption for maintaining a low and stable inflation rate is well documented in monetary economic literature (Ha et al., 2019; Cabral, et al., 2020). Alongside its success, the efficacy of IT in mitigating exchange rate volatility remains challenging. Standard theory postulates that an ideal IT regime should not conduct along with an exchange rate target (Obstfeld et al., 2005). The increase in exchange rate volatility within the IT framework is as a consequence of removing from the fixed exchange rate to flexible exchange rate systems (Edwards, 2006) but keeps providing lower volatility (Berganza and Broto, 2012).

However, the low degree of exchange rate pass-through in the IT regime leads to destabilizing the domestic inflation rate, which suppresses its external value (Kuncoro, 2015). The primary instrument of using policy rate to stabilize future inflation expectation proves ineffective in controlling exchange rate fluctuations (Kuncoro, 2020). The emerging markets with IT have more managed exchange rate arrangements. Consequently, the exchange rate in IT regime is more volatile (Chițu and Quint, 2018) and the frequency of market intervention is higher (Sikarwar, 2020).

The studies on central bank intervention have grown up and constitute a great body of international finance literature. Deploying foreign reserves, the market interventions not only stabilize the exchange rate volatility but also influence its overall magnitude (Kearns and Rigobon, 2005). Conversely, the central bank interventions might either induce the volatility of exchange rate (Frenkel et al., 2005) or have a minimal influence on exchange rate volatility over extended periods (Dominguez, 2006). Moreover, the intense interventions frequently result in sterilization, thereby posing the systemic financial risks (Agenor et al., 2020).

Despite interventions in most IT countries more helpful to reduce volatility, their effectiveness for individual IT countries are divergent. The foreign exchange purchases in Colombia appreciate the exchange rate and reduce its volatility both in the short-term and the medium-term (Echavarría et al., 2010). The reduction in the reserves in Korea boosts the home currency to appreciate in the long-run (Law, 2019). Market intervention is more sound in Chile when the level of foreign reserves are sufficient and when the level of exchange rate is high (Hansen and Morales, 2019).

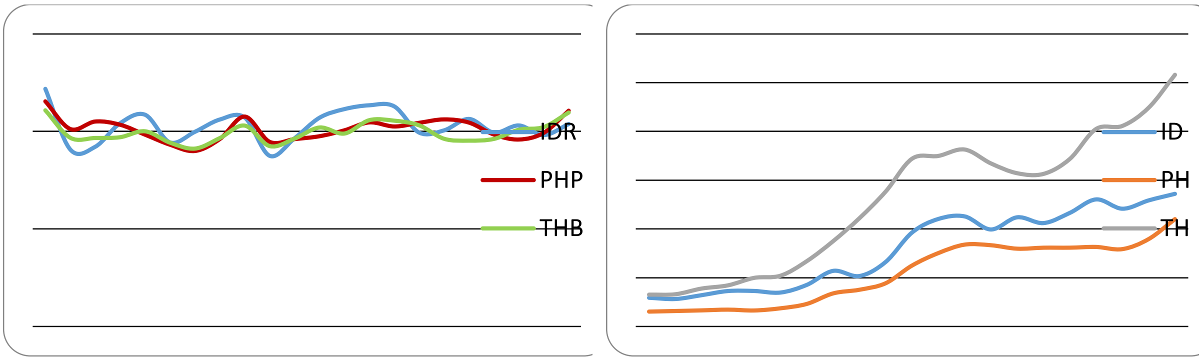
Others focus on the effectiveness of market intervention by considering its characteristics. The impact of sale interventions in Slovakia is pronounced compared to the purchasing interventions (Banerjee et al., 2018). On the contrary, the purchasing operations in Turkey have no impact on the exchange rate movements and volatility (Tümtürk, 2019). Hence, there is a discrepancy regarding the extent or direction of the effects of market intervention in IT countries on exchange rate volatility, warranting further examination.

Indonesia, the Philippines, and Thailand are not an exception. The three emerging countries in Southeast Asia were worst affected by the 1997/1998 monetary crisis. After implementing an IT regime in the early 2000s, they experienced low inflation rates and steady exchange rates (Fermo and Lemence, 2014; Raksong, 2021). The stable exchange rate fluctuations were supported by the increase in foreign reserves. Figure 1 clearly illustrates the stylized fact of the relationship between the stable exchange rate and foreign reserves accumulation.

However, our inquiry revolves around the durability of their stable exchange rates – whether they are persistent or temporary. As small-open economies, their individual economic performances exert minimal influence on the global economy. Furthermore, adopting the regime of floating exchange rate renders their currencies susceptible. Meanwhile, like many other emerging Asian economies, they face substantial external risks in the medium term, making it risky to reduce reserves to attract potential speculative attacks.

The main contribution of this paper is the use of non-linear quantile regression in conjunction with the natures of market intervention as well as exchange rate fluctuations. The quantile regression accommodates outlier observations, which are frequently found in developing countries. A non-linear quantile regression model might capture the asymmetric impact of market intervention on the exchange rate volatility across the entire distribution, considering purchases/sales and appreciation/depreciation. The paper is structured in the following manner. Following the introduction, Section 2 outlines the methodology and dataset. Subsequently, Section 3 presents the main empirical results. Finally, the last section offers a conclusion.

Figure 1 - Exchange Rate and Foreign Reserves



Exchange Rate Fluctuations (%) Foreign Reserves Stock (million USD)

Source: http://data.imf.org accessed on January 24, 2024

2. Research Method

Most empirical studies on the exchange rate volatility above relied on the GARCH (Generalized Autoregressive Conditional Heteroscedasticity) model. The GARCH type models primarily concentrate on calculating the conditional mean function, with mean effects obtained via conditional mean regression. Consequently, the distributional impact attributes are not entirely discerned, potentially leading to biased covariate effects. Some studies have employed alternative methodologies, such as regime switching, to address these limitations (Taylor, 2004) and vector autoregression (Wang and Zhao, 2021) but with ambiguous results. Others (Huang et al., 2011; Tümtürk, 2022) employ quantile regression without incorporating market intervention.

Utilizing quantile regressions in analyzing foreign exchange market intervention presents several benefits. Quantile regression offers a robust or reliable estimator even when there are outlier observations in the dependent variable dataset. It is also well-suited for a dataset suffering highly diverse conditions. Moreover, it provides distinct estimators for each quantile, enabling evaluation of the distribution of the dependent variable and identification of the most effective policy options.

Adler et al. (2021) highlighted that monetary authorities aiming to achieve both inflation and exchange rates stability tend to intervene more frequently, leading to potential overshooting of the exchange rate. This indicates that the dispersion of unconditional currency volatility is often right-skewed. The prevalence of positively skewed currency volatility and frequent market interventions indicates that the intervention coefficient increases with quantiles, implying the influence of intervention on currency volatility is more significant for higher quantiles.

The unconditional model of quantile regression can be employed to explore the association between market intervention (*fr* represented by the change in the logarithmic real foreign reserve) and exchange rate volatility (v) (Koenker and Bassett, 1978).

$$v_t = a + b\,\Delta fr_t + \varepsilon_t \qquad (1)$$

where v represents the real exchange rate (*er*) volatility, expressed as the quotient of its standard deviation to its mean. Each variable is computed by using a 12-month moving average.

$$v_t = \sqrt{\frac{\sum_i^{12} (er_i - \overline{er})^2}{n-1}} \div \overline{er} \quad (2)$$

The moving average and first-difference treatments will smooth the seasonal component which are embodied in the time series data.

The coefficients of *a* and *b* represent the unidentified parameters requiring estimation, with the expected sign of *b* being positive. We hypothesize that central bank involvement could potentially decrease exchange rate volatility. By imposing the quantile ranging from 0 to 1, we can observe the complete distribution of the dependent variable conditioned with respect to the explanatory variables.

The central bank market intervention is publicly unavailable. The relative change in foreign reserves depicts the central bank intervention (Lin and Wang, 2009; Berganza and Broto, 2012; Daude et al., 2016). Buying foreign exchange increases reserves and selling foreign exchange reduces reserves. The unconditional exchange rate volatility is estimated by splitting up the relative change in foreign reserve into buying and selling:

$$d_1 = \begin{matrix} 1 - if \Delta fr_t > 0 \\ 0 - if \Delta fr_t \leq 0 \end{matrix} \text{ and } d_2 = \begin{matrix} 1 - if \Delta fr_t < 0 \\ 0 - if \Delta fr_t \geq 0 \end{matrix} \quad (3)$$

where *d* is a dummy variable. Substituting (3) into (1), we have:

$$v_t = a + b_1 [d_1 \times \Delta fr_t] + b_2 [d_2 \times \Delta fr_t] + \varepsilon_t \quad (4)$$

The symmetric impact of buying or selling states on the exchange rate volatility can be carried out by using the Wald test.

Similar to (3), we can also set the central bank intervention in the foreign exchange market based on the appreciation and depreciation states.

$$d_3 = \begin{matrix} 1 - if\ \Delta\ er_t > 0 \\ 0 - if\ \Delta\ er_t \leq 0 \end{matrix} \text{ and } d_4 = \begin{matrix} 1 - if\ \Delta\ er_t < 0 \\ 0 - if\ \Delta\ er_t \geq 0 \end{matrix} \quad (5)$$

Substituting (5) into (1), we have:

$$v_t = a + b_1 [d_3 \times \Delta fr_t] + b_2 [d_4 \times \Delta fr_t] + \varepsilon_t \quad (6)$$

Equations (4) and (6) could also address the asymmetry and non-linearity obstacles commonly encountered in financial markets, providing a comparable alternative to the GARCH method.

Given our focus on volatility levels, we necessitate extensive and dependable time series data on currency values and foreign reserves. Exchange rates are denoted as the US Dollar price against the respective domestic currencies (Rupiah, Peso, and Baht). The foreign reserve basket encompasses diverse overseas financial holdings managed by the bank of central, quantified in billion US Dollars, and readily accessible for any balance of payments requirements.

The real terms of these variables stem from price levels, with price levels determined by the CPI (Consumer Price Index), using a base year of 2012 (indexed at 100). By transforming all variables into real terms, our model inherently accounts for inflation rates. The sample period spans from July 2005 to December 2022, capturing the adoption of the IT regime in the three countries. This yields a total of 210 sample points. All monthly data is sourced from the central banks of Indonesia, the Philippines, and Thailand.

3. Results and Discussion

Descriptive statistics illustrated on Table 1 details exchange rate volatility and foreign reserves for each country. The mean values of all variables of interest exhibit minimal disparity among them. Furthermore, the proximity of mean values to their respective medians implies a normal distribution of exchange rate volatility and foreign reserves across the three countries.

Nevertheless, the skewed distribution of exchange rate volatility data is evident from positive skewness values. As noted by Adler et al. (2021), the distribution of exchange rate volatility tends to be slightly right-skewed. On the contrary, the foreign reserves distribution is left-skewed, indicated by the negative value of skewness. It suggests that most of the foreign reserves in the three countries during the observation period were lower than the expected (or mean) value.

Table 1 - Descriptive Statistics

	Indonesia		The Philippines		Thailand	
	v	fr	v	fr	v	fr
Mean	0.03	11.34	0.03	11.00	0.03	11.93
Median	0.03	11.39	0.02	11.17	0.03	12.05
Maximum	0.10	11.75	0.07	11.36	0.08	12.39
Minimum	0.01	10.78	0.01	10.02	0.01	10.97
Std. Dev.	0.02	0.20	0.01	0.36	0.01	0.35
Skewness	1.34	-0.76	1.29	-1.29	0.95	-1.26
Kurtosis	4.13	3.21	4.78	3.43	4.02	3.77
Jarque-Bera	74.08	20.71	85.74	60.10	40.62	61.05
Probability	0.00	0.00	0.00	0.00	0.00	0.00
Observations	210	210	210	210	210	210

Source: the author's calculation.

Exchange rate volatility could be induced by the sharp depreciation and appreciation. The descriptive statistics from two types of change in the exchange rate reports on Table 2. Most of the relative changes in exchange rate in the three countries is unproportionally over the observation period. The appreciations are 86-81 cases and the depreciation are 118-123 cases respectively. Each value of depreciation and appreciation states does not vary indicated by the low distance between maximum and minimum values along with their standard deviation.

Comparing Table 1 and 2 offers an interesting figure. Exchange rate volatility might be related more to depreciation rather than appreciation. Accordingly, the central bank intervention is directed more to handle depreciation rather than appreciation, indicated by the negative value of skewness of the foreign exchange reserves. The mass of foreign exchange reserves mostly occupy in the lower-tail due to the selling intervention. This raises a preliminary hypothesis that market intervention will be effective to dampen the currency volatility.

Table 2 - Exchange Rate Appreciation and Depreciation

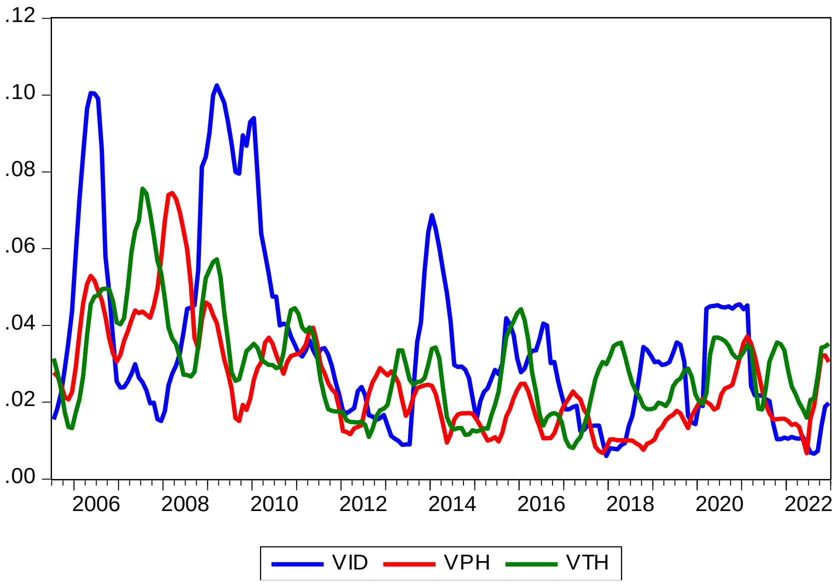
	Indonesia		The Philippines		Thailand	
	Δ er >0	Δ er <0	Δ er >0	Δ er <0	Δ er >0	Δ er <0
Mean	0.02	-0.02	0.01	-0.01	0.01	-0.01
Median	0.01	-0.01	0.01	-0.01	0.01	-0.01
Maximum	0.17	0.00	0.04	0.00	0.05	0.00
Minimum	0.00	-0.10	0.00	-0.04	0.00	-0.06
Std. Dev.	0.03	0.02	0.01	0.01	0.01	0.01
Skewness	3.31	-2.23	1.56	-1.03	1.29	-1.50
Kurtosis	16.19	8.85	5.45	3.80	4.18	5.69
Jarque-Bera	816.52	268.41	56.17	24.83	30.38	79.88
Probability	0.00	0.00	0.00	0.00	0.00	0.00
Observations	90	119	86	123	91	118

Source: the author's calculation.

How large is the currency volatility in each country? Figure 2 presents the exchange rate volatility. Indonesia exhibits the highest currency fluctuation compared to the Philippines and Thailand, as evidenced by the substantial gaps between the highest and lowest values and their standard deviation. The high exchange rate volatility experienced in 2006 in accordance with the end of commodity boom, around 2008 associated with the global financial crisis, and around 2014 in relation to 'mini crisis'. In the pandemic Covid-19, the exchange rate volatility was relatively moderate.

Those economic turbulences have urged the central banks of the three countries in response to economic downturns and various monetary measures have been implemented to initiate economic recovery and stabilization programs. During the COVID-19 pandemic, all three countries introduced diverse economic stimulus packages aimed at revitalizing declining purchasing power trends. Given those phenomena, market intervention to reduce the exchange rate volatility would produce different results. It will be checked using quantile regression in the subsequent section.

Figure 2 - Real Exchange Rate Volatility



Source: the author's calculation.

Before addressing the research problems, it is necessary to examine the stationarity of the dataset. Stationarity necessitates that the series data possess a unit root, ensuring valid regression outcomes and unchanging estimates. Two conventional unit root tests are employed: the Augmented Dickey-Fuller (ADF) test and the ADF test with structural break. Each test is conducted on the exchange rate, its volatility, and the central bank intervention data.

As presented in Table 3, both tests accept the null hypothesis of unity roots at 5 percent significance level. It appears that the exchange rate, its volatility, and the central bank intervention data series for the three countries are integrated of order zero (*I(0)*). It implies that although structural breaks exist, any shock's impact will dissipate over time, and the three data series will converge towards their steady-state average. Ultimately, the three variables typically trend towards alignment with the steady-state equilibrium relationship as posited by relevant theory.

Table 3 - Unit Roots Test

	v		er		Δ fr	
	t-stat	Break Point	t-stat	Break Point	t-stat	Break Point
Indonesia	-3.3005**	-	-3.3005**	-	-11.9051***	-
	-5.0170***	2009M10	-5.0170***	2009M10	-12.4924***	2008M10
The Philippines	-3.0209**	-	-3.0209**	-	-7.2039***	-
	-6.4264***	2008M12	-6.4264***	2008M12	-11.6673***	2011M08
Thailand	-3.9790***	-	-3.9790***	-	-10.9032***	-
	-7.1954***	2011M04	-7.1954***	2011M04	-12.2461***	2008M03

Note: *** and ** denote significance at 1% and 5% levels respectively.
Source: the author's calculation.

Does central bank intervention effectively reduce the exchange volatility? Table 4 showcases the estimation results of Equation (1) through both Ordinary Least Squares (OLS) and quantile regressions. The results of the conditional mean in the first column demonstrate that the OLS estimate, ranging from 0.13 to 0.17, is statistically significant at the 1 percent level of significance. This finding, exhibiting the expected sign, preliminarily supports the efficacy of central bank involvement in the foreign exchange market as many researchers found in the introduction section.

Divergent findings emerge for quantiles ranging from 0.10 to 0.90 in the conditional median. Specifically, in Indonesia, the coefficient b is solely significant for the 0.90 quantile. For the Philippines, the corresponding coefficient is statistically significant for quantiles below 0.90. In the case of Thailand, the coefficients b are determined to be statistically significant for the second-half quantiles. They suggest that the efficacy of market intervention differs depending on the level of exchange rate volatility.

For coefficients significant at the 1 percent in a specific equation, the size of the coefficients for the Philippines remains consistent across quantiles. Conversely, in Thailand, the quantile regression estimation for exchange rate volatility exhibits an up-ward linear trend. At this point, the efficacy of market intervention depends on the intensity of intervention. Hence, dividing the change in market intervention into the buying and selling states will allow a clearer explanation.

Table 4 - Estimation Results of Quantile Regression

	OLS	Quantile				
		0.10	0.25	0.50	0.75	0.90
Indonesia						
C	0.03***	0.01***	0.02***	0.03***	0.04***	0.07***
Δ fr	0.13***	0.08	0.11	0.10	0.12	0.35***
Pseudo R^2	0.04	0.03	0.02	0.02	0.01	0.04
Adj R^2	0.03	0.02	0.02	0.01	0.00	0.04
S.E.R	0.02	0.03	0.03	0.02	0.02	0.05
The Philippines						
C	0.02***	0.01***	0.01***	0.02***	0.03***	0.04***
Δ fr	0.14***	0.11***	0.16***	0.19***	0.14***	0.09
Pseudo R^2	0.05	0.03	0.05	0.05	0.03	0.01
Adj R^2	0.04	0.03	0.05	0.05	0.03	0.01
S.E.R	0.01	0.02	0.02	0.01	0.02	0.02
Thailand						
C	0.03***	0.01***	0.02***	0.03***	0.04***	0.04***
Δ fr	0.17***	-0.02	0.09	0.17***	0.19***	0.25***
Pseudo R^2	0.09	0.00	0.02	0.05	0.06	0.08
Adj R^2	0.08	0.00	0.02	0.05	0.06	0.07
S.E.R	0.01	0.02	0.02	0.01	0.01	0.02

Note: *** denotes significance at 1% levels.
Source: the author's calculation.

Partitioning the intervention component with respect to the buying and selling states produces an intriguing outcome. As shown in Table 5, the OLS regression outcomes for Indonesia and the Philippines show that the selling foreign exchange *($\Delta fr < 0$)* does not affect the currency volatility, which confirms the study of Tümtürk (2019). The similar result is obtained for quantile regression for all specifications. We conclude that there is no different impact of selling involvement on the exchange rate volatility either in the lower-quantile or the upper-quantile.

In the context of Indonesia, the magnitude of the coefficient for the buying state ($\Delta fr > 0$) coefficient is indifferent among the quantiles. Conversely, the quantile process estimates for the selling state portray a linearly rising pattern, extending from 0.25 to 0.30. The same results are found in the case of the Philippines (from 0.15 to 0.29) and Thailand (from 0.16 to 0.20). Hence, the impact of purchasing interventions is stronger than the selling interventions, which denies the study of Banerjee *et al.* (2018) in the case of Slovakia. Nevertheless, most symmetry tests suggest that there is no discernible difference in impact selling and buying states pertaining to currency volatility.

Table 5 - Estimation Results of the Market Intervention Based on Buying and Selling

	OLS	Quantile				
		0.10	0.25	0.50	0.75	0.90
Indonesia						
C	0.03***	0.01***	0.01***	0.02***	0.04***	0.06***
Δ fr < 0	-0.05	0.03	0.02	-0.11	-0.14	0.05
Δ fr > 0	0.30***	0.15	0.28***	0.34***	0.40***	0.55***
Pseudo R^2	0.07	0.04	0.03	0.04	0.05	0.06
Adj R^2	0.06	0.03	0.02	0.03	0.04	0.05
S.E.R	0.02	0.03	0.03	0.02	0.02	0.04
Symmetric	No	Yes	Yes	No	No	Yes
The Philippines						
C	0.02***	0.01***	0.01***	0.02***	0.03***	0.04***
Δ fr < 0	0.06	0.03	0.11	0.10	0.07	0.17
Δ fr > 0	0.17***	0.18***	0.18***	0.25***	0.25***	0.05
Pseudo R^2	0.05	0.04	0.06	0.06	0.03	0.01
Adj R^2	0.04	0.03	0.05	0.05	0.02	0.00
S.E.R	0.01	0.02	0.02	0.01	0.01	0.02
Symmetric	Yes	Yes	Yes	Yes	Yes	Yes
Thailand						
C	0.03***	0.01***	0.02***	0.02***	0.03***	0.04***
Δ fr < 0	0.07	-0.08	-0.03	-0.03	0.10	0.22***
Δ fr > 0	0.23***	0.16	0.25***	0.30***	0.25***	0.30***
Pseudo R^2	0.10	0.01	0.05	0.06	0.07	0.08
Adj R^2	0.09	0.00	0.04	0.05	0.06	0.07
S.E.R	0.01	0.02	0.02	0.01	0.01	0.02
Symmetric	Yes	Yes	No	No	Yes	Yes

Note: *, **, and *** denote significance at 10%, 5%, and 1% levels, respectively.
Source: the author's calculation.

Splitting up the market intervention component in relation to exchange rate depreciation and appreciation states as Equation (6) does not change the initial conclusion. As presented in Table 6, the OLS regression results for Indonesia show that the market intervention at the depreciation state ($d(\Delta er<0)*\Delta fr$) affects the exchange rate volatility reduction, which confirms Kearns and Rigobon (2005). The similar result is obtained for most quantile regression specifications. We conclude that there is a different impact of intervention at the depreciation and appreciation states on the exchange rate volatility either in the lower-quantile or the upper-quantile.

For the case of the Philippines and Thailand, the market intervention at the time of depreciation does not have any impact on the exchange rate volatility. Conversely, during depreciation, market intervention effectively decreases exchange rate volatility in the upper quantiles. However, all symmetric tests prove that there is no different impact of depreciation and appreciation states on the exchange rate volatility. It means that the central banks of Philippines and Thailand do not aggressively intervene in the foreign exchange market either in the depreciation or appreciation states.

Table 6 - Estimation Results of the Market Intervention Based on Depreciation and Appreciation

	OLS	Quantile				
		0.10	0.25	0.50	0.75	0.90
Indonesia						
C	0.03***	0.01***	0.02***	0.03***	0.04***	0.07***
d(Δer<0)*Δfr	0.30***	0.17*	0.23***	0.22***	0.34***	0.41***
d(Δer>0)*Δfr	-0.06	0.03	-0.01	-0.06	-0.10	-0.29**
Pseudo R^2	0.10	0.05	0.05	0.04	0.06	0.08
Adj R^2	0.09	0.04	0.04	0.03	0.05	0.07
S.E.R	0.02	0.03	0.03	0.02	0.02	0.04
Symmetric	No	Yes	No	No	No	No
The Philippines						
C	0.02***	0.01***	0.01***	0.02***	0.03***	0.04***
d(Δer<0)*Δfr	0.16***	0.17***	0.18***	0.22***	0.23**	0.12
d(Δer>0)*Δfr	0.10	0.04	0.12	0.12	0.16**	0.12
Pseudo R^2	0.05	0.04	0.06	0.05	0.03	0.01
Adj R^2	0.04	0.03	0.05	0.05	0.02	0.00
S.E.R	0.01	0.02	0.02	0.01	0.01	0.02
Symmetric	Yes	Yes	Yes	Yes	Yes	Yes
Thailand						
C	0.03***	0.01***	0.02***	0.03***	0.04***	0.05***
d(Δer<0)*Δfr	0.12**	-0.05	0.11	0.15**	0.12**	0.13
d(Δer>0)*Δfr	0.20***	0.03	0.09	0.17***	0.22***	0.32***
Pseudo R^2	0.09	0.00	0.02	0.05	0.07	0.08
Adj R^2	0.08	-0.01	0.01	0.04	0.06	0.08
S.E.R	0.01	0.02	0.02	0.01	0.01	0.02
Symmetric	Yes	Yes	Yes	Yes	Yes	Yes

Note: *, **, and *** denote significance at 10%, 5%, and 1% levels, respectively.
Source: the author's calculation.

To confirm our findings, we also perform dummy variables to accommodate the global financial crisis (2008-2009) and pandemic Covid-19 (2020 and so forth). The 2008 global financial crisis significantly affected the exchange rate volatility in the three countries, primarily for Indonesia. Meanwhile the effect of pandemic Covid-19 on the exchange rate volatility was little for the Philippines or even insignificant for Thailand. These results confirm the previous analysis on Figure 1 and unit roots test. Overall, the sign, magnitude, and significance of the market intervention coefficients do not change, implying that our models are robust for each country.

Furthermore, it is important to assess whether the outcomes of the basic model are statistically equivalent to those of the expanded model. Table 7 displays the Wald test for comparing the equivalence of slope coefficients among quantiles for each nation. In the case of Indonesia, there are slight disparities in slope coefficients among quantiles. Some slope coefficients substantially vary among 0.90th quantiles pairwise. For the Philippines, the only different slope coefficient is 0.75th-0.90th quantiles pairwise. For Thailand, most of the 0.1th and 0.9th quantiles pairwise are significantly different.

Those results confirm that the market intervention (selling and appreciation states) exerts a more pronounced influence in the upper quantiles of exchange rate volatility, supporting the findings of Hansen and Morales (2019). Such results suggest that within the IT regime, monetary authorities should account for potential shifts in exchange rate expectations over the medium term as a crucial policy objective to uphold long-term exchange rate stability. Failure to manage changes in exchange rate expectations could potentially result in persistent high volatility.

Table 7 - Wald Test for Slope Equality across Quantiles

Quantile	0.10	0.25	0.50	0.75	0.90
0.10	Indonesia	1.16	1.94	5.91*	9.06**
0.25			0.66	3.16	6.74**
0.50				3.96	6.52**
0.75					3.98
0.10	The Philippines	1.22	1.12	2.77	0.20
0.25			0.53	0.57	0.95
0.50				0.13	1.35
0.75					4.98*
0.10	Thailand	3.06	6.89**	6.54**	12.36***
0.25			1.38	1.77	5.05*
0.50				0.94	4.73*
0.75					2.79

Note: *, **, and *** denote significance at 10%, 5%, and 1% levels, respectively.
Source: the author's calculation.

4. Conclusion

This paper aims to analyze the effect of market intervention on the exchange rate volatility in the case of three IT countries. The results of quantile regression indicate that market intervention reduces the exchange rate volatility. Notably, the coefficient associated with market intervention exhibits an upward linear trend, with quantile process estimates being higher in upper quantiles compared to lower quantiles. This suggests an escalating effect of central bank intervention on exchange rate volatility.

Central bank intervention affects exchange rate volatility differently across the three countries. Quantile process estimates for Indonesia on the buying state are notably higher compared to the Philippines and Thailand. However, the impact of buying foreign exchange predominantly influences the upper quantile of the distribution of real exchange rate volatility. Similarly, central bank intervention during periods of depreciation exerts a more significant effect pertaining to the upper quantile of the distribution of real exchange rate volatility, particularly evident in Indonesia and the Philippines.

Furthermore, the distinct impacts of central bank intervention on currency volatility are evident not only across quantiles but also within quantiles. Those findings suggest that central bank intervention in the foreign exchange market in each country should be selective following the nature of the real exchange rate volatility. The central bank intervention during depreciation in terms of selling foreign exchange could reduce exchange rate volatility. However, it will seriously affect the domestic money supply, and inflation rates, potentially undermining the credibility of IT monetary policy. The selective market intervention can control not only the exchange rate volatility but also inflation rates. Eventually, IT countries may not necessarily pursue dual objectives of exchange rate and inflation stability.

The market intervention in this paper is limited on the purchasing/selling and depreciation/appreciation states. Further research is recommended to differentiate foreign reserves into sterilized and unsterilized states so that the exchange rate stabilization policy will be more targeted.

Conflict of Interest

The authors declared no potential conflict of interest with respect to the research, authorship and/or publication of this article.

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