The Relationship Between Currency Substitution and Exchange Rate Volatility

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Abstract

This study examines the relationship between the rate of currency substation on nominal exchange rate volatility in eight sample countries (the Philippines, Czech Republic, Indonesia, Poland, Peru, Nigeria, and Hungary). The sample period considered is in the 2000s. Threshold ARCH model is employed to account for the ratchet effect of currency substitution and to proxy exchange rate volatility as the conditional variances of the depreciation rate of exchange rate. Additionally, Vector Autoregression (VAR) and Vector Error Correction Model (VECM) approaches were used to further explore the relationship. Impulse Response Functions (IRF) were used to examine the responses of the variables to shocks. The results of TARCH regression show significant positive correlation between currency substitution and exchange rate volatility in 4 countries and significant negative correlation in 2 countries. VAR results show that currency substitution Granger causes exchange rate volatility in 4 countries and the opposite in 4 countries. IRF results show in 5 countries, shocks to currency substitution rate leads to increases in exchange rate volatility in the short-run. VECM results show that in the long-run, exchange rate volatility has significant association with currency substitution in all countries with cointegrating relationship between the variables.

Keywords: Currency Substitution, Exchange Rate Volatility, TARCH, VAR, VECM

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Contents

1 Introduction **3**

2 Literature Review **4**
2.1 Currency Substitution 4
2.2 Econometric Methodology 5

3 Empirical Method **6**
3.1 Threshold ARCH Model 6
3.2 Vector Error Correction Model 8

4 Data **11**

5 Empirical Results **15**
5.1 Threshold ARCH Model 15
5.2 Vector Error Correction Model 16
5.2.1 Reduced-Form Estimation Results 17
5.2.2 Impulse Response Functions 18
5.2.3 Vector Error Correction Model 20

6 Conclusion **21**

Appendix A Data Sources **25**

Appendix B Vector Autoregression Model **26**

Appendix C Diagnostic Tests: VAR **27**

Appendix D Diagnostic Tests: VECM **29**

1 Introduction

The relationship between currency substitution and exchange rate volatility in emerging economies is a topic investigated by many in both theoretical and empirical literature. Currency substitution can be defined as the phenomenon where the domestic residents of a country prefer using more stable foreign currencies such as the U.S. Dollar or Euro as opposed to using their home currency as a means of payment. This is a common characteristic of emerging and transitioning economies that went through periods of high inflation. It is worth studying the relationship between currency substitution and exchange rate volatility because when a country is experiencing high levels of currency substitution, the domestic money demand for home currency depends on both the domestic and foreign nominal interest rates. As a result, the currency becomes more unstable and volatile.

The decision to use domestic or foreign currency for domestic residents depends on two main factors: the currency's usefulness as a means of payment and as a store of value. The usefulness of a currency is determined mainly by the acceptability, the more people use the currency, the more widely it is accepted, thus useful. Therefore, a foreign currency is more useful in a country if the currency substitution level is high. As a result, when inflation rate, as well as the nominal interest rate differential and rate of exchange rate depreciation in the country falls, domestic residents could remain using foreign currency if it has good store of value. This also implies that if there is a relationship between currency substitution and exchange rate volatility, the different direction of exchange rate shocks could have contrasting effect on currency substitution level. In that case, negative shocks to the exchange rate cause the currency substitution level to increase rapidly, affecting the exchange rate volatility significantly. On the other hand, positive shocks to the exchange rate generate only mild reactions, affecting the exchange rate volatility only slightly. Kumamoto and Kumamoto (2014) describe this phenomenon as the ratchet effect of currency substitution. To account for the ratchet effect, I will be employing the Threshold AutoRegressive Conditionally Heteroskedastic (TARCH) Model.

This study examines the relationship between the degree of currency substitution and exchange rate volatility in eight sample countries (the Philippines, Czech Republic, Indonesia, Poland, Peru, Nigeria, and Hungary). I use sample periods in the 2000s. I follow the approach taken by Kumamoto and Kumamoto (2014) by using the TARCH model to proxy the exchange rate volatility as a conditional variance of the depreciation rate of the nominal exchange rate. I also use the TARCH method to investigate the relationship between currency substitution and exchange rate volatility. The TARCH model takes into account the ratchet effect of currency substitution. In addition to the TARCH model, I will be employing Vector AutoRegression (VAR) Model and Vector Error Correction Model (VECM) to further explore the relationship between currency substitution and exchange rate volatility. Granger causality test and impulse response functions will allow me to investigate the relationship in more detail. Granger causality test can be used to account for the possibility of bidirectional relationship. Finally, VECM estimation will be used to check for long-run relationship between currency substitution and exchange rate volatility.

The remainder of the paper is organized as follows. Section 2 reviews related literature, while Section 3 outlines the econometric techniques used. Section 4 provides insights into the data use, while Section 5 presents the results. Section 6 concludes.

2 Literature Review

2.1 Currency Substitution

The earliest studies regarding currency substitution and nominal exchange rate volatility can be dated back to 1981. Kareken and Wallace (1981) used the overlapping-generations (OLG) model to show that the equilibrium exchange rates are indeterminate in the laissez-faire regime. They demonstrate the potential for instability in nominal exchange rate through an extreme example of two monies being perfect substitutes. Girton and Roper (1981) similarly demonstrate that currency substitution can cause instability because as currency substitution increases, shifts in anticipated rate of exchange rate change can produce unlimited volatility in the exchange rates.

More recently, there is a significant number of empirical literature that discuss the significance of currency substitution and exchange rate volatility especially in developing or transitioning economies. Clements and Schwartz (1993) analyze the determinants of currency substitution in Bolivia. Isaac (1989) utilizes a conventional small open economy macro model to explore new implications of currency substitution. The author finds that higher degrees of currency substitution can intensify movements in exchange rate in response to commodity demand shocks, which imply that currency substitution increases exchange rate volatility. Yinusa and Akinlo (2008b) in a study using a multi-perspective unrestricted portfolio balance approach, find that Nigeria has significant currency substitution and exchange rate variability was responsible for driving such phenomenon.

2.2 Econometric Methodology

Akçay et al. (1997) employed an Exponential General Autoregressive Conditional Heteroskedasticity (E-GARCH) model to measure the effect of currency substitution on the conditional variance of exchange rate depreciation. They demonstrate evidence for the effect of degree of currency substitution on exchange rate volatility for the Turkish Lira-US Dollar exchange rate. Kumamoto and Kumamoto (2014) examines the effects of the level of currency substitution on nominal exchange rate volatility in seven countries (Indonesia, the Philippines, the Czech Republic, Hungary, Poland, Argentina, and Peru). Using the Threshold Autoregressive Conditional Heteroskedasticity (TARCH) model proposed by Glosten et al. (1993) and Zakoian (1994), Kumamoto and Kumamoto (2014) showed that the level of currency substitution has statistically significant positive impacts on the exchange rate volatility in the majority of the sample countries.

On the other hand, there are also research that show evidence against the relationship between currency substitution and exchange rate volatility. Petrovic et al. (2016) empirically investigated the effect of currency substitution on exchange rate depreciation volatility using Serbia as a case study. Using a modified EGARCH-M model, they find that there is no relationship between currency substitution level and monthly log depreciation rate volatility in Serbia.

Asari et al. (2011) used Vector Error Correction Model (VECM) approach to analyze the relationship between interest rate, inflation rate and exchange rate volatility in Malaysia using time series data between 1999-2000. They also used Impulse Response Function (IRF) to explain the effects of shocks to one variable on other endogenous variables. Yinusa and Akinlo (2008b) applied Granger causality test on time series data from Nigeria from 1986 and 2003 to investigate the relationship between nominal exchange rate volatility and dollarization. Khin et al. (2017) employed VECM to test for short-run and long-run relationships between exchange rate volatility and various macroeconomic variables in Malaysia.

Zardad et al. (2013) employed autoregressive conditional heteroskedasticity (ARCH), generalized autoregressive conditional heteroskedasticity (GARCH) and Vector Error Correction model (VECM) on time series data from Pakistan. The conditional variance of exchange rate (volatility) was estimated using ARCH and GARCH model and VECM was used to determine the short-run dynamics of the system. Similarly, Menyari (2018) used EGARCH modeling to determine exchange rate volatility and used VECM to analyze the impact of exchange rate volatility on Moroccan exports.

3 Empirical Method

3.1 Threshold ARCH Model

One of the empirical method that will be employed in this paper is the TARCH model that was developed by Glosten et al. (1993) and Zakoian (1994), and was used by Kumamoto and Kumamoto (2014). The TARCH model will allow me to estimate the exchange rate movement as a conditional variance of the depreciation rate of the nominal exchange rate of the domestic currency while accounting for the ratchet effect of currency substitution. In addition to Kumamoto and Kumamoto (2014), I will be adding an additional control variable VIX index[1] VIX index is widely recognized as a measurement for volatility (Whaley, 2000) (Whaley, 2009). The model specification for TARCH model is:

$$\Delta s_t = \alpha + \beta_1(i_t - i_t^*) + \beta_2 vix_t + \varepsilon_t \tag{1}$$

$$E_{t-1}[\varepsilon_t] \sim N(0, \sigma_t^2) \tag{2}$$

$$\sigma_{\mathrm{t}}^2 = \mu + \delta cs_t + \sum_{j=1}^{q} \boldsymbol{\kappa}_j \boldsymbol{\sigma}_{t-j}^2 + \sum_{i=1}^{p} \lambda_i \varepsilon_{t-i}^2 + \sum_{k=1}^{r} \boldsymbol{\eta}_k \boldsymbol{\varepsilon}_{t-i}^2 I_{t-k}^- \tag{3}$$

where $I_t^- = 1$ if $\varepsilon_t < 0$ and 0 otherwise.

s_t is a natural logarithm of the nominal exchange rate defined by the price of domestic currency in term of foreign currency (US Dollars or Euro). This implies that an increase in s_t represents the appreciation of the domestic currency. i_t and i_t^* represent nominal domestic interest rate and nominal foreign interest rate (LIBOR or EURIBOR), respectively. vix_t represents the VIX index. The level of currency substitution is denoted by $cs_t = m_{F,t} + s_t - m_{H,t}$ and $m_{F,t}$ where $m_{H,t}$ represent the natural logarithms of demand deposits denominated in domestic and foreign currency, respectively. Equation (1) is a simple linear regression of the change in the log of nominal exchange rate on the nominal interest rate differential and VIX index. This equation is inspired by the uncovered interest rate parity (UIP) condition and states that the nominal exchange rate is determined by both the interest rate differential and risk factors. The residual, ε_t and vix_t, capture the deviations from the UIP condition if $\beta = 1$. Equation (2) means that $\varepsilon_{t-1}[\varepsilon_t$ is a random variable normally distributed with mean 0 and variance σ_t^2. Equation (3) is the TARCH variance equation and the coefficient, δ, measures the impact of the degree of currency substitution on the conditional variance.

In our empirical model, $\varepsilon_t > 0$, represents a positive UIP shock that causes an appreciation of the domestic currency and has an effect of λ_i, while $\varepsilon_t < 0$, represents a negative UIP shock that causes a depreciation of the domestic and has an effect of $\lambda_i + \eta_i$. $\eta_i \neq 0$, indicate that the effect of the UIP shock is asymmetrical and $\eta_i > 0$ indicate the existence

[1] VIX index, published by the Chicago Board Options Exchange (CBOE), estimates the 30-day expected volatility of the U.S. stock market using real-time, mid-quote prices of S&P 500 Index (SPXSM) call and put options.

of the ratchet effect discussed previously. The domestic residents react to UIP shocks differently depending on the direction of the shock. If the ratchet effect exists, the domestic residents react to negative UIP shock by increasing their degree of currency substitution, whereas they react only slightly to positive UIP shocks. This means a negative UIP shock would exaggerate exchange rate volatility while a positive UIP shock wouldn't impact exchange rate volatility. Consequently, if the ratchet effect of currency substitution exists, the expected sign of η_i is positive.

Furthermore, the δ in Equation (2) estimates the association between the degree of currency substitution and exchange rate volatility. $\delta > 0$ indicates that there is a positive relationship between the degree of currency substitution and exchange rate volatility, meaning higher degree of currency is associated with higher exchange rate volatility.

In addition to exploring the relationship between currency substitution and exchange rate volatility, the TARCH regression will be used to extract the conditional variance that will be used to estimate exchange rate volatility. The estimated exchange rate volatility will be used as a variable for the Vector Error Correction Models (VECM) in the next section.

3.2 Vector Error Correction Model

In addition to TARCH regression estimation, I will be using the Vector Error Correction Models (VECM) to explore the relationship between currency substitution and exchange rate volatility. When using time series data in any empirical study, it is important to start by looking at the stationarity since many statistical approaches to analyze time series data rely on the stationarity of the data. If two series are not stationary, then the estimation could be spurious. A time series is considered a stationary process if both its mean and auto-covariances are constant over time (i.e. no unit root) and finite.

$$x \text{ level:} \qquad x_t \tag{4}$$

$$x \text{ 1st-differenced value:} \qquad x_t - x_{t-1} \tag{5}$$

A series is considered $I(0)$, or integrated of order 0, if it is stationary at level (no differencing), and $I(1)$, or integrated of order 1, if it is stationary when first differenced. To test for stationarity, I will be using the Augmented Dickey-Fuller (ADF) test suggested by Dickey and Fuller (1979) to test if the variables are stationary. Monte Carlo experiments by Schwert (1989) suggest that unit root tests different finite-sample distribution, making them sensitive to specification. Since it is better to error on the side of including too many lags, I will be using lag(4) as specification for all the ADF tests.

The VAR method relies on the implicit assumption of known lag order (Hamilton, 1994). However, in empirical application, the optimal lag order is rarely known so it has to be determined before estimating VAR. I will be using various lag-order selection tests[2] (LR, AIC, and FPE tests) to determine the optimal lag-order for each country.

Since I will be using VAR and VECM, I will be estimating the variables in levels. When there is cointegration between two or more of $I(1)$ variables, estimating first differenced variables in VAR models will lead to misspecification and a VECM needs to use level of cointegrated series. According to Hamilton (1994), it is not appropriate to fit a vector autoregression to the differenced data if there is cointegration between the variables. Johansen (1988) also suggested that using variables at levels for VECM suggests long-run relationship between the variables. As a result, I will be using currency substitution rate and exchange rate volatility at levels.

In order to determine the number of cointegration vectors, I will be using the Johansen test for cointegration developed by Johansen and Juselius (1990). I will be using both the Maximum eigenvalue statistic test and the trace statistic test to test for cointegration

[2]To conserve space, the lag-order selection test results are not presented here but is available on request.

between currency substitution and exchange rate volatility at levels. VECM will be applied to countries with cointegrated variables, since cointegration suggest long run stable relationship between the variables.

The identified model is a two variable VAR model. Each equation is an autoregression plus distributed lag with p lags of each variable.

$$CS_t = \mu_1 + \alpha_{11}CS_{t-1} + \alpha_{12}CS_{t-2} + \cdots + \alpha_{1p}CS_{t-p} + \tag{6}$$

$$\beta_{11}ERV_{t-1} + \beta_{12}ERV_{t-2} + \cdots + \beta_{1p}ERV_{t-p} + e_{2t} \tag{7}$$

$$ERV_t = \mu_2 + \alpha_{21}CS_{t-1} + \alpha_{22}CS_{t-2} + \cdots + \alpha_{2p}CS_{t-p} + \tag{8}$$

$$\beta_{21}ERV_{t-1} + \beta_{22}ERV_{t-2} + \cdots + \beta_{2p}ERV_{t-p} + e_{2t} \tag{9}$$

CS_t is the currency substitution rate defined by the ratio of demand deposits denominated in foreign currency and total demand deposits. ERV_t is the exchange rate volatility estimated by TARCH regression as the conditional variance of the depreciation rate of the nominal exchange rate of the domestic currency. Both variables in the system are endogenous. I will be using VAR estimation to explore the short-run relationship between CS and ERV, and additionally, VECM to explore the long-term relationship if the variables are cointegrated. The regression equation form for VECM is specified as follows:

$$CS_t = \alpha + \Sigma_{i=1}^{n}\phi_i CS_{t-1} + \Sigma_{j=1}^{n}\rho_j ERV_{t-1} + u_{1t} \tag{10}$$

$$ERV_t = d + \Sigma_{i=1}^{n}\phi_i CS_{t-1} + \Sigma_{j=1}^{n}\rho_j ERV_{t-1} + u_{2t} \tag{11}$$

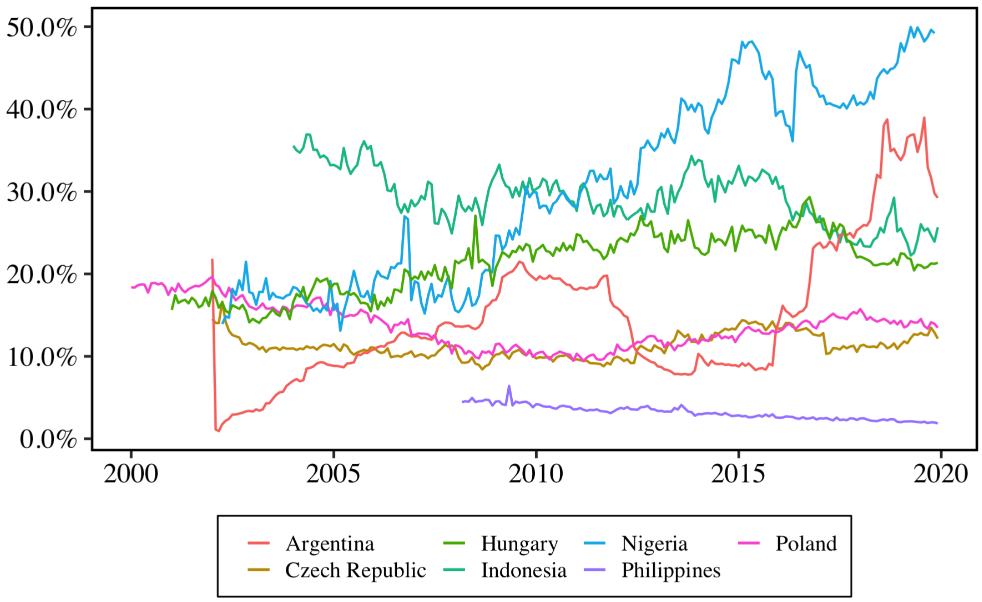
Finally, I will be using impulse response functions (IRFs) to measure the effects of one standard deviation shock to an endogenous variable on itself and on another endogenous variable. This will generate visual explanation of the effect of changes in currency substitution on exchange rate volatility.

4 Data

The sample of eight emerging countries chosen for this study includes three European nations (the Czech Republic, Poland, Hungary), two Asian nations (Indonesia and the Philippines), two South American nations (Argentina and Peru), and one African nation (Nigeria). The chosen countries were largely inspired by Kumamoto and Kumamoto (2014) and the availability of monthly data for demand deposits. Nigeria was added to the analysis since Yinusa and Akinlo (2008a) find empirical evidence on the relationship between exchange rate volatility, currency substitution, and monetary policy shocks in Nigeria.

In addition to adding Nigeria to the analysis, this study covers longer data period than Kumamoto and Kumamoto (2014). The data used in this paper is a monthly time series data covering various time periods between 2000 and 2019. Each country had different data availability, leading to different time periods for each country. The sample time period was chosen due to data availability and the fact that it covers the time in which the macroeconomy in the merging countries were relatively stable and when the foreign currency (US Dollars or Euro) was generally depreciating against the domestic currencies.

Figure (1) Degree of currency substitution in the sample countries

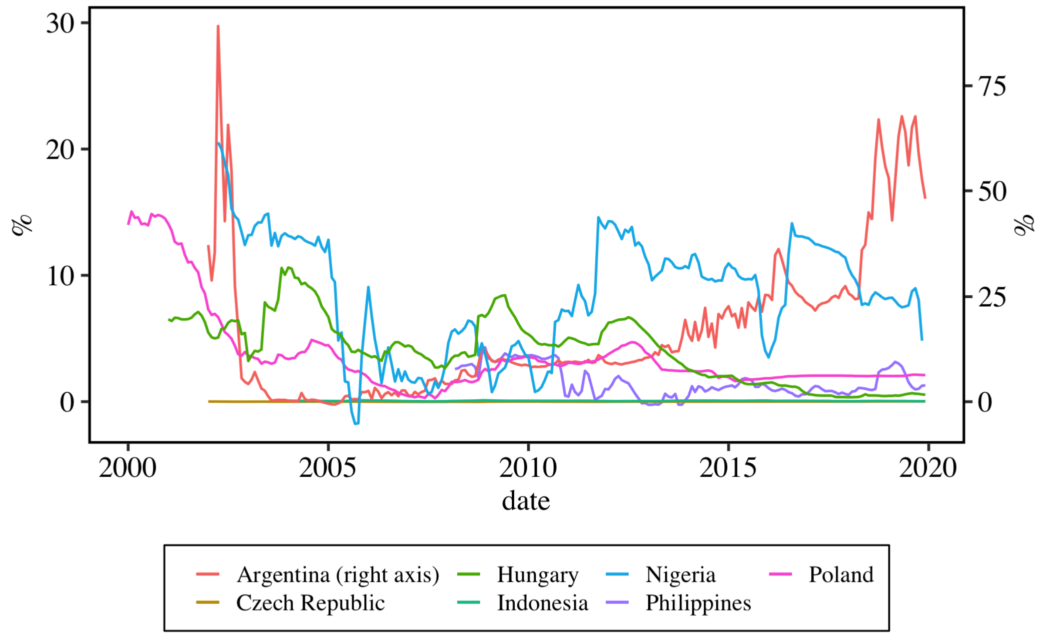


Note: Degree of currency substitution is defined by the proportion of demand deposits in foreign currency relative to total deposits.

The total amount of foreign currency in circulation and demand deposits denominated in foreign currency is often used to calculate the nominal balance of a foreign currency. However, it is difficult to accurately measure and collect data on foreign currencies in circulation. As a result, I use as a proxy the demand deposits denominated in foreign currency for nominal balance of foreign currency. Correspondingly, I also use as a proxy the demand deposits denominated in domestic currency for nominal balance of the domestic currency. The data on demand deposits are sourced from the central bank of the countries. The nominal exchange rate is defined by the price of domestic currency in terms of foreign currency. This is used to calculate the rate of depreciation of the nominal exchange rate[3].

[3]Exchange rate data for all the countries were sourced from CEIC Data.

Figure (2) Nominal interest rate differential



Note: The nominal interest rate differential is defined as difference between each nation's monthly average three-month interbank offered rate and the three-month LIBOR or EURIBOR. The domestic interest rate for the Philippines and Nigeria are the Treasury Bill rate with 91 days. The right axis is for Argentina, while the left axis is for the other countries.

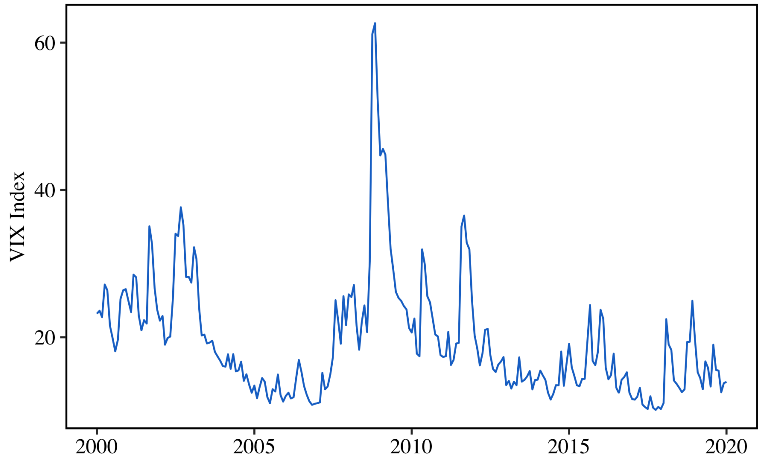
Additionally, I calculate the nominal interest rate differential by taking the difference of the domestic interbank offered rate[4] and London Interbank Offered rate (LIBOR)[5] or Euro Interbank Offered Rate (EURIBOR)[6]. The foreign interest rate is LIBOR for Asian, South American, and African countries and EURIBOR for European countries. Owing to data availability, the nominal interest rate for the Philippines and Nigeria are proxied by Treasury Bill rate with 91 days. VIX index data was sourced from FRED.

[4]Interbank offered rates were sourced from central banks, CEIC Data, and FRED

[5]Monthly LIBOR data was sourced from FRED.

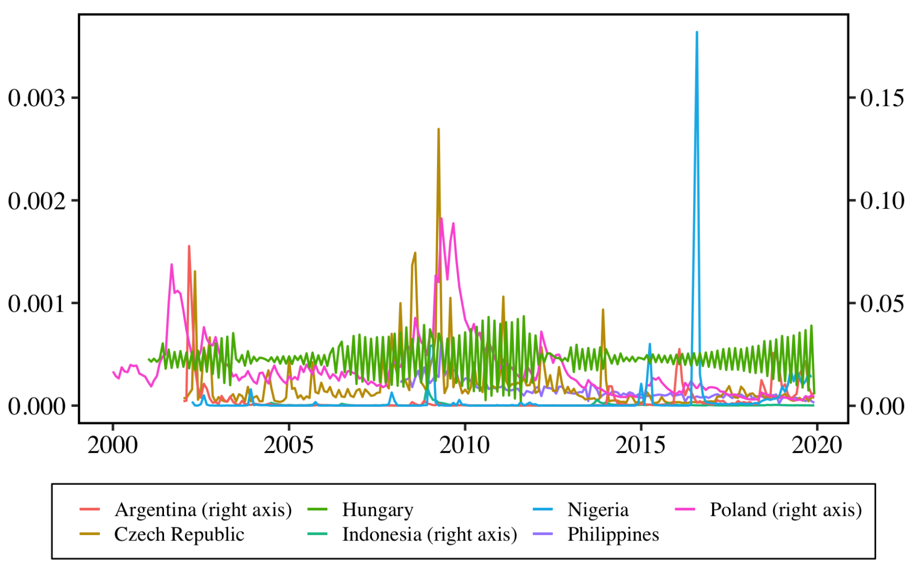
[6]Monthly EURIBOR data was sourced from the ECB Statistical Data Warehouse.

Figure (3) CBOE Volatility Index (VIX)



For the VECM analysis, I transform the monthly time series data of currency substitution rate and exchange rate volatility into quarterly average data for simpler interpretation. I use the same data as TARCH regression to calculate the currency substitution rate for each country. Exchange rate volatility was extracted as the conditional variance of the depreciation rate of the nominal exchange rate of the domestic currency from TARCH regression.

Figure (4) Exchange rate volatility



Note: The exchange rate volatility for each country is defined by the conditional variances of the depreciation rate of the nominal exchange rate estimated from TARCH(1,1,1) estimation. The right axis is for Argentina, Poland, and Indonesia, while the left axis is for the rest of the countries.

5 Empirical Results

5.1 Threshold ARCH Model

Table (1) TARCH(1,1,1) regression results

	(1) Philippines	(2) Czech	(3) Indonesia	(4) Poland	(5) Argentina	(6) Peru	(7) Nigeria	(8) Hungary
β_1: *i-i**	-0.319**	-3.670	-19.63**	-0.0935**	0.145***	0.0227	0.0102***	-0.1315*
	(0.005)	(0.673)	(0.007)	(0.002)	(0.000)	(0.199)	(0.000)	(0.054)
β_2: *VIX*	0.000384*	0.000222*	0.000419**	0.000883***	-0.000177**	0.0000691	0.000155***	0.00076***
	(0.017)	(0.028)	(0.002)	(0.000)	(0.009)	(0.377)	(0.000)	(0.000)
α	-0.00107	-0.00356*	0.00555	-0.0122***	0.0000456	-0.00206	-0.00390***	-0.00925**
	(0.658)	(0.044)	(0.273)	(0.000)	(0.972)	(0.183)	(0.000)	(0.018)
HET								
δ: *cs*	2.031***	-3.430***	0.794	-3.006	1.733***	-1.102*	8.137***	0.0223***
	(0.000)	(0.000)	(0.665)	(0.096)	(0.000)	(0.018)	(0.000)	(0.010)
μ	-9.717***	-5.472***	-16.65	-13.02***	-11.80***	-10.25***	-50.16***	-7.095
	(0.000)	(0.000)	(0.272)	(0.000)	(0.000)	(0.000)	(0.000)	
ARCH								
λ: ARCH	-0.152	1.015***	0.121	0.208*	1.479***	0.938***	9.176***	0.0653***
	(0.072)	(0.000)	(0.312)	(0.032)	(0.000)	(0.000)	(0.000)	(0.000)
η: TARCH	0.0433	-0.643*	0.560***	-0.0605	0.0495	0.162	-4.350*	-0.0048
	(0.777)	(0.034)	(0.001)	(0.519)	(0.865)	(0.674)	(0.018)	(0.751)
κ: GARCH	0.106	0.0145	0.531***	0.794***	0.337***	0.103	0.0228*	-1.053***
	(0.881)	(0.852)	(0.000)	(0.000)	(0.000)	(0.097)	(0.014)	(0.000)
Observations	141	215	191	241	215	239	212	228

Note: *p*-values are reported in parentheses (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$)

Table 1 shows the empirical results of running TARCH regression on the sample countries. The results show that the degree of currency substitution has statistically significant association with the conditional variance of the depreciation rate of the nominal exchange rate in most countries except Indonesia and Poland. I find significant positive relationship in the Philippines, Argentina, Nigeria and Hungary at the 0.1% level, and significant negative relationship in Czech Republic at the 0.1% level and in Peru at the 5% level. The results imply that an increase in the currency substitution rate increases exchange rate volatility in half of the sample countries, but decreases exchange rate volatility in Czech Republic and Peru. Contrary to my expectation, I only find the existence of the ratchet effect in Indonesia at the 0.1% level. The coefficient for the TARCH term is statistically significant for Czech Republic and Nigeria but the sign is negative, which is opposite of what I hypothesized. This result may suggest that UIP shocks might not have asymmetric effects on the exchange rate volatility depending on the direction of the shocks. It could also suggest that domestic residents adjust currency substitution rate in similar magnitude to both depreciation and appreciations shocks.

5.2 Vector Error Correction Model

Table (2) Augmented Dickey-Fuller unit root test

	Philippines		Czech		Indonesia		Poland	
Variable	Level	1st Diff	Level	1st Diff	Level	1st Diff	Level	1st Diff
CS	0.7801	0.0037***	0.4965	0.0019***	0.4137	0.0023***	0.3192	0.0103**
ERV	0.5842	0.0000***	0.3689	0.0002***	0.0195*	0.0001***	0.1081	0.0009***

	Argentina		Peru		Nigeria		Hungary	
Variable	Level	1st Diff	Level	1st Diff	Level	1st Diff	Level	1st Diff
CS	0.1884	0.0404**	0.2709	0.0005***	0.9612	0.0036***	0.5470	0.0002***
ERV	0.3212	0.0000***	0.0114	0.0000***	0.0239**	0.0000***	0.0090***	0.0000***

Note: *reported values represent p-values* (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)

The standard Augmented Dickey-Fuller (ADF) unit root test was employed to test the order of integration of currency substitution rate (CS) and exchange rate volatility (ERV). The results are reported in Table 2. Based on the ADF unit root test statistic, CS was non-stationary at level for all countries, but became stationary after taking the first differences. ERV was non-stationary at level for most countries except for Nigeria and Hungary that were stationary at level. The ERV for rest of the countries became stationary after taking the first differences.

Table (3) Johansen cointegration test

		Philippines			Czech			Indonesia			Poland		
Rank	Params	Eigenvalue	Trace Statistics	5% Critical Value	Eigenvalue	Trace Statistics	5% Critical Value	Eigenvalue	Trace Statistics	5% Critical Value	Eigenvalue	Trace Statistics	5% Critical Value
0	6	.	6.5597*	15.41	.	28.9234	15.41	.	28.8314	15.41	.	17.0563	15.41
1	9	0.11128	1.1331	3.76	0.29657	4.2984	3.76	0.31464	5.4067	3.76	0.16403	2.9022*	3.76
2	10	0.02433			0.05956			0.08351			0.03607		

		Argentina			Peru			Nigeria			Hungary		
Rank	Params	Eigenvalue	Trace Statistics	5% Critical Value	Eigenvalue	Trace Statistics	5% Critical Value	Eigenvalue	Trace Statistics	5% Critical Value	Eigenvalue	Trace Statistics	5% Critical Value
0	6	.	38.2892	15.41	.	17.7105	15.41	.	30.3093	15.41	.	37.3348	15.41
1	9	0.41250	1.0580*	3.76	0.17379	2.8196*	3.76	0.35502	0.0505*	3.76	0.37409	2.6626*	3.76
2	10	0.01500			0.03550			0.00073			0.03534		

Johansen cointegration test was used to estimate the cointegration rank. I use maximum eigenvalue test and trace statistic test to determine the cointegration rank. The results are presented in Table 3. The trace statistic test the null hypothesis of no cointegration among the variables and rejects the null if there is one cointegrating relationship between the CS and ERV. The results show that there is one cointegrating equation, in five countries. As a result, I will proceed to run VECM on those five countries and unrestricted VAR on the other three countries with no cointegration among the variables.

5.2.1 Reduced-Form Estimation Results

Table (4) Granger causality test

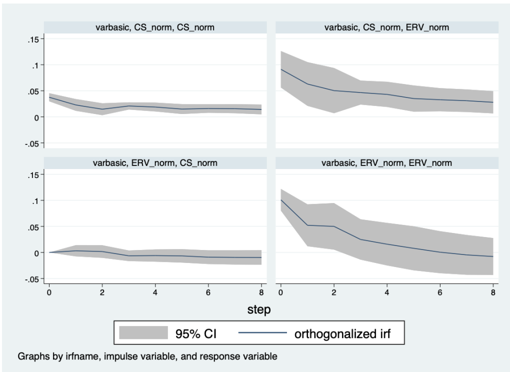
Countries	Direction	Chi2	df	Prob > Chi2
Philippines	CS ← ERV	3.639732	3	0.303086
	ERV ← CS	4.111251	3	0.249699
Czech	CS ← ERV	3.12334	2	0.209785
	ERV ← CS	7.107871	2	0.028612**
Indonesia	CS ← ERV	8.917145	4	0.063204*
	ERV ← CS	11.30507	4	0.023341**
Poland	CS ← ERV	6.255425	3	0.099823*
	ERV ← CS	0.104796	3	0.991256
Argentina	CS ← ERV	14.412	4	0.006089***
	ERV ← CS	30.20666	4	0.000004***
Peru	CS ← ERV	2.111281	3	0.549634
	ERV ← CS	1.838084	3	0.606683
Nigeria	CS ← ERV	2.596693	1	0.107087
	ERV ← CS	3.359749	1	0.066808*
Hungary	CS ← ERV	7.613235	2	0.022223**
	ERV ← CS	0.141617	2	0.93164

Note: *reported values represent p-values* (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)

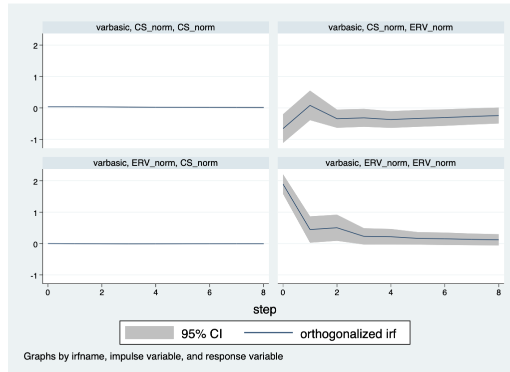
The VAR estimation result for CS and ERV is available in the Appendix B. Granger causality test is useful for determining whether one time series is useful in forecasting another time series as opposed to only using past values of one time series. Table 4 shows the results of Granger causality Wald test obtained from running VAR on CS and ERV at level. The second column indicates the direction of causality. The null hypothesis of no Granger causality is rejected if Granger causality exists between the variables. The results show that bidirectional relationship only exists in Argentina while other countries have unidirectional causality, excluding the Philippines and Peru. CS Granger causes ERV in Czech Republic, Indonesia, Argentina, and Nigeria. Furthermore, ERV Granger causes CS in Indonesia, Poland, Argentina, and Hungary. This result for the most part agrees with the results published by Kumamoto and Kumamoto (2014), who find significant relationship between currency substitution and exchange rate volatility in Argentina, the Czech Republic, Hungary, Indonesia, and the Philippines. On the other hand, the result for Nigeria is contrary to the findings of Yinusa and Akinlo (2008b), who find bidirectional relationship between CS and ERV.

5.2.2 Impulse Response Functions

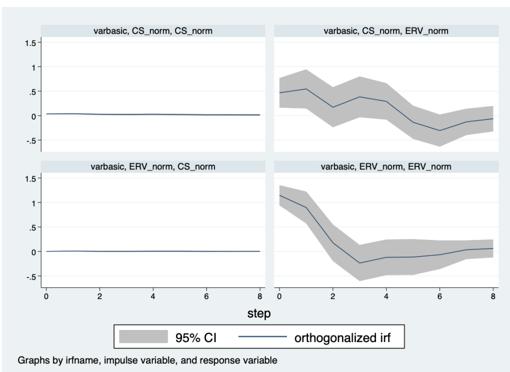
Figure (5) Impulse Response Functions (IRFs)



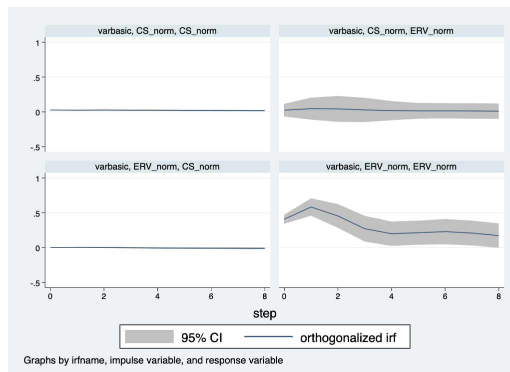
(a) Philippines



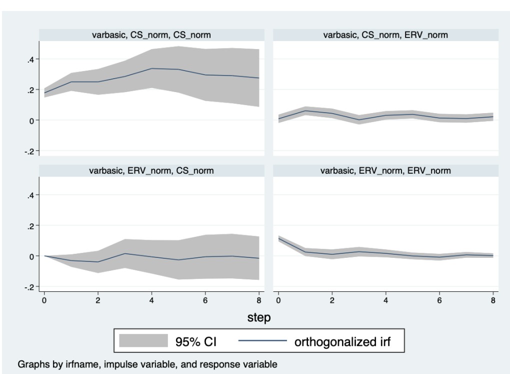
(b) Czech Republic



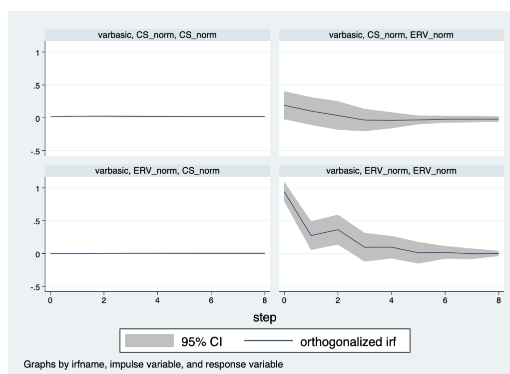
(c) Indonesia



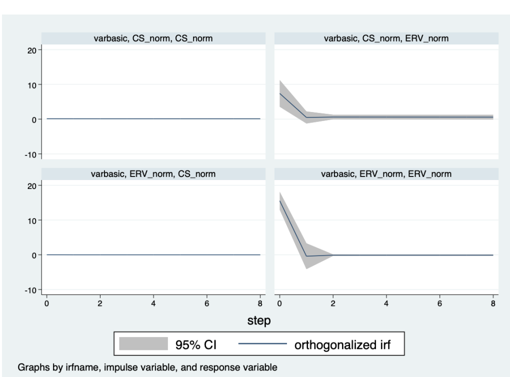
(d) Poland



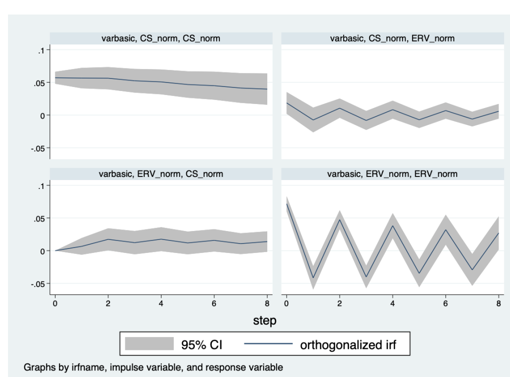
(e) Argentina



(f) Peru



(g) Nigeria



(h) Hungary

Additionally, this study uses impulse response functions (IRFs) generated from VAR estimation to explore the relationship between CS and ERV. IRFs show how the response variable reacts to one standard deviation shock to the impulse variable. The IRF for each sample countries is presented in Figure 5. For easier interpretation of the results, the initial values of both variables were normalized to 1. The graphs on top have CS as the impulse variable, whereas the graphs on the bottom have ERV as the impulse function. The results show that the response variables react to shocks to impulse variables differently across countries. In the Philippines, Indonesia, Peru, and Nigeria, one standard deviation shock to CS led to increases in ERV. However, the duration for the ERV to return back to normal state is different for each country. The ERV in Nigeria seems to return back to normal relatively quickly compared to the other countries. In the Czech Republic, a shock to CS caused ERV to decrease and increase for brief period before returning back to normal gradually. In Poland, shocks to CS had no effect on ERV, both short-term and long-term. On the other hand, ERV seems to have very little effect on CS in most sample countries, except Hungary where shock to ERV seems to cause CS to be increased in the long-run.

5.2.3 Vector Error Correction Model

Table (5) VECM regression table

	(1) Poland	(2) Argentina	(3) Peru	(4) Nigeria	(5) Hungary
D_CS					
L._ce1	-0.0209*	-0.00375	0.00100	0.0169*	-0.00993
	(0.025)	(0.709)	(0.468)	(0.013)	(0.072)
LD.CS	-0.0901	0.315**	0.460***	0.129	-0.000495
	(0.423)	(0.008)	(0.000)	(0.321)	(0.997)
LD.ERV	8.828*	-0.608*	-2.824	0.186	-79.84*
	(0.030)	(0.027)	(0.718)	(0.165)	(0.019)
constant	-0.000000680	0.00240	-0.0000153	0.00321	6.43e-08
	(0.999)	(0.272)	(0.997)	(0.192)	(1.000)
D_ERV					
L._ce1	-0.000789**	0.0224***	-0.0000725***	0.0393***	0.000106***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
LD.CS	-0.000775	0.127**	0.000312	0.0486	0.000103
	(0.794)	(0.001)	(0.839)	(0.697)	(0.806)
LD.ERV	0.436***	-0.133	-0.251*	0.0429	-0.324**
	(0.000)	(0.146)	(0.027)	(0.739)	(0.006)
constant	0.0000180	0.000401	-0.000212***	-0.00138	0.00000603
	(0.276)	(0.580)	(0.001)	(0.560)	(0.146)

Note: p-values are reported in parentheses (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$)

For sample countries that were found to have cointegrating equations through the Johansen cointegration test, I apply the VECM estimation to test for long-run dynamics between the variables. The VECM estimation result for CS and ERV is reported in Table 5. The error correction term (ECT) is represented by L._cel for CS and ERV as the dependent variable in the estimation. The coefficient for ECT, if statistically significant, suggests the convergence speed in in which previous period's errors (or deviation from long-run equilibrium) are corrected within one period. The results show that there is a long-run relationship running from ERV to CS in Poland and Nigeria. The results also show that there is long-run relationship running from CS to ERV in Poland and Peru.

Table (6) VECM long-run equation

Country	Dependent Variable	Independent Variable	Coefficient	P > |z|
Poland	CS	ERV	202.4429	0.000***
	ERV	CS	0.0049397	0.106
Argentina	CS	ERV	-27.58099	0.000***
	ERV	CS	-0.0362569	0.008***
Peru	CS	ERV	6470.28	0.000***
	ERV	CS	0.0001546	0.577
Nigeria	CS	ERV	-27.85656	0.000***
	ERV	CS	-0.0358982	0.056*
Hungary	CS	ERV	-11810.01	0.000***
	ERV	CS	-0.0000847	0.275

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The long-run dynamics of the system for each sample countries is reported in Table 6. The second and third column indicate the dependent and independent variable in the regression. In order to interpret the results, the signs of the coefficients must be reversed. The results show that in all sample countries with cointegration, ERV has significant long-run effect on CS. The effect is positive in Argentina, Nigeria, and Hungary, meaning high ERV causes CS to be also high in the long-run. The effect is negative in Poland and Peru, meaning high ERV causes CS to be low in the long-run. Additionally, the results demonstrate that CS has significant positive effect on ERV in the long-term in Argentina at the 1% level and in Nigeria at the 10% level. This implies that high degrees of currency substitution in the long-run leads exchange rate volatility to be high. This is in line with the results obtained by Kumamoto and Kumamoto (2014).

6 Conclusion

The major contribution of this study is that it presents supporting evidences for significant relationship between the degree of currency substitution and exchange rate volatility using various econometric approaches. TARCH model presents significant positive effect of currency substitution on exchange rate volatility in the Philippines, Argentina, Nigeria, and Hungary, while finding significant negative effect in Czech Republic and Peru. Granger causality tests from VAR estimation showed that currency substitution Granger causes exchange rate volatility in Czech Republic, Indonesia, Argentina, and Nigeria. The test also found that exchange rate volatility Granger causes currency substitution in Indonesia, Poland, Argentina, and Hungary. Furthermore, the analysis of impulse response functions indicated that in the Philippines, Indonesia, Peru, and Nigeria, one standard deviation shock to currency substitution led to increases in exchange rate volatility, with different rate of return to normal levels. Using the Johanen cointegration test, I identified the existence of cointegrating relationship in 5 of 8 sample countries. VECM estimation on those sample countries showed that in the long-run, exchange rate volatility seems to have significant relationship with currency substitution. Contrary to VAR estimation, in the long-run, currency substitution only had positive effect on exchange rate in Argentina and Nigeria. This means that high exchange rate is associated with high currency substitution in the long-run.

The findings have some monetary policy implications. The results obtained in this study imply that the relationship between currency substitution and exchange rate volatility is quite varied across sample countries. But generally, there seems to be positive relationship between currency substitution and exchange rate volatility across the sample countries. This implies that low currency substitution rate can be a desirable goal for central banks of developing countries since volatile exchange rate can have undesirable macroeconomic effects. However, our results also show that Czech Republic seems to be one country that has negative relationship between the two variables. This indicates that the relationship can be different for each country and the dynamics that exist in the country. Therefore, central banks must be careful in making monetary policy decision to affect currency substitution rate. Additionally, the long-term relationship demonstrated in this study suggest that high exchange rate volatility in the long-run could cause currency substitution to increase. If currency high substitution causes volatile exchange rate and exchange rate volatility causes an increase in currency substitution, not addressing high rate of currency substitution could lead to a destabilizing cycle that continues to increase both. Hence, central banks should aim to keep both currency substitution and exchange rate volatility low in order to prevent destabilization in the economy.

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Appendix A Data Sources

Table (7) Data sources

Country	Time	Source
Argentina	2002M1-2019M12	The Central Bank of the Argentine Republic Statistics
Czech Republic	2002M1-2019M12	Czech National Bank ARAD
Hungary	2001M1-2019M12	Magyar Nemzeti Bank Statistics
Indonesia	2004M1-2019M12	Bank Indonesia Statistics
Nigeria	2002M4-2019M11	Central Bank of Nigeria Statistics Database
Peru	2000M1-2019M12	Banco Central de Reserva del Perú Statsitics
Philippines	2008M3-2019M12	The Bangko Sentral ng Pilipinas Statistics
Poland	2000M1-2019M12	Narodowy Bank Polski Statistics

Appendix B Vector Autoregression Model

Table (8) VAR regression table

	(1) Philippines	(2) Czech	(3) Indonesia	(4) Poland	(5) Argentina	(6) Peru	(7) Nigeria	(8) Hungary
CS								
L.CS	0.530**	0.957***	1.004***	0.868***	1.417***	1.595***	1.000***	0.961***
	(0.004)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
L2.CS	0.0528	-0.137	-0.288	0.206	-0.497*	-0.944***		-0.0200
	(0.791)	(0.220)	(0.129)	(0.156)	(0.011)	(0.000)		(0.864)
L3.CS	0.500**		0.235	-0.128	0.323	0.335**		
	(0.006)		(0.206)	(0.232)	(0.088)	(0.002)		
L4.CS			-0.0620		-0.303*			
			(0.637)		(0.010)			
L.ERV	6.300	-4.871	4.052	5.073	-0.496	2.630	-0.214	33.99
	(0.554)	(0.156)	(0.051)	(0.224)	(0.129)	(0.724)	(0.107)	(0.309)
L2.ERV	-3.138	-2.437	-7.030**	-9.112	0.176	9.434		76.58*
	(0.783)	(0.484)	(0.006)	(0.161)	(0.626)	(0.211)		(0.019)
L3.ERV	-16.10		6.127*	0.750	0.897**	-5.362		
	(0.134)		(0.019)	(0.863)	(0.004)	(0.464)		
L4.ERV			-2.228		-0.692**			
			(0.285)		(0.007)			
constant	-0.00177	0.0214**	0.0302	0.00793*	0.0104**	0.00119	0.00603	-0.0376
	(0.289)	(0.001)	(0.094)	(0.014)	(0.008)	(0.818)	(0.379)	(0.193)
ERV								
L.CS	0.00215	0.00380	0.00887	0.000768	0.183***	0.000764	0.0369	0.000155
	(0.521)	(0.324)	(0.294)	(0.783)	(0.000)	(0.654)	(0.067)	(0.709)
L2.CS	-0.00155	-0.00726*	-0.0110	-0.000767	-0.165*	-0.00207		-0.000142
	(0.672)	(0.045)	(0.340)	(0.833)	(0.017)	(0.472)		(0.729)
L3.CS	0.00251		0.0284*	-0.0000545	-0.0793	0.00114		
	(0.455)		(0.012)	(0.984)	(0.236)	(0.495)		
L4.CS			-0.0264***		0.0878*			
			(0.001)		(0.036)			
L.ERV	0.517**	0.236*	0.782***	1.428***	0.216	0.291*	-0.0268	-0.582***
	(0.008)	(0.034)	(0.000)	(0.000)	(0.062)	(0.012)	(0.826)	(0.000)
L2.ERV	0.215	0.229*	-0.493**	-0.929***	0.132	0.301*		0.318**
	(0.305)	(0.042)	(0.001)	(0.000)	(0.302)	(0.011)		(0.005)
L3.ERV	-0.118		0.101	0.404***	0.225*	-0.104		
	(0.550)		(0.521)	(0.000)	(0.044)	(0.361)		
L4.ERV			-0.0615		-0.158			
			(0.627)		(0.084)			
constant	-0.0000489	0.000488*	0.000475	0.0000400	-0.00238	0.000163*	-0.00613	0.000576***
	(0.112)	(0.022)	(0.664)	(0.621)	(0.087)	(0.042)	(0.332)	(0.000)
Observations	45	70	60	78	68	77	70	74

Note: p-values are reported in parentheses (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$)

Appendix C Diagnostic Tests: VAR

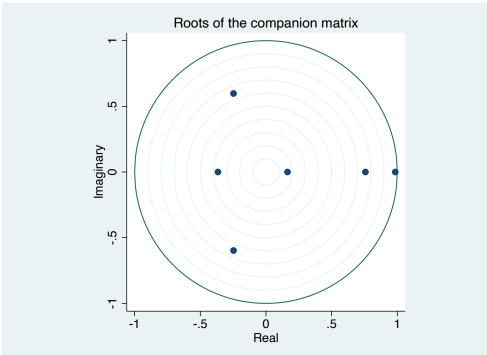
Table (9) Autocorrelation Tests

Country	Lag	Chi2	df	Prob > Chi2	Decision
Philippines	1	4.283969	4	0.368937	no autocorrelation
	2	2.192353	4	0.700429	
	3	1.472103	4	0.831571	
Czech	1	8.637863	4	0.070817	no autocorrelation
	2	4.144572	4	0.386794	
Indonesia	1	3.551173	4	0.47014	no autocorrelation
	2	6.135458	4	0.189258	
	3	2.43702	4	0.655948	
	4	4.413798	4	0.352892	
Poland	1	5.538629	4	0.236355	no autocorrelation
	2	1.415041	4	0.841577	
	3	4.741814	4	0.314829	
Argentina	1	3.563515	4	0.468287	no autocorrelation
	2	1.907448	4	0.752777	
	3	0.789023	4	0.939914	
	4	2.201227	4	0.698805	
Peru	1	2.581517	4	0.630101	no autocorrelation
	2	1.055754	4	0.901227	
	3	3.452875	4	0.48508	
Nigeria	1	6.391096	4	0.171783	no autocorrelation
Hungary	1	0.929558	4	0.920283	no autocorrelation
	2	1.540782	4	0.819394	

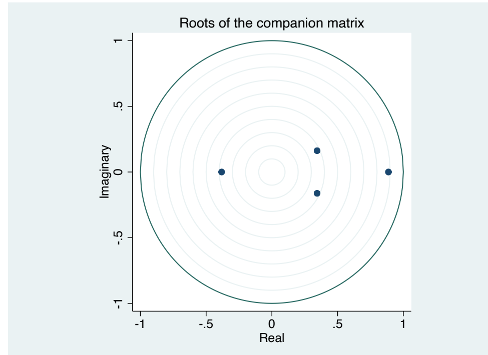
Table (10) Jacque-Bera Normality Tests

Country	Equation	Chi2	df	Prob > Chi2	Decision
Philippines	CS	12.44831	2	0.00198	non-normal errors
	ERV	51.88898	2	0.00000	non-normal errors
	ALL	64.33729	4	0.00000	non-normal errors
Czech	CS	1.287747	2	0.52525	normal errors
	ERV	385.4924	2	0.00000	non-normal errors
	ALL	386.7802	4	0.00000	non-normal errors
Indonesia	CS	0.035879	2	0.9822	normal errors
	ERV	1620.464	2	0.0000	non-normal errors
	ALL	1620.5	4	0.0000	non-normal errors
Poland	CS	1.283278	2	0.52643	normal errors
	ERV	157.8262	2	0.00000	non-normal errors
	ALL	159.1095	4	0.00000	non-normal errors
Argentina	CS	68.82953	2	0.00000	non-normal errors
	ERV	413.9184	2	0.00000	non-normal errors
	ALL	482.7479	4	0.00000	non-normal errors
Peru	CS	3.598008	2	0.1655	normal errors
	ERV	55.12709	2	0.0000	non-normal errors
	ALL	58.7251	4	0.0000	non-normal errors
Nigeria	CS	1.350568	2	0.50901	normal errors
	ERV	4175.15	2	0.00000	non-normal errors
	ALL	4176.5	4	0.00000	non-normal errors
Hungary	CS	2.089023	2	0.35186	normal errors
	ERV	136.1101	2	0.00000	non-normal errors
	ALL	138.1991	4	0.00000	non-normal errors

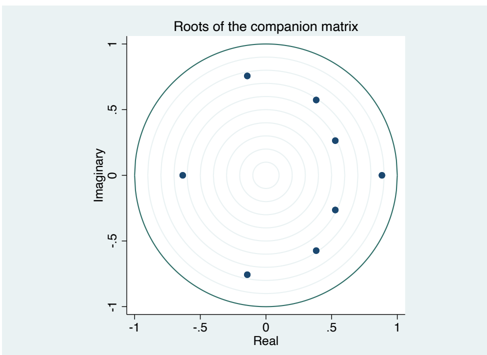
Figure (6) VAR: Stability Tests



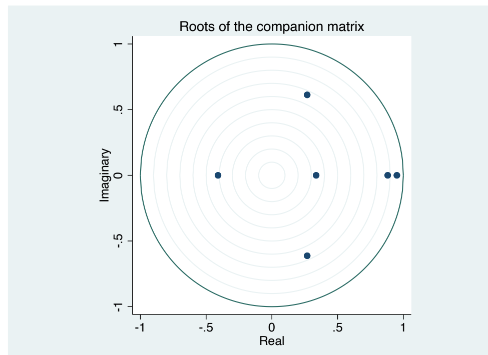
(a) Philippines



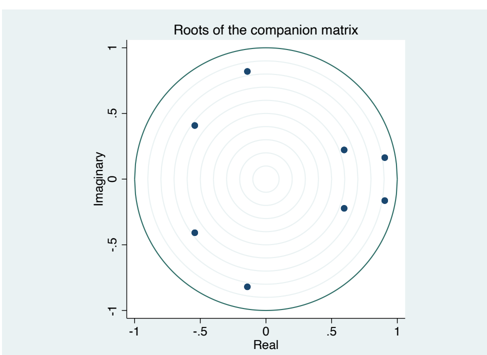
(b) Czech Republic



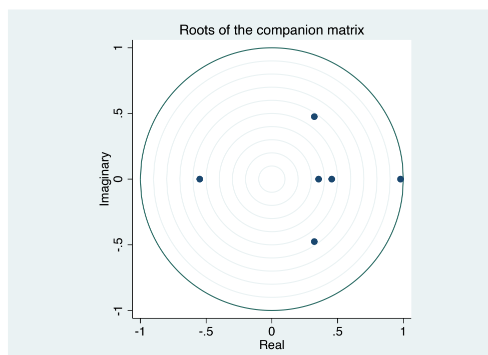
(c) Indonesia



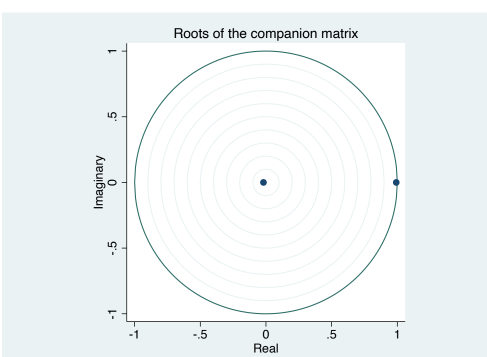
(d) Poland



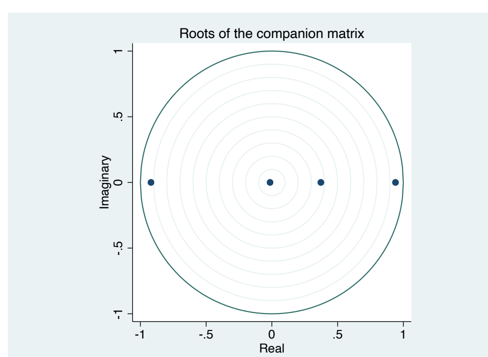
(e) Argentina



(f) Peru



(g) Nigeria



(h) Hungary

Appendix D Diagnostic Tests: VECM

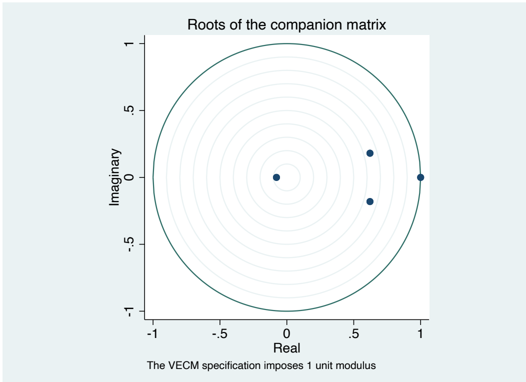
Table (11) Autocorrelation Tests

Country	Lag	Chi2	df	Prob > Chi2	Decision
Poland	1	13.69067	4	0.008351	autocorrelation
	2	17.06741	4	0.001876	autocorrelation
	3	4.030841	4	0.401848	no autocorrelation
Argentina	1	3.548281	4	0.470575	no autocorrelation
	2	0.801481	4	0.938249	no autocorrelation
	3	15.05917	4	0.00458	autocorrelation
	4	6.313948	4	0.176897	no autocorrelation
Peru	1	9.99495	4	0.040513	autocorrelation
	2	5.662169	4	0.225838	no autocorrelation
	3	6.807894	4	0.146395	no autocorrelation
Nigeria	1	1.150028	4	0.886256	no autocorrelation
Hungary	1	0.736588	4	0.946741	no autocorrelation
	2	1.802591	4	0.772008	no autocorrelation

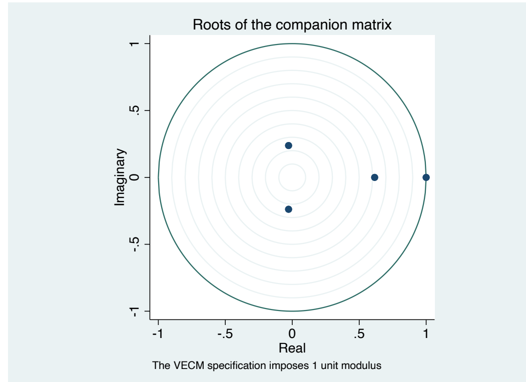
Table (12) Jacque-Bera Normality Tests

Country	Equation	Chi2	df	Prob > Chi2	Decision
Poland	CS	1.087225	2	0.5806	normal errors
	ERV	235.9763	2	0.0000	non-normal errors
	ALL	237.0636	4	0.0000	non-normal errors
Argentina	CS	46.48715	2	0.0000	non-normal errors
	ERV	401.6445	2	0.0000	non-normal errors
	ALL	448.1317	4	0.0000	non-normal errors
Peru	CS	6.809676	2	0.0332	non-normal errors
	ERV	61.81192	2	0.0000	non-normal errors
	ALL	68.62159	4	0.0000	non-normal errors
Nigeria	CS	3.336041	2	0.1886	normal errors
	ERV	3922.893	2	0.0000	non-normal errors
	ALL	3926.229	4	0.0000	non-normal errors
Hungary	CS	3.707999	2	0.1566	normal errors
	ERV	132.1232	2	0.0000	non-normal errors
	ALL	135.8312	4	0.0000	non-normal errors

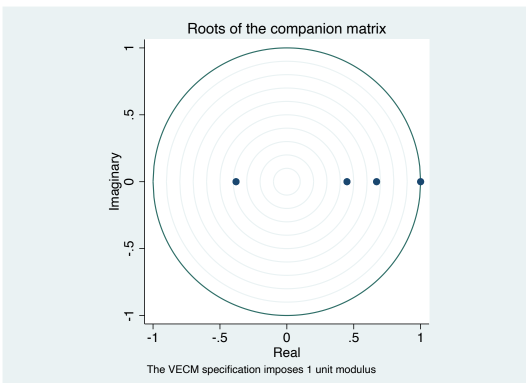
Figure (7)   VECM: Stability Tests



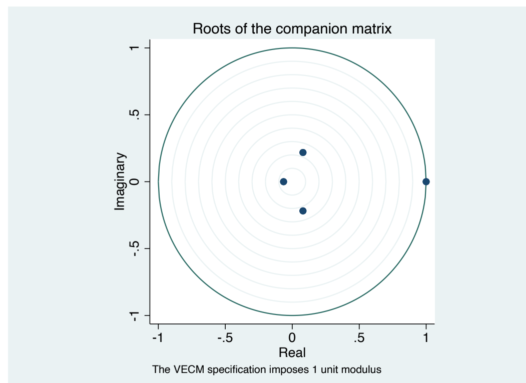
(a) Poland



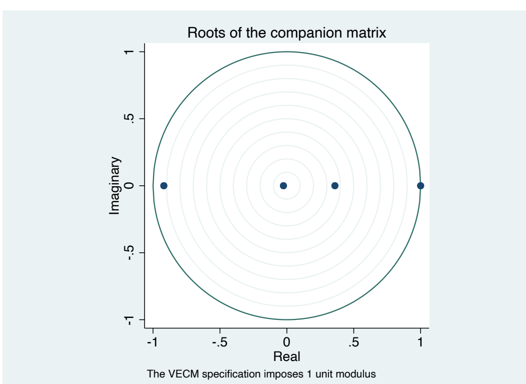
(b) Argentina



(c) Peru



(d) Nigeria



(e) Hungary