

Dynamic Volatility Transmissions among Emerging Asian Foreign Exchange Markets along the Belt and Road Initiative: A Connectedness Approach

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Abstract

This study investigates the dynamics of volatility spillovers among 10 emerging Asian foreign exchange markets along the Belt and Road Initiative. Daily realized volatility data from May 2005 to December 2023 are analyzed through Spillover Index Method based on Forecast Error Variance Decomposition introduced by Diebold and Yilmaz (2012). The study measures Total, Directional, Net and Pairwise Spillovers and also explores the time-varying behavior through Rolling Window Analysis. Results reveal a moderate to high level of interdependence across considered markets where approximately half of the each country's volatility is due to cross market spillovers. Turkish, Indonesian and Thailand currencies emerged as net volatility contributors while Sri Lankan, Malaysian and Pakistani Currencies as net receivers. The dynamic analysis shows that volatility spillovers across the sample are time-varying and sensitive to regional integration and global crises. The findings have important implications for investors, policy makers and future researchers.

Keywords: Belt and Road Initiative, Covid-19 Pandemic, Foreign Exchange Markets, Spillover Index Method, Volatility Spillovers

Introduction

The dynamic linkages among different currencies traded in foreign exchange markets affect the investment decision of individuals, corporations and government bodies. International financial markets are closely linked with one another, thus a particular change in the value of one currency may have a profound impact on prices of other currencies. The association among currencies may be unidirectional or bidirectional.

Such associations and linkages can be studied in terms of return and volatility spillovers among currency markets. A wide array of studies has investigated the spillover effect among major currencies of the world like US Dollar, UK Pound Sterling, and Canadian Dollar etc. Financial participants like investors and policy makers are particularly interested in such investigations because it helps to measure and understand the impact of global shocks and other international developments on external value of currencies (Kavli and Kotze, 2014).

Foreign exchange markets play important role in facilitating and ensuring international trade, financial stability and cross border investment. The dynamic behavior of exchange rates especially their volatility transmission has important implications for portfolio diversification and financial regulation. Foreign exchange markets volatility not only reveals macroeconomic insecurities but also serves as a channel of spillover shocks transmission across countries (Ahmad et al., 2024). In an increasing interdependent global financial environment, understanding how volatility in one foreign exchange market influence others have become a policy concern and attractive research area.

In recent past, emerging Asian economies are more integrated with global financial systems which have intensified cross market linkages. Chinese Belt and Road initiative is one viable example. This multinational program was launched in 2013 by Chinese government in order to build infrastructure, promote trade and financial connectivity across Asia, Europe and Africa. BRI has not only boosted trade and economic connectivity but have a profound impact on volatility spillovers among financial markets of participating countries (Ali et al., 2025).

Previous literature documents that risk and volatility spillovers have intensified in the wake of turbulent periods like Global Financial crises of 2008 and Covid-19 Pandemic etc. Crises episodes have exposed the vulnerabilities of emerging financial markets to external disturbances and highlighted their dynamic role as transmitters and receivers of volatility. The degree of interdependence among emerging foreign exchange markets has particularly became important for regulators like central banks which are seeking to formulate effective monetary and exchange rate policies. In order to understand such linkages, this study investigates the nature of risk spillovers among emerging Asian currency markets along Belt and Road Initiative by using Spillover Index Method.

The initial construction of spillover index is proposed by Diebold and Yilmaz (2009) based on a variance decomposition associated with an N-variable Vector Auto-Regressive (VAR) framework of Engle et al. (1988). This index provides separate quantitative measures of interdependence in the form of spillover tables and plots for both returns and volatilities. Spillover Index framework is dependent on variance decomposition which aggregate spillover effects across markets thus providing a lot of information in the form a single spillover measure. The framework defines Spillovers as the share of forecast error variance in particular financial markets that is caused by shocks in other financial markets. Forecast Error Variances were decomposed through 'Cholesky Factor Identification' in order to orthogonalize the shocks. The results of the orthogonal innovations suffer few limitations; like the

results were dependent on variable ordering and directional spillovers were totally ignored. In order to overcome these limitations, the authors motivated from the Generalized VAR framework of Koops, Pesaran and Potter (1996) and Pesaran and Shin (1998) used 'Generalized Identifications' in their subsequent study i.e Diebold and Yilmaz (2012) in place of 'Cholesky Factor Identification'.

Literature Review

Plenty literature is available on co-movement and volatility spillovers among foreign exchange markets. Ingaki (2007) investigated the volatility spillovers between the great British Pound and Euro against US dollar spot exchange rate from 1999 to 2004 through residual cross correlation function and found unidirectional volatility spillover from Euro to Pound. Similarly, Nikkinen et al. (2006) used a VAR model on currency options for Euro, Swiss Franc and Pound between 2001 and 2003 and found that Euro is still a dominant currency in volatility transmission. Moreover, Mcmillan and Speight (2010) studied the return and volatility spillovers among 3 major currencies 2002 and 2006. They documented that US dollar exchange rate dominated Japanese Yen and British pound in both return and volatility spillovers. Perez (2006) examined the interdependencies among Yen, Euro and Pound against US dollar over the period 1999-2004 through Dynamic Conditional Correlation model of Engle (2002) and found significant volatility spillovers with high correlation between Euro and Pound.

In the same manner, Kitamura (2010) studied volatility spillovers among Euro, Pound and Franc using high frequency data during April 2 and August 31, 2006. The Author found high integration among considered exchange rates. Moreover, Nikkinen et al. (2011) analyzed the short run and long run spillovers among US Dollar, Euro, Yen and GB Pound and found that in short run Yen is affecting Euro and Pound while in long run Pound is affecting Yen exchange rate. While Black and McMillan (2004) investigated return co-movement and volatility spillovers among Canadian Dollar, Deutsche Mark, Swiss Franc, Italian Lira, GB Pound and Japanese Yen during 1974 and 1998 and found European Exchange rates shows significant spillover effects. Melvin and Melvin (2003) also found significant volatility spillovers among Japanese Yen and Deutsche Mark against US dollar exchange rates.

Besides world major currencies, another strand of studies focused on Asian currencies. Like, Baharumshah and Goh (2005) studied the exchange rate relationship between Japanese Yen and currencies of seven East Asian countries i.e Indonesia, Philippine, Singapore, Taiwan, Malaysia, South Korea and Thailand. The authors used quarterly data from 1978 to 1998 and except Philippine Peso and Korean won, all currencies shows co-integration with Japanese Yen playing a dominant role. Similarly Azali et al. (2009) examined the co-movement among Japan, East Asian currencies and Indian Rupee 1988 to 2007 and found no co-integration during pre-crises period. However, significant interdependence was observed during post crises period. Furthermore, Lee and Azali (2010) also documented similar dynamics before and after crises episodes while investigating the potential spillovers and linkages among ASEAN-4 exchange rates.

In 2013 Chinese government launched an initiative for regional economic cooperation in the name of “the Silk Road Economic Belt and 21st Century Maritime Silk Road” more commonly known as The Belt and Road Initiative or BRI. The program is intended for the free flow of various economic factors (Huang, 2016). This initiative has not only promoted policy coordination and regional economic development among member countries but facilitated unobstructed trade and financial markets integration (Wong, 2017). BRI has also paved the way for internationalization of RMB just like US dollar (Zhang et al., 2017). According to Liang (2020) the dominant position of US Dollar international trade settlement has affected the RM internationalization process in BRI context. Investors and Policymakers are therefore interested in understanding the dynamics of potential systemic risk and volatility spillovers derived from heterogeneous status of economic development of member countries.

Exchange rate of a country is determined by money supply, national income, price level, output and most importantly interest rate along with other relative economic variables (Bacchetta & Van, 2006). According to Stancik (2006), exchange rate of a country fluctuates with the changes associated with economic openness, arrival of new information and flexibility of exchange rate regime. Lai and Guo (2017) documented that exchange rate of participant’s countries fluctuated significantly in the near past. With this experience, the author believe that as for as the globalization effect get deepens, the spillover effect will not restrict itself to domestic assets but will spread across markets and countries.

Exchange rate spillovers are transmitted across countries in 3 main ways. The first, through trade integration: in which specific countries in one geographical region tend to make regional currency block (Subramanian and Kessler, 2013). The second channel is active regional and global financial markets, where geographically dispersed countries align with one another (Shu et al., 2015). The third medium is correlation between pegged exchange rate regimes i.e among countries that have pegged their currencies to stable currencies like US Dollar. McMillan and Speight (2010) and Bubak et al. (2011) constructed spillover indices to study spillover effects among exchange rates.

Similarly, Liao et al. (2019) identified the spillover transmission path and investigated the dynamic spillover structure of fluctuations in exchange rate system. Very few studies analyzed the spillover effect in the BRI nascent currency system. Like Wei et al. (2020) studied the intensity of currency interdependence and stability of each currency during Covid- 19 pandemic. To fill this gap, this study tries to analyze various measures of volatility spillovers in emerging Asian BRI currencies over an extended period of time. Specifically, this study calculates the total, directional and net volatility spillovers through connectedness approach. This will add important insights to the literature on volatility risk spillovers bearing important implication for investors, portfolio managers and policy making regulatory bodies.

Data and Methodology

Data Description

The study employed daily closing exchange rate data of 10 emerging Asian foreign exchange markets that are part of or closely associated with the multifaceted economic program i.e Chinese Belt and Road Initiative,. The currencies selected for this purpose are given in Table 1. These currencies were selected for varying degrees of financial openness and exchange rate regimes, significant trade and policy linkages between member countries and active trading nature. The data period ranges from May 2005 till December 2023. This period covers nearly 2 decades of daily observations and major global episodes like Global Financial Crises (2008-09) and Covid-19 Pandemic (2020-21). The data on exchange rates was collected from official financial databases of Investing.com, Wall Street Journal and Yahoo finance. All the series are expressed as unit of domestic currency against US dollar. It means that an increase in the exchange rate signals a depreciation of local currency against US dollar. This study has used realized volatility which is derived from daily exchange rate returns.

If $P_{i,t}$ represent daily closing exchange rate for currency i at time t , the continuously compounded daily exchange rate returns are calculated as

$$R_{i,t} = \ln(P_{i,t}) - \ln(P_{i,t-1})$$

Where $\ln$ is natural log of daily exchange rates. Next, we calculated realized volatility as square root of the variance of daily exchange rate returns. Variance is calculated as squared deviation of exchange rate returns from their mean value.

Table 1 List of Asian Emerging Countries and their Currencies

S.No	Country	Currency	Code
1	Turkey	Lira	TRY
2	India	Rupee	INR
3	Sri Lanka	Rupee	LKR
4	Malaysia	Ringgit	MYR
5	Indonesia	Rupiah	IDR
6	Pakistan	Rupee	PKR
7	Philippine	Peso	PHP
8	Thailand	Baht	THB
9	China	Yuan	CNY
10	Vietnam	Dong	VND

$$RV_{i,t} = \sqrt{\frac{1}{n-1} \sum_{t=1}^n (R_{i,t} - \bar{R}_i)^2}$$

Where n is the number of daily observations in the sample window. We followed the concept of realized volatility being widely used in empirical finance literature (Andersen et al., 2003; McAleer & Medeiros, 2008). Realized volatility provides a non-parametric measure of actual variability of exchange rate returns as opposed to model based volatility series. Another advantage of realized volatility is that it captures both small and large changes in market prices of assets, thus reflect market risk more accurately and comprehensively.

Methodology

For analysis of transmission of volatility spillover from one currency to another, we applied the Diebold and Yilmaz (2012) Spillover or Connectedness Index approach. This method is based on Forecast Error Variance Decomposition (FEVD) obtained from a Vector Auto-regression Model.

The VAR Model

Let suppose we have N number of exchange rate volatility series $RV_t = (RV1, t, RV2, t, \dots, RVN, t)$ for $N=10$ currencies. A VAR (p) Model is written as:

$$RV_t = \sum_{i=1}^p \Phi_i RV_{t-i} + \varepsilon_t$$

Where Φ_i are $N * N$ coefficient matrices and $\varepsilon_t \sim (0, \Sigma)$ is a vector of innovations with covariance matrix Σ . A standard information criterion named Akaike Information Criterion (AIC) is used for optimal lag length (p).

Moving Average Representation and Forecast Error Variance Decomposition

The VAR model may be expressed in its infinite Moving Average (MA) representation as:

$$RV_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i}$$

Where, A_i are coefficients or parameter matrices capturing the dynamic response of the exchange rate system to internal and external shocks.

For decomposing the forecast error variance decomposition, Diebold and Yilmaz (2012) used the Generalized Variance Decomposition approach of Koop, Pesaran and Potter (1996) and Pesaran and Shin (1998) more commonly known as KPPS approach. KPPS method is order invariant unlike the Cholesky Factor Identification.

The H -step ahead forecast error variance decomposition is given as:

$$\theta_{ij}^{(H)} = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' A_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i' A_h \Sigma A_h' e_i)}$$

Where $\theta_{ij}(H)$ measures the proportion of H -step ahead forecast error variance of variable i due to shocks in variable j . σ_{jj} is the standard deviation of the error term for variable j . e_i is selection vector with 1 at position i and zeros elsewhere. Every

element of variance decomposition is normalized so that row sums to 1. The normalization process helps in easy interpretation i.e the sum of all contributions to a currency's forecast error variance is equal to 100%.

$$\tilde{\theta}_{ij}^{(H)} = \frac{\theta_{ij}^{(H)}}{\sum_{j=1}^N \theta_{ij}^{(H)}}$$

Measures of Volatility Spillovers

Using the normalized variance shares, Diebold and Yilmaz (2012) calculated various measures of volatility spillovers which quantify the magnitude and direction of spillovers among considered exchange rates.

Total Volatility Spillovers

The formula used to calculate the average contribution of cross market spillover shocks to the total forecast error variance in the exchange rate system is:

$$C^{(H)} = \frac{\sum_{i \neq j} \tilde{\theta}_{ij}^{(H)}}{N} \times 100$$

Directional Spillovers 'TO'

The formula for measuring how much spillover shocks currency i transmit to other currencies in the system is given as:

$$C_{i \rightarrow \bullet}^{(H)} = \frac{\sum_{j \neq i} \tilde{\theta}_{ji}^{(H)}}{N} \times 100$$

Directional Spillovers 'FROM'

We can show how much volatility spillovers each currency receives from other currencies as:

$$C_{i \leftarrow \bullet}^{(H)} = \frac{\sum_{j \neq i} \tilde{\theta}_{ij}^{(H)}}{N} \times 100$$

Net Spillovers

Net Spillovers can be calculated as:

$$C_{ij}^{(H)} = \left(\tilde{\theta}_{ij}^{(H)} - \tilde{\theta}_{ji}^{(H)} \right) \times 100$$

Pairwise Spillovers

The bilateral direction of volatility spillovers between pairs of currencies is written as:

$$C_{ij}^{(H)} = \left(\tilde{\theta}_{ij}^{(H)} - \tilde{\theta}_{ji}^{(H)} \right) \times 100$$

Graphical Representation and Network Analysis

A Rolling Window analysis based on 200-days Rolling Window is used for capturing time varying nature of spillovers. The rationale is the spillover index tables provide a static measure of total, directional and net spillovers. The dynamic spillover graph helps in identifying how systematic foreign exchange market linkages evolve over period of time or get intensified during crises episodes. The Network visualization technique is also employed to illustrate how volatility transmits from market to market. In this network plot the node represents a particular currency while the thickness of pointed arrows represents the strength and direction of volatility spillovers. The network approach helps in identifying the spillover hubs i.e transmitters and vulnerable nodes which are key spillover receivers.

Results and Discussion

Results are presented in 3 different forms; Averaged Dynamic Connectedness Table or Volatility Spillover Table, Dynamic Total Connectedness Graph and Network Plot.

Averaged Dynamic Connectedness Table

Table 2 exhibit averaged dynamic volatility spillovers among 10 emerging Asian foreign exchange markets over an extended period from 2005 to 2023. The sample results revealed total volatility spillovers of 44.97%. This shows that on average nearly about 45% of the forecast error variance in realized volatility of each exchange rate is due to cross market spillovers while the remaining shocks are caused by own market or idiosyncratic factors. The value for Total Spillover Index of 44.97% exhibits a moderate to high degree of interconnectedness among considered currencies. Our results are in line with findings of Bajo et al. (2017), Salisu et al. (2018) and Atenga and Mougoue (2021) that currencies do not move independently in terms of volatility spillovers. Thus emerging Asian foreign exchange markets becomes a meaningful channel for regional volatility spillovers transmission.

Regarding Directional Spillovers, Indonesia and Indian currencies appeared as major volatility transmitters with a respective 'TO' value of 54.43% and 51.90%. Philippine and Turkish currency markets followed the same pattern. Malaysian Ringgit appeared as major volatility spillover receiver followed by Indonesian Rupee. Indian Rupee played dual roles of spillover shocks contributor and receiver over the considered period. On the Net spillover front, Turkish Lira appeared as the largest net contributor with a net value of +5.31% followed by Indonesian and Thailand currencies. While Sri Lankan Rupee appeared as largest net receiver with a net value of -8.23% followed by Malaysian Ringgit and Pakistani Rupee. In the context of Net Pairwise Spillovers, Indonesian and Malaysian currency pairs shows highest net pairwise spillovers of 9.54%. Moreover, Turkish and Indonesian currencies transmit volatility spillover shocks to more markets than they received from i.e 7.00. Sri Lankan and Pakistani currencies receive volatility spillover from more markets than they transmit to i.e 2.00.

Dynamic Total Connectedness Graph

Figure 1 shows time varying volatility transmission among 10 emerging Asian currencies along Belt and Road initiative. The Rolling Window analysis for 200-day Window and 10-step Horizon shows Substantial temporal variation in total volatility spillover index. The index fluctuates between 30% and 65% over the sample period of 2005-23 which shows that intensity of volatility spillover effect is sensitive to crises episodes. By observing the graph, three distinct phases can be observed. During Pre-Global Financial Crises (2005-2007) period, volatility spillovers remained at a relatively low level i.e around 35% which reflects that currency markets are segmented and cross markets spillovers are low. The Index surged significantly during Global Financial Crises and Post Crises Period (2008-2012) i.e above 60% which mark the very first wave of regional currency markets contagion. In Post 2015 to Covid-19 Era a notable spike can be seen attributable to China exchange rate reform followed by the highest peak during the whole sample period. In the post pandemic years, the index remains elevated around 50% which suggest persistence interdependence in regional currency market spillover system.

Volatility Spillover Network Plot

From Net Spillover series, volatility spillover network plot is constructed as shown in Figure 2. Plot clearly shows that Turkish Lira, Indonesian Rupiah and Thai Baht acted as net transmitter due to their large node size and thicker edges going towards other currencies. On the other Sri Lanka, Pakistan and Vietnamese Currencies appeared as net spillover receivers due to their smaller node size and arrows coming towards them from other markets.

Conclusion and Recommendations

Conclusion

This study analyzed the volatility spillovers among 10 Asian emerging foreign exchange markets namely; the Turkish Lira, Indian Rupee, Sri Lankan Rupee, Malaysian Ringgit, Indonesian Rupiah, Pakistani Rupee, Philippine Peso, Thai Baht, Chinese Yuan and Vietnamese Dong by using daily realized volatility data for a period from May 2005 to December 2023. Employing the Spillover Index framework of Diebold and Yilmaz (2012) based on GFEVD the paper calculated total, directional and net spillover measures across these markets and also examined the time varying dynamics through Rolling Window analysis.

The findings revealed several important outcomes. First, the Total Spillover Index is equal to 44.97% which indicates a moderate to high degree of volatility spillovers among emerging Asian foreign exchange markets. Nearly half of the each country's foreign exchange market volatility forecast error variance is due to cross-market shocks. This confirms that foreign exchange markets across Emerging Asian are closely linked with one another. This also suggests that risk spillovers represent a significant channel for transmission of financial shocks. Second, the directional spillover measures also reveal a distinct hierarchy of volatility spillover transmission. The emergence of TRY, IDR and THB as net volatility transmitters

indicates their systemic importance and ability of propagating shocks to other currencies. In contrast, the LKR, MYR and PKR appeared as net receivers showing their absorption capacity from external sources and their minimal ability to the regional volatility system. Third, the time varying spillover analysis exhibits that foreign exchange volatility spillovers are dynamic and crises sensitive.

Table 2 Averaged Dynamic Connectedness Table

	USD_TRY	USD_INR	USD_LKR	USD_MYR	USD_IDR	USD_PKR	USD_PHP	USD_THB	USD_CNY	USD_VND	USD FROM
USD_TRY	57.67	5.28	4.18	4.54	5.61	3.86	4.78	4.59	4.22	5.27	42.33
USD_INR	7.16	51.35	4.70	4.56	6.80	3.34	5.06	5.37	6.50	5.15	48.65
USD_LKR	4.60	6.90	57.53	3.39	5.99	4.93	4.50	4.61	3.77	3.77	42.47
USD_MYR	5.22	5.57	3.07	47.88	9.54	3.71	8.21	7.31	5.16	4.32	52.12
USD_IDR	5.29	8.36	3.24	9.12	50.24	2.61	5.77	5.44	5.72	4.22	49.76
USD_PKR	4.25	4.16	3.76	4.34	3.69	61.54	5.86	3.49	4.63	4.29	38.46
USD_PHP	5.88	6.23	3.36	5.68	6.70	3.85	54.59	5.17	4.68	3.85	45.41
USD_THB	5.29	4.29	3.35	5.72	5.14	3.92	4.54	57.60	5.19	4.95	42.40
USD_CNY	5.54	6.28	3.88	4.69	5.88	4.20	4.30	5.87	54.73	4.62	45.27
USD_VND	4.41	4.83	4.70	4.78	5.09	3.70	5.75	4.79	4.82	57.13	42.87
TO	47.64	51.90	34.24	46.83	54.43	34.12	48.79	46.65	44.69	40.44	449.73
Including Own	105.31	103.24	91.77	94.71	104.67	95.66	103.38	104.26	99.43	97.57	CTCI/TCI
NET	5.31	3.24	-8.23	-5.29	4.67	-4.34	3.38	4.26	-0.57	-2.43	49.97/44.97
NPT	7.00	5.00	2.00	3.00	7.00	2.00	4.00	6.00	5.00	4.00	7

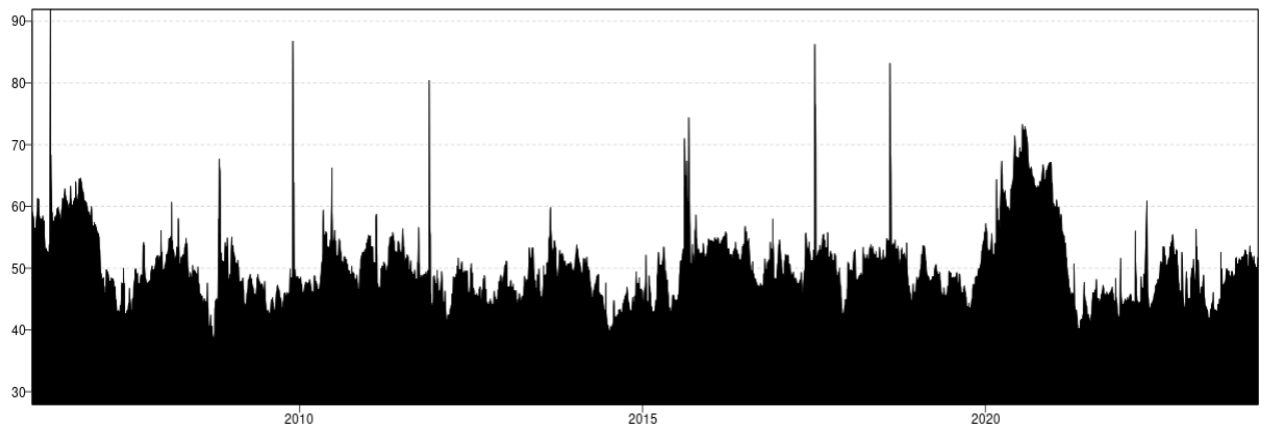


Figure 1 Dynamic Total Connectedness Graph

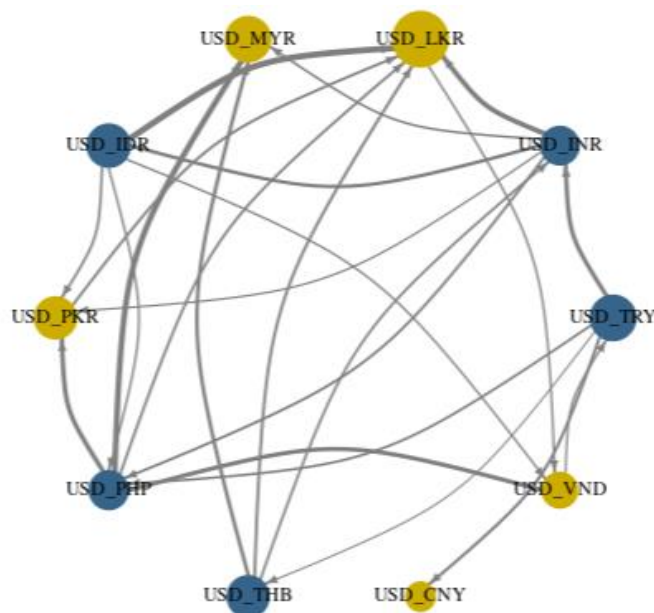


Figure 2 Volatility Spillover Network Plot

Policy Implications

The findings of the study have important implications for various stakeholders. For investors and Fund managers, identifying net transmitters and receivers help design cross currency hedging strategies and optimize exposure to systemic risk. Traditional portfolio diversification strategies may not perform well during period of higher connectedness, as currency shocks tend to propagate regionally. For Policy makers and regulators, the higher connectedness among considered currency markets suggests that volatility in domestic currency cannot be managed in isolation. Central banks in the recipient countries shall enhance macro prudential buffers, reserve adequacy and exchange rate flexibility. Future researchers may compare the return and volatility

spillover dynamics before and after major policy initiatives. Researchers may also distinguish the short and long run spillovers by using frequency domain connectedness measures.

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