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Symmetric and Asymmetric Effects of Financial Innovation and FDI on Exchange Rate Volatility: Evidence from South Asian Countries

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Abstract

The study explores the nexus between foreign direct investment (FDI), financial innovation, and exchange rate volatility in selected South Asian countries for 1980 to 2017. The study applies the unit root test, Autoregressive Distributed Lagged, nonlinear ARDL, and causality test following Toda-Yamamoto. Unit root tests ascertain that variables are integrated in a mixed order; few variables are stationary at a level and few after the first difference. Empirical model estimation with ARDL, Long-run cointegration revealed with the tests of FPSS, WPSS, and tBDM by rejecting the null hypothesis of "no cointegration." This finding suggests that, in the long-run financial innovation, FDI inflows, and exchange rate volatility move together. Moreover, study findings established adverse effects running from FDI inflows and financial innovation to exchange rate volatility in the long run. These findings suggest that continual FDI inflows and innovativeness in the financial system assist in lessening the volatility in the foreign exchange market. Furthermore, nonlinear ARDL confirms the presence of asymmetric cointegration in the model. The standard Wald test established asymmetric effects running from FDI inflows and financial innovation to exchange rate volatility, both in the long and short run. Directional causality unveils feedback hypothesis holds for explaining causality between FDI, financial innovation, and exchange rate volatility.

Keywords: FDI, Financial Innovation, Exchange Rate Volatility, ARDL, NARDL

JEL Classification Code: E44, F31, F37, G15

1. Background

Over the past few decades, economic integration opens a new window for developing nations by attracting foreign capital and international trade. Economic integration observed in the economy due to an investment opportunity, poverty reduction, and domestic capital accumulation (Lee & Zhao, 2014). However, the economic integration benefits demand stability in the macro fundamentals, such as a less volatile exchange rate. It is said that the volatile exchange rate increases the level of risk for investors.

The importance of a stable exchange rate is critical macroeconomic growth and sustainability and the equal importance established to internationalize economic activities. Exchange rate behavior, according to Jamil, Streissler, and Kunst (2012) and Danmola (2013), determines the level of trade, international competitiveness, debt servicing costs; on top its exhibits the health of the economy. In imperial literature, based on the exchange rate, two lines of study's findings can be observed. First, line of the empirical conclusions focused on establishing the key determinants of exchange rate volatility, see for instance Damani and Vora (2018); Kemboi and Kosgei (2018); Abdoh, Yusuf, Zulkifli, Bulot, and Ibrahim (2016); Mirchandani (2013); Saheed and Ayodeji (2012). Second, a growing number of researchers invested their efforts in analyzing the effects of exchange rate volatility on variables aspects of macro-fundamental

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such as Kilicarslan (2018); Bari and Togba (2017); Kibiy and Nasieku (2016); Danmola (2013), Capolupo and Jonung (2008); Choudhry (2005).

The study's motivation is to investigate the effects of financial innovation, foreign direct investment, and money supply on exchange rate volatility in selected south Asian countries. The novelty of this study lies in the following facts. First, with my best knowledge, financial innovation was used in the empirical model for gauging potential effects on exchange rate volatility for the first time. Second, prospective effects are investigated under the framework of symmetry following linear Autoregressive Distributed Lagged (ARDL), proposed by Pesaran, Shin, and Smith (2001) and asymmetric following Nonlinear Autoregressive Distributed Lagged (NARDL), proposed by Shin, Yu, and Greenwood-Nimmo (2014). Third, the presence of directional causality is invested by applying the non-granger casualty test proposed by Toda with the symmetric and asymmetric presence of financial innovation, FDI, and Money supply.

Referring to the results of long-run association, i.e., Fpss, Wpss and $t_{BDM,}$ the test statics are statistically significant at a 1% level under linear framework. These findings revealed a long-run association between financial innovation, FDI, money supply, and exchange rate volatility. Furthermore, the NARDL model estimation established a long-run asymmetric relationship between financial innovation, FDI, money supply, and exchange rate volatility since the results of Fpss, Wpss and t_{BDM} rejected the null hypothesis that is long-run symmetry.

The remaining structure of the article as follows. The survey of empirical literature pertinent to exchange rate volatility is exhibited in Section II. Data, variable definition, and econometric methodology are explained in Section III. Empirical model estimation and interpretation are exhibited in Section IV. Finally, the summary findings and policy implications are inserted in Section V.

2. Literature Review

Shifting from a fixed exchange rate regime to a floating exchange rate allows countries to actuate their money, and the issue of exchange rate volatility has emerged in the economy. According to Martins (2015), exchange rate volatility is the currency price variation due to the economy's macro fundamentals movements. Furthermore, exchange rate volatility is the unpredictable shocks in currency price because of certain deviations in crucial determinants for the economy, including FDI, foreign portfolio investment, and economic growth (Abdul Majeed, 2019; Aigheyisi & Oaikhenan, 2015; Ajao, 2015; Giannellis & Papadopoulos, 2011). The degree of each of these factors' impact varies and depends on a particular country's economic condition. Muhammad (2012) argues that exchange rate fluctuations encourage speculative behavior based on expectations that the exchange rate will continue to appreciate. This could lead to liquidity deficiencies and immediate noteworthy record effects, which can require financial institution action to calm the system, as an example, by providing short-term foreign currency liquidity to the banks. Higher exchange instability surges the ambiguity over the return of investment, which lowers foreign direct investment, an important plank for development in small economies, for instance, Kenya (Kemboi & Kosgei, 2018)

In certain countries, factors such as the imports and exports, economic and political conditions, supply chain, inflation, and real income had effects on the prices of commodities. They reacted to the exchange rates of the country. The leverage of a particular industry had inclining effects on the prices of those commodities. Thus, the trades with connecting countries resulted in the increase or decrease in the value of a currency, which found that unstable inflation created complications for business activities planning. The currency appreciated and depreciated due to these factors and created a push for the market to raise prices and a hurdle for more new investments (Rahmi et al., 2016). The market prices of commodities also had effects on the exchange rates.

2.1. Exchange Rate Volatility and Financial Innovation

In financial economics, financial innovation represented financial products and services and observed harmful effects on financial institutions. However, in reality, financial innovation combines various financial products and services, different forms of financial institutions, and various financial system processes, stimulating economic activities (Tufano, 2003). In a study, Merton (1992) documented that financial innovation creates a wave in the financial system through accumulating and reallocating money, risk management through investment diversification, and facilitating trade by offering payment intermediation.

In empirical litterateur, the effects of financial innovation have been extensively investigated considering the difference both macro and micro facts, including economic growth (Michalopoulos, Laeven, & Levine, 2009; Mishra, 2010; Mwinzi, 2014; Nazir, Tan, & Nazir, 2018; Qamruzzaman, 2017; Qamruzzaman & Jianguo, 2017), financial development (Plosser, 2009)), money demand (Mannah-Blankson & Belnye, 2004; Nagayasu, 2012; Napier, 2014; Odularu & Okunrinboye, 2008), financial inclusion (Qamruzzaman & Wei, 2019), financial volatility (Gennaioli, Shleifer, & Vishny, 2012), growth of banking sector (Kiprop, Ayuma, & Bokongo, 2016) stock market development (Qamruzzaman & Wei, 2018), Bank performance (Mugane, 2015), credit risk (Norden, Silva Buston, & Wagner, 2014), microfinance institutions (Mugo, 2009).

However, the direct relationship between financial innovation and exchange rate volatility yet to under investigation.

Nonetheless, the indirect association can be detected since standard macro fundamentals were available in the literature, those influence on the movement in financial innovation and exchange rate variability; macro fundamentals include trade openness, financial development, foreign direct investment, etc.

In a study, De Carvalho (1997) advocated that financial innovation plays a critical role in capital accumulation through liquidity offerings. The study was suggesting that the adaptation and diffusion of innovative financial products and services. Liquidity in the financial system augments money supply in the economy. Solans (2003) documented operational efficiency in the financial system accelerated with financial innovation and demand for effective monetary policy, simultaneously.

2.2. Nexus Between Exchange Rate Volatility and FDI

The interest in the impacts of the exchange rate volatility on international capital flows such as foreign direct investment (FDI) is growing among policymakers, as the number of countries adopting floating exchange rate system has been increasing. Nexus between ERV and FDI is getting immense since FDI transfer brings several benefits to the host country, including technological Know-how, financial resources, capital flows for long-run investment, and business expansion. On top of that, FDI inflows augmented economic resources' reallocation more efficiently, allowing greater output possibilities in the home and host countries.

A growing number of researchers established a positive association between Exchange Rate Volatility and Foreign Direct Investment. In their respective studies, Hartman (1972) Abel (1983) suggests that higher price volatility improves the anticipated profitability of capital, improves the needed capital stock, and ultimately raises the investment level. As of late, numerous analysts have inspected the connection between genuine conversion standard vulnerability and the degree of the total interest in the economy. In their respective studies (Goldberg, 1993) and (Goldberg & Kolstad, 1994) postulated that uncertainty in the exchange rate and firm-level output play a pivotal role in motivating foreign investors for bringing capital in the form of investment. Nevertheless, they also argued that the tangible demand and exchange rate tremors are expected, exchange rate volatility inclines to upsurge the FDI share even with undistinguishable production expenses across countries. Empirical studies established a positive association between exchange rate volatility and FDI (Qin, 2000; Rashid & Husain, 2013; ullah Khan, Sultan, & Rehman, 2017; Zhaozhi, 2010; Cushman, 1985, 1988; Goldberg & Klein, 1997). Furthermore, a negative association between Exchange Rate Volatility and Foreign Direct Investment available (Bénassy-Quéré, Fontagné, & Lahrèche-Révil, 2001); Servén (2003); (Urata & Kawai, 2000). Neutral effects also available in the empirical literature, see for instance (Foad, 2005; Osinubi & Amaghionyeodiwe, 2009)

According to Bernanke (1983), it has been suggested that although uncertainty can increase the profitability of all investment projects, its relative ranking is uncertain. Darby, Hallett, Ireland, and Piscitelli (1999) examine real instability of the exchange rate and cumulative investment for five OECD countries and finds mixed success in the sense that there are situations under which increased volatility will increase or decrease investment. Currency depreciation produces inventive for foreign investors, resulting in higher FID inflows,, the more significant fluctuation of the exchange rate discourages FDI in the long run. In a study by Furceri and Borelli (2008), they postulated that the effects of exchange rate volatility ion FDI immensely rely on economic conditions. Furthermore, they concluded that exchange rate volatility has a positive or null effect for relatively closed economies; it harms economies with a high level of openness; it is so because of nonlinear relationship between them.

3. Data and Methodology

The study utilizes annual time-series data for the period from 1971 to 2018 in empirical estimation. All the data were extracted from World Development Indicators (WDI) published by the World Bank and International Financial Statistics (IFS) published by the International Monetary fund. All the variables were transformed into a natural logarithm before estimate the empirical model.

3.1. Exchange Rate Volatility

No consensus avail for addressing the effects of exchange rate vitality in literature, however, A common statistics widely utilize, i.e., the standard deviation of the exchange rate. In a study, Bahmani Oskooee and Hegerty (2007) postdated that exchange rate volatility can detect by applying standard deviation with a moving average.

Economic scholars, including Akhtar and Hilton (1984); Aghion, Bacchetta, Ranciere, and Rogoff (2009); Grossmann, Love, and Orlov (2014), advocated detecting volatility in exchange rate by applying standard deviation. Kenen and Rodrik (1986) familiarized a moving standard deviation to quantify month-wise variations in the exchange rate. This technique has the advantage of being stationary. This technique was considered before the co-integration analysis was designed. Bleaney (1992) also suggests an identical procedure using the level instead of gauging the exchange rate variation.

Engle and Granger (1987) familiarized the novel time-series technique, called "Autoregressive Conditional Heteroskedasticity (ARCH)," to extent volatility. In the literature, it is more frequently used to quantify exchange

rate volatility. This mode computes the disturbance term's variance for each period as a part of errors in prior periods. This model can be prolonged by totaling more lags; the additional extension is commonly acknowledged as the GARCH model, including the moving average method. Moreover, Latief and Lefen (2018); Dal Bianco and Loan (2017); Aftab, Syed, and Katper (2017) also measured exchange rate volatility by using the GARCH process.

3.2. Financial innovation

Over the past decade, numerous indicators were utilized. However, a growing number of empirical studies concerted on the ratio of broad-to-narrow money (B1/B2) consider as a proxy for financial innovation see for instance, (Ansong, Marfo-Yiadom, & Ekow-Asmah, 2011; Bara & Mudxingiri, 2016; Qamruzzaman & Jianguo, 2018). This study also trails the identical proxy in measuring the effects on exchange rate volatility.

3.3. Methodology

Variables order of integration, in empirical studies, plays a critical role in the process of selecting the appropriate econometric model. in this study, we performed four widely used unit root tests those are augmented Dickey and Fuller (1979), Phillips and Perron (1988) with the null hypotheses of data is not stationary and Kwiatkowski, Phillips, Schmidt, and Shin (1992) with the null hypothesis of data is stationary.

In the recent period, investigating long-run association in empirical study Autoregressive distribute Lagged (ARDL) become on top due to certain benefits over traditional cointegration test (Adams Jr, 2006; Chaouachi & Slim, 2020; Qamruzzaman & Karim, 2020)

This study is using the ARDL model for study due to the following benefits over other cointegration models. First, according to Ghatak and Siddiki (2001), ARDL has more adaptive capacity for establishing relationships between variables, i.e., regardless of sample size, can either small or finite, consisting of 30 to 80 observations. Second, the issue pertinent to mixed order of integration is fully accommodated in ARDL. Third, Pesaran, Shin, and Smith (2001) advocated that serial correlation and the problem of indignity can be resolved by selecting appropriate lags. And finally, empirical model estimation with ARDL can produce long-run and short-run coefficients simultaneously (Pesaran et al., 2001). A basic ARDL model (Paul, 2014) for these variables X, Y, and Z can be expressed as;

$$\begin{aligned}\Delta y_t = {} & \varnothing_1 + \gamma_1 y_{t-1} + \gamma_2 x_{t-1} + \gamma_3 z_{t-1} \\ & + \theta_1 \sum_{i=1}^{n} \Delta y_{t-1} + \theta_2 \sum_{i=1}^{n} \Delta x_{t-1} \\ & + \theta_3 \sum_{i=1}^{n} \Delta z_{t-1} + \varepsilon_{it} \end{aligned} \quad (1)$$

Where, $\gamma_1, \gamma_2, \gamma_3$ are long-run coefficients whose sum is equivalent to the error correction term at the VECM model and $\theta_1, \theta_2, \theta_3$ are short-run coefficients.

The generalized ADRL model for assessing the nexus between financial innovation, FDI, and exchange rate volatility in selected south Asian countries as follows;

$$\begin{aligned}\Delta EXV_t = {} & \alpha_0 + \beta_1 EXV_{t-1} + \beta_2 FI_{t-1} + \beta_3 FDI_{t-1} \\ & + \beta_4 M_{t-1} + \beta_5 FD_{t-1} + \beta_6 DEBT_{t-1} + \beta_7 FDTR_{t-1} \\ & + \sum_{j=1}^{m1} \lambda \Delta EXV_{t-j} + \sum_{j=1}^{m2} \lambda_1 \Delta FI_{t-j} + \sum_{j=0}^{m3} \lambda_2 \Delta FDI_{t-j} \\ & + \sum_{j=0}^{m4} \lambda_3 \Delta M_{t-j} + \sum_{j=0}^{m5} \lambda_4 \Delta TR_{t-j} + \sum_{j=0}^{m6} \lambda_5 \Delta DEBT_{t-j} \\ & + \sum_{j=0}^{m6} \lambda_6 \Delta FD_{t-j} + \varepsilon_t \end{aligned} \quad (2)$$

Where, α is an intercept, the long-run coefficients of the empirical model represented by $\beta_1 \ldots\ldots \beta_6$, the short-run coefficients exhibited by $\lambda_0 \ldots\ldots \lambda_5, \varepsilon_t$. The error correction term and m1, m2, m3, m4, m5, and m6 are the optimal lag for the first difference variables selected by the Akaike Information Criterion (AIC).

Table 1: Variable definition and sources of data

Notation	Measures	Data source
ECV	GARCH effects	Author calculation
FDI	Foreign Direct Investment inflows % of GDP	WDI
FI	The ratio of Broad to Narrow money	Authors calculation
List of control variables		
TO	Trade openness (% of GDP	WDI
MS	Aggregated Money supply in the economy	WDI
FD	Domestic credit to Private Sector % of GDP	WDI
DEBT	Public debt % of GDP	WDI

To implement the ARDL model the ordinary least square (OLS) method is used to estimate equation (2), and then cointegration between the variables can be established in three different ways, first, using the F-test of Pesaran et al. (2001) with the null hypothesis of no-cointegration ($H_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = 0$) against the alternative of cointegration ($H_0 = \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq 0$). Second, Second, a Wald-test (*W*PSS), which also tests the above joint null. Third, the tBDM-test statistic of Banerjee, Dolado, and Mestre (1998) with the null hypothesis of no-cointegration $(H_0 : \beta_1 = 0)$ against the alternative of cointegration $(H_0 : \beta_1 < 0)$. The testing procedure uses two critical bounds: upper and lower. If the values of the *F*PSS, *W*PSS or *t*BDM statistics exceed the upper bound, the null hypothesis is rejected. If they lie below the lower critical bound, the null cannot be rejected, and if they lie between the critical bounds, the test is inconclusive.

3.4. Nonlinear ARDL

The asymmetric effect of FDI and financial innovation on exchange rate volatility to be investigated by utilizing the nonlinear ARDL offered by Shin et al. (2014) and considered the following asymmetric long-run regression.

$$U_t = (\beta^+ E^+_{1,t} + \beta^- E^-_{1,t}) + (\gamma^+ E^+_{2,t} + \gamma^- E^-_{2,t}) + \delta_i X_i + \varepsilon_t \quad (3)$$

Where $\beta^+, \beta^-, \gamma^+, \gamma^-$ and δ_i associated with long-run pavements. $\beta^+, \beta^-, \gamma^+, \gamma^-$ measure the effects of positive and negative shocks in FDI and financial innovation on exchanger rate volatility and δ_i measures the effects of control variables, i.e., financial development, money supply, debt, and total trade. The positive and negative shocks in FDI and financial innovation represent in the equation by $FI^+_{1,t} + FI^-_{1,t}$, $FDI^+_{2,t} + FDI^-_{2,t}$, which is calculated by using the following equations.

$$\begin{cases} POS(FDI)_{1,t} = \sum_{k=1}^{t} lnFI_k^+ = \sum_{K=1}^{T} MAX(\Delta lnFI_k, 0) \\ NEG(FI)_t = \sum_{k=1}^{t} lnFI_k^- = \sum_{K=1}^{T} MIN(\Delta lnFI_k, 0) \end{cases} \quad (4)$$

$$\begin{cases} POS(FDI)_{2,t} = \sum_{k=1}^{t} lnFDI_k^+ = \sum_{K=1}^{T} MAX(\Delta lnFDI_k, 0) \\ NEG(FDI)_t = \sum_{k=1}^{t} lnE_k^- = \sum_{K=1}^{T} MIN(\Delta lnFDI_k, 0) \end{cases} \quad (5)$$

By incorporating the decomposition variables of financial innovation and foreign direct investment into the equation (2), we get the following nonlinear form of ARDL:

$$\begin{aligned} \Delta E_t = {} & \partial E_{t-1} + (\beta^+ FI^+_{1,t-1} + \beta^- FI^-_{1,t-1}) + (\gamma^+ FDI^+_{2,t-1} \\ & + \gamma^- FDI^-_{2,t-1}) + \beta_3 \inf_{t-1} + \beta_4 Y_{t-1} + \beta_5 fd_{t-1} \\ & + \sum_{j=1}^{m-1} \lambda_j \Delta E_{t-j} + \sum_{j=1}^{n-1} (\pi^+ FI^+_{1,t-1} + \pi^- FI^-_{1,t-1}) \\ & + \sum_{j=0}^{p-1} (\rho^+ FDI^+_{2,t-j} + \rho^- FDI^-_{2,t-1}) + \sum_{j=0}^{m-1} \lambda_4 \Delta fd_{t-j} \\ & + \sum_{j=0}^{m-1} \lambda_5 \Delta y_{t-j} + \varepsilon_t \end{aligned} \quad (6)$$

The equation (9) can be rewritten in the following manner,

$$\begin{aligned} \Delta E_t = {} & \partial e_{t-1} + \sum_{j=1}^{m-1} \lambda_j \Delta E_{t-j} + \sum_{j=1}^{n-1} (\pi^+ FI^+_{1,t-1} + \pi^- FI^-_{1,t-1}) \\ & + \sum_{j=0}^{p-1} (\rho^+ FDI^+_{2,t-j} + \rho^- FDI^-_{2,t-j}) \\ & + \sum_{j=0}^{m-1} \lambda_4 \Delta fd_{t-j} + \sum_{j=0}^{m-1} \lambda_5 \Delta y_{t-j} + \varepsilon_t \end{aligned} \quad (7)$$

Where $e_{t-1} = U_{t-1} - (\delta^+ FI^+_{1,t-1} - \delta^- FI^-_{1,t-1}) - (\mu^+ FDI^+_{2,t-1} - \mu^- FDI^-_{2,t-1}) - \theta inf_{t-1} - \vartheta Y_{t-1} - \tau fd_{t-1}$ is the nonlinear error correction term with $\delta^+ = \frac{-\beta^+}{\partial}; \delta^- = \frac{-\beta^-}{\partial}; \mu^+ = \frac{-\gamma^+}{\partial}; \mu^+ = \frac{-\gamma^+}{\partial}; \theta = \frac{-\beta_3}{\partial}; \vartheta = \frac{-\beta_4}{\partial}; \tau = \frac{-\beta_5}{\partial}$ are the associate long-runparameters. $\partial = \sum_{j-1}^{m} \varphi_j - 1, \lambda_j = \sum_{i=j+1}^{m} \varphi_j$,$forj = 1 \ldots., m.$ $\delta^+ = \sum_{j=0}^{p} \delta_j^+; \delta^- = \sum_{j=0}^{q} \delta_j^-; \mu^+ = \sum_{j=0}^{p} \mu_j^+; \mu^- = \sum_{j=0}^{p} \mu_j^-$.

The short-run adjustments to positive and negative oil price changes are captured by π^+; π^-; ρ^+ and ρ^-, respectively. To gauge the asymmetric relationship between financial innovation, foreign direct investment, and exchange rate volatility, the following NARDL is considered;

$$\begin{aligned} \Delta E_t = {} & \alpha + \partial E_{t-1} + \beta^+ FI^+_{1,t-1} + \beta^- FI^-_{1,t-1} + \gamma^+ FDI^+_{2,t-1} \\ & + \gamma^- FDI^-_{2,t-1} + \beta \inf_{t-1} + \beta Y_{t-1} \\ & + \beta fd_{t-1} + \sum_{j=0}^{m1} \lambda_j \Delta E_{t-j} + \sum_{j=0}^{m2} (\pi^+ FI^+_{1,t-1}) + \sum_{j=0}^{m3} \pi^- FI^-_{1,t-1} \\ & + \sum_{j=0}^{m4} \rho^+ FDI^+_{2,t-j} + \sum_{j=0}^{m5} \rho^- FDI^-_{2,t-1} + \sum_{j=0}^{m6} \lambda_4 \Delta fd_{t-j} \\ & + \sum_{j=0}^{m7} \lambda_5 \Delta y_{t-j} + \varepsilon_t \end{aligned} \quad (8)$$

The existence of asymmetry long-run relationship can be analyzed in the same manner applied in linear ARDL by *F*PSS and *W*PSS statistics under the join null hypothesis of no-cointegration $(H_0 : \beta_1 = 0)$ against the alternative of cointegration ($H_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = 0$) and the t_{BDM}-test statistic of Banerjee et al. (1998) involves testing the null hypothesis of no-cointegration $(H_0 : \beta_1 < 0)$ against the alternative of cointegration ($H_0 \neq \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq 0$). Where nonlinear cointegration is confirmed, the next step is to assess long-run symmetry, i.e. $(\beta^+ = \beta^-, \gamma^+ = \gamma^-)$ and short-run (additive) symmetry i.e., $\left(\sum_{j=1}^{n-1}(\pi^+ E^+_{1,t-1}) = \sum_{j=1}^{n-1}\pi^- E^-_{1,t-1}\right)$; $\sum_{j=0}^{p-1}(\rho^+ E^+_{2,t-j}) = \sum_{j=1}^{p-1}(\rho^- E^-_{2,t-j})$. By using a standard Wald test (Qamruzzaman, Karim, & Wei, 2019).

4. Empirical Model Estimation and Interpretation

4.1. Unit Root Test

To gauge variables order of integration, the study performed ADF test, PP test, and KPSS test and results of unit root test reports. We observed variables are integrated in mixed order, i.e., few variables are stationary at a level I (0) and few variables becomes stationary after first.

Panel –A exhibits the results of long-run cointegration between financial innovation, FDI, and exchange rate volatility. Referring to test statistics of FPSS, WPSS, and tBDM, the null hypothesis of "no cointegration" is rejected at a 1% level of significance. These findings suggest that in the long-run financial innovation, FDI, and exchange rate volatility move together. This verdict applies to all sample countries. Once the cointegration test ascertains long-run relationships, we move to assess long-run effects running from financial innovation, FDI to exchange rate volatility.

Results of the long-run model display in Panel-B. The study revealed that foreign direct investment inflows induce exchange rate volatility in Bangladesh (a coefficient of 0.036). In contrast, the negative association established in India (a coefficient of -0.092) in Pakistan (a coefficient of -0.032) and in Sri Lanka (a coefficient of -1.892). More precisely, a 10% increase in FDI inflows in the economy will cause a 0.36% increase in exchange rate volatility in Bangladesh; this is suggesting that an increase in FDI inflows accelerates domestic capital accumulation side by side demand of foreign currency also increase, which cause instability in the exchange market. In contrast, due to a 10% increase in FDI inflows Indian economy experienced a reduction of exchange rate volatility by 0.92% of the Pakistan economy by 0.32%, and the Sri Lankan economy by 18.92%. These findings suggest that the economy's FDI reduces foreign currency demand, and market friction decline brings exchange rate stability.

Table 2: Results of unit root test

	ADF				PP				KPSS			
	BD	**IND**	**PAK**	**SL**	**BD**	**IND**	**PAK**	**SL**	**BD**	**IND**	**PAK**	**SL**
FD	0.605	-1.193	-1.012	-1.492	1.251	-0.450	-1.278	-1.556	0.727a	0.628b	0.397b	0.698c
∆FD	-5.811a	-1.705	-4.966a	-5.547a	-5.818a	-5.165a	-4.967a	-5.630a	0.218c	0.143c	0.139c	0.082a
Debt	-2.157	-2.218	-1.876	-2.085	-2.162	-2.215	-2.053	-2.183	0.188c	0.512b	0.144c	0.172a
∆debt	-3.922b	-5.541a	-5.293a	-5.879a	-3.751b	-5.583a	-5.343a	-5.879a	0.402b	0.175c	0.140c	0.209a
Exv	-2.014	-2.454	-5.391a	-3.668b	-3.954b	-2.547	-3.554	-4.492a	0.292c	0.064c	0.146c	0.265a
∆exv	-2.466	-6.538a	-6.093a	-5.051a	-9.044a	-6.546a	-5.076a	-5.051a	0.414b	0.068c	0.213c	0.302a
Fdi	-3.010b	-1.732	-4.435a	-4.621a	-3.133b	-1.749	-4.435a	-4.492a	0.448b	0.448b	0.339c	0.738c
∆fdi	-5.951a	-6.054a	-9.097a	-7.011a	-14.807a	-6.054a	-7.610a	-7.454a	0.202c	0.074c	0.459b	0.345a
Fi	0.969	4.939	2.139	0.220	-0.335	3.805	1.911	0.390	0.447b	0.539a	0.542a	0.600a
∆fi	-2.790c	-2.740c	-4.598a	-3.687b	-3.907b	-2.648c	-4.725a	-3.788b	0.246c	0.510a	0.422b	0.230a
M	0.403	-0.987	-1.093	-1.103	0.296	-0.751	-1.017	-0.922	0.717a	0.697a	0.742	0.726c
∆M	-4.604a	-3.906a	-5.250a	-7.417a	-4.540a	-3.906a	-6.731a	-7.398a	0.154c	0.153c	0.221a	0.118a
Tr	0.744	-1.616c	-1.757	-2.054	0.778	-1.107	-1.751	-2.167	0.575b	0.488a	0.416b	0.343a
∆tr	-4.560a	-2.523	-5.646a	-5.536a	-4.584a	-4.619a	-5.940a	-5.515a	0.357c	0.159c	0.155a	0.078a

Financial innovation effects on exchange rate volatility found a negative association, which suggests that innovativeness in the financial system brings stability in the foreign exchange market in the long-run. In particular, 10% further development in financial innovation declined exchange rate volatility by 4.78% in Bangladesh, by 7.86% in India, by 2.27% in Pakistan, and by 3.47% in Sri Lanka. Financial innovation accelerates global financial integration, thus improve international transaction efficiency and efficient intermediation in exchange for foreign currency across nations. Furthermore, institutional development by offering innovative means of payment mechanisms also established efficiency in handling domestic and foreign transactions; thus, exchange rate fractions mitigate and provide a stable foreign exchange market.

Table 3: Result of ARDL model estimation

	BD	IND	PAK	SL
Panel –A: Long-run cointegration test				
F*pss*	8.142_{a}	10.641_{a}	13.945_{a}	24.947_{a}
W*pss*	21.867_{a}	15.986_{a}	11.934_{a}	13.996_{a}
t_{BDM}	-5.845_{a}	-5.412_{a}	-8.958_{a}	-11.184_{a}
Panel –B: Long-run coefficient				
FDI	0.036_{a}	-0.092_{a}	-0.032_{a}	-1.892_{a}
FI	-0.478_{a}	-0.786_{a}	-0.227_{a}	-0.347_{a}
MS	-0.013_{b}	-0.017_{a}	-0.034_{a}	-0.031_{a}
TO	0.097_{a}	-0.018_{b}	0.014_{b}	0.019_{b}
DEBT	-0.018_{a}	0.079_{a}	-0.095_{a}	0.015_{a}
FD	-0.037_{c}	0.057_{b}	-0.025_{b}	0.048_{c}
Panel –C: Short-run coefficients				
ECT	-0.788_{a}	-0.256_{a}	-0.602_{a}	-0.785_{a}
C	NS	NS	-0.146	-0.128
@TREND	NS	NS	-0.049	-0.023
FDI	0.028	-0.041a	-0.094a	-0.085
FI	-0.377a	-0.015a	-0.032b	-0.317a
MS	0.011a	-0.305a	-0.014a	0.015
TR	0.076a	-0.031	0.013a	0.014b
DEBT	-0.014a	0.015a	0.021	0.014
FD	-0.029	-0.074	0.099b	-0.011b
Panel –D: Residual diagnostic stets				
R2	0.842	0.747	0.843	0.657
F-test	25.038a	34.067a	18.432a	47.638a
$x^2_{sR.corr}$	0.056	0.224	0.657	
x^2_{Nor}	0.912	0.042	0.553	
$x^2_{.hete}$	1.450	0.663	1.274	
RESET	1.7611	0.945	0.664	
test bounds critical values (K = 6) *Pesaran et al. (2001)* critical values				
	Bounds	1%		5%
	Upper bound	6.537		4.793
	Lower bound	4.704		3.426

Panel –C exhibits short-run coefficients. The error correction term's coefficients exhibit negative and statistically significant at a 1% level, which suggests that long-run convergence will be established due to short-run shocks in independent variables. Considering FDI impact on the exchange rate volatilely, the study demonstrated a statistically significant negative association in India (a coefficient of -0.041) and Pakistan (a coefficient of -0.094), but insignificant impact observed for Bangladesh and Sri Lanka. Besides, the study document a negative link between financial innovation and exchange rate volatility in Bangladesh (a coefficient of-0.377) in India (a coefficient of -0.015) in Pakistan (a coefficient of -0.032), and Sri Lanka (a coefficient of-0.317). More precisely, a 10% development in financial innovation can bring stability in the exchange rate by 3.77% in Bangladesh, by 0.15% in India, by 0.32% in Pakistan, and 3.17% in Sri Lanka, respectively.

Results of residual diagnostic tests report in Panel –D. Study findings revealed that the empirical model is free from serial correlation, residuals of the error correction term is normally distributed, and model formation is efficiently capable of estimating unbiased output. For control variables effect on exchange rate. In the long run, we observed that money supply helps establish stability in exchange rate movement, i.e., the negative association found with exchanger rate volatility. Trade openness is revealed as a responsible factor for exchange rate volatility in selected countries except in India. Simultaneously, foreign debt and financial development aid for established stable exchange rate movement in Bangladesh and Pakistan, but India and Sri Lanka experienced more volatility in the exchange rate due to financial development and foreign debt in the economy.

Next, asymmetric effects of financial development and financial innovation on exchange rate volatility investigated by performing asymmetry equation, and estimation results display.

Panel–A reports the results of asymmetric cointegration following FPSS, WPSS, and tBDB. The study documented that the test statistics of all the test is statistically significant at a 1% level of significance which reject the null hypothesis of "no asymmetric cointegration." These findings suggest the presence of an asymmetric association between foreign direct investment, financial innovation, exchange rate volatility, and selected macro variables. Once the asymmetric relationship was established, we moved to assess the long-run magnitude of positive and negative shocks in FDI and financial innovation on exchange rate volatility.

Panel –B exhibits long-run coefficients. It appears that positive shocks in FDI are positively linked with exchange rate volatility in Bangladesh (a coefficient of 0.019), in India (a coefficient of 0.013) and Sri Lanka (a coefficient of 0.534), but negative linked established in Pakistan (a coefficient of -0.423). More precisely, 10% augmentation in FDI inflows in the economy will increase exchange rate volatility in Bangladesh by 0.19%, in India 0.13%, and Sri Lanka by 5.34%, but in Pakistan, FDI will reduce exchange rate volatility by 4.23%. Furthermore, negative shocks in FDI established positive linkage with exchange rate volatility in the economy of Bangladesh (a coefficient of 0.016) and the economy of Sri Lanka (a coefficient of 0.123), in contrast, negative shocks in FDI exhibit negative linkage in India (a coefficient of -0.066) and Pakistan (a coefficient of -0.359). Study findings suggest that a 10% decline in FDI inflows results in reduced ERV reduction by 0.16% in Bangladesh and 1.23% in Sri Lanka. More variability in EXV was experienced in India by 0.66% and in Pakistan by 3.59%.

Financial innovation asymmetric effects on EXC that is positive and negative variation in financial innovation, the study disclosed positive variations in financial innovation negatively linked with EXV in Bangladesh [a coefficient of -0.079), in India (a coefficient of -0.084), and Sri Lanka (a coefficient of -0.030),. positive tie established in Pakistan (a coefficient of 0.066]. These findings suggesting that a 10% growth in financial innovation can reduce the state of EXV by 0.79% in Bangladesh, by 0.84% in India, and by 0.30% in Sri Lanka; however, in Pakistan, EXV will be augmented by 0.66%. conversely, negative shocks in financial innovation established a positive association with EXV in Bangladesh (a coefficient of 0.082) and negative yoke revealed in India (a coefficient of -0.011), in Pakistan (a coefficient of -0.047), and Sri Lanka (a coefficient of -0.0).

Panel – C displays model coefficients in the short-run. Considering the error correction term, it apparat negative in sign and statistically significant at a 1% level of significance. This finding suggests long-run convergence in the empirical model due to prior year shocks in independent variables. Refers to asymmetric effects of FDI and financial innovation on EXV, the study revealed that both positive and negative shocks in FDI revealed a negative association with EXV in all empirical models. These findings suggest that in the short-run variability in FDI inflows, they play a vital role in establishing stability in rare exchange movements. Therefore, it is essential to maintain continual inflows of FDI to ensure less volatility in the economy's exchange rate. Likewise, the study unveils positive shocks in financial innovation induces EXV in the economy such as, in Bangladesh by 0.85%, in India by 0.44%, in Pakistan by 0.12%, and in Sri Lanka by 0.29% with a 10% positive growth. In contrast, a 10% negative variation in financial innovation helps mitigate the effects of EXV by 0.12% in Bangladesh, by 0.98% in India, by 1.31% in Pakistan, and by 0.50% in Sri Lanka, respectively.

Table 4: Asymmetric ARDL estimation results

	BD	IND	PAK	SL
Asymmetric cointegration test				
F*pss*	16.896	15.059	66.769363	62.050
W*pss*	11.754	9.956	21.647	45.934
t_{BDM}	-8.266	-5.034	-9.382	-4.778
Long- run coefficients				
δ^+	0.019a	0.013a	-0.423a	0.534a
δ^-	0.016a	-0.066a	-0.359a	0.123a
μ^+	-0.079a	-0.084a	0.066a	-0.030a
μ^-	0.082a	-0.011a	-0.047a	-0.081a
MS		-0.011a		
TR	-0.0747a	0.025a	0.013a	0.017a
DEBT	0.0800a	0.480b	0.024a	0.019a
FD	-0.012a	0.0503a	-0.045a	-0.025a
Wald test for Long-run and short-run asymmetry				
W_{LR}^{FDI}	15.544a	22.861a	16.971a	11.024a
W_{LR}^{FIA}	11.762a	9.884a	12.341a	8.912a
W_{LR}^{MS}	6.153a	12.841a	10.567a	8.004a
W_{SR}^{FDI}	18.775a	16.077a	12.911a	15.227a
Short-run coefficients				
C	0.052a	0.059a	0.139a	-0.026b
@TREND	-0.053a	0.017c	-0.044a	-0.014b
FDI_POS(-1)	-0.046a	-0.081b	-0.029a	-0.076b
FDI_NEG(-1)	-0.096a	-0.048b	-0.038a	-0.379b
FI_POS	0.085a	0.044a	0.012a	0.029b
FI_NEG	-0.012a	-0.098b	-0.131b	-0.050b
MS_POS	0.026b	-0.051a	-0.013b	-0.807b
DTR	0.040c	0.091a	0.0115b	0.024b
DDEBT	-0.012b	-1.064b	0.0981b	0.013a
DFD	-0.041b	-2.698a	-0.034c	0.024a
CointEq(-1)	-0.366a	-0.059a	-0.752a	-0.823a
Residual diagnostic stets				
R2	0.734	0.844	0.783	0.654
F-test	142.078	134.667	165.078	45.065
$x^2_{sR.corr}$	0.223	0.745	0.744	0.339
x^2_{Nor}	1.213	1.834	2.012	1.943
$x^2_{.hete}$	1.345	1.833	2.843	2.056
RESET				
CUSUM test	S	S	S	S
CUSUMQ test	S	S	S	S

Table 5: Toda-Yamamoto casualty test

	EXV	FDI	FI	MS	TR	DEBT	FD	*Summary of causality*
Panel –A: Bangladesh								FDI→EXV; FI←→EXV; MS←→EXV; TR→EXV; FD←→EXV; MS←→FI; DEBT←→FI; FD←→FI; DEBT←→MS, FD←→MS; FDI→TR; MS→TR; FD→TR; TR→DEBT DEBT→FD
EXV	-	7.931c	13.582a	8.493b	11.998a	0.521	6.249c	
FDI	0.325	-	0.122	2.623	3.022	3.461	3.935	
FI	22.52a	0.218	-	9.872a	1.648	6.764c	6.147c	
MS	6.216b	1.185	7.1598b	-	3.757	5.647c	6.505c	
TR	1.298	20.953a	1.268	9.144a	-	4.898	8.032b	
DEBT	2.054	2.503	5.82c	7.414b	5.117c	-	0.957	
FD	9.953a	0.993	14.251a	11.836a	3.951	11.882a	-	
Panel –B: for India								FDI←→EXV; FI←→EXV; FD→EXV; M→FDI; FD→FDI; FDI→FI; FI→M; TR→M; DEBT→M; FD→M;EXV→TR; FDI→TR; EXV→DEBT; FI→DEBT; TR→DEBT;
EXV	-	10.061a	6.923c	0.213	1.427	0.612	9.408a	
FDI	12.011a	-	3.664	6.397c	4.206	0.005	10.703a	
FI	8.424b	6.848c	-	1.044	0.001	0.184	3.987	
MS	2.883	0.723	8.266b	-	10.431a	10.954a	8.227b	
TR	14.239a	14.119a	0.475	0.043	-	2.156	2.574	
DEBT	9.171a	0.949	6.269c	4.612	11.336a	-	0.107	
FD	0.599	12.751a	0.528	10.02a	11.861a	0.532	-	
Panel –C: for Pakistan								FDI←→EXV; FI→EXV; M←→EXV; TR→EXV; FD→EXV; FI→FD; M→FDI; FDI→FI; FD→FI;DEBT→M; FD→M;
EXV	-	11.091a	11.381a	11.261a	12.868a	3.411	6.672c	
FDI	11.762a	-	15.276a	11.415a	2.31	2.859	2.556	
FI	4.557	13.452a	-	1.716	0.281	0.313	14.012a	
MS	15.712a	3.907	0.311	-	1.669	7.844c	7.285c	
TR	1.313	11.161a	2.235	1.363	-	1.186	1.382	
DEBT	12.621a	15.483a	11.638a	16.757a	14.547a	-	12.522	
FD	12.963a	1.469	0.394	1.128	11.874a	1.103	-	
								FDI←→EXV; FI→EXV; FD←→EXV; TR←→FDI; FDI→FI; FD←→FI; EXV→M; TR←→M; FD→M; FI→TR; EXV→DEBT; FDI→ DEBT; M→DEBT; TR→DEBT; FD→ DEBT; TR→FD
Panel –D: for Sri Lanka								
EXV	-	11.415a	9.568a	3.404	3.531	2.952	7.597b	
FDI	12.601a	-	1.945	3.381	11.651a	4.447	1.734	
FI	3.183	13.326a	-	1.03	1.054	1.385	12.371a	
MS	9.129b	5.219	0.841	-	17.607a	3.235	7.604c	
TR	4.087	8.556b	12.53a	6.063c	-	0.728	4.207	
DEBT	20.203a	10.333a	2.453	9.391a	8.384b	-	11.498a	
FD	6.933c	3.924	8.097b	2.163	13.673a	5.085	-	

Wald test results to assess the presence of asymmetric association both in the long-run and short-run displays in Panel –D. Study customary the presence of asymmetry, by rejecting the null hypothesis, i.e., symmetry, effects running from FDI and financial innovation to EXV both in the long-run and short-run.

Referring to the residual diagnostic test, it appears that empirical models are free from serial correlation, residual errors are normally distributed, and empirical models are internally efficient in producing unbiased estimation.

Next, causal effects among FDI, financial innovation, and exchange rate volatility investigated performing causality tests following Toda Yamamoto. Results of causality display with Panel-A for Bangladesh, Panel-B for India, Panel-C for Pakistan, and Panel-D for Sri Lanka, respectively.

However, the study revealed several causalities in the empirical model dealing with the prime impetus between FDI, financial innovation, and EXV. The study holds the feedback hypothesis for elucidating the causality between financial innovation and exchange rate volatility, i.e., bidirectional effects running between them [FI←→EXV] in Bangladesh and India. Furthermore, unidirectional causality revealed running from financial innovation to exchange rate volatility [FI→EXV] in Pakistan and Sri Lanka.

Considering causality between FDI and exchange rate volatility, the study explodes evidence favoring feedback hypothesis, i.e., bidirectional casualty running between FDI and exchange rate volatility [FDI←→EXV] in India, Pakistan, and Sri Lanka. Furthermore, unidirectional causality running from foreign direct investment to exchange rate volatility [FDI→EXV] in Bangladesh.

5. Findings and Conclusion

This study has invested the nexus between inflows of FDI, financial innovation, and exchange rate volatility in selected South Asian countries for the period 1980 to 2017. The study applied Autoregressive distributed Lagged (ARDL) proposed by Pesaran et al. (2001) and nonlinear ARDL introduced by Shin et al. (2014). Furthermore, the directional association assesses by performing a causality test following Toda and Yamamoto (1995).

The unit root test established a mixed order of integration, implying that few variables are stationary at a level, and few become stationary after the first difference. However, long-run cointegration ascertains by the test statistics of FPSS, WPSS, and t_{BDM} by rejecting the null hypothesis of no-cointegration. These findings suggest that continual inflows of FDI in the economy assist in domestic's capital accumulation and bring stability in the international exchange market. Furthermore, in the long run, FDI inflows exhibit adverse effects running to exchange rate volatility except in Bangladesh. On the other hand, a negative association also revealed between financial innovation and exchange rate volatility in all sample countries. Financial innovation accelerates economic integration and helps in efficient intermediation in international trade, thus reducing the economy's foreign currency price movement.

Nonlinear ARDL offers asymmetric cointegration in the empirical model since the test statistics of FPSS, WPSS, and t_{BDM} reject the null hypothesis. Therefore, one can assume the asymmetric effects of FDI and financial innovation's inflows to exchange rate volatility. The standard Wald test confirms both the long-run and short-run asymmetric relationship between FDI inflows and exchange rate volatility and economic innovation and exchange rate volatility. These findings suggest that positive and negative shocks in FDI inflows and financial innovation might not generate similar effects to what happened in respective variables.

Finally, the directional causality test revealed feedback hypothesis holds for postulating association between FDI and exchange rate volatility [FDI←→EXV] in all sample countries except Bangladesh and financial innovation and exchange rate volatility [FI←→EXV] in Bangladesh and India.

Considering study findings, it appears that the role of FDI inflows and financial innovation is critical to subsidies for the erratic movement in the exchange rate. According to Crowley and Lee (2003), receiving FDI in the host economy from the home economy helps expand international trade, domestic capital accumulation, and foreign currency. The bilateral trade association brings stability to the foreign exchange rate by eliminating the trade gap across the border.

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