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Economic Policy uncertainty and financial innovation: Is there any affiliation?

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Abstract: The study's motivation is to gauge the nexus between economic policy uncertainty and financial innovation from 2004M1 to 2018M12 in BRIC nations. For establishing a long-run cointegration study applied Autoregressive Distributed Lagged (ARDL) and asymmetry effects of economic policy uncertainty investigated following nonlinear framework known as NARDL. Furthermore, directional causality is established by performing a non-granger causality test. Cointegration test results of Fpss, Wpss, and tBDM confirmed the long-run association between EPU and financial innovation. On the other hand, the Wald test results proved asymmetry effects furring from EPU to financial innovation both in the long-run and short-run. The asymmetry effects that are positive and negative shocks in financial innovation revealed that negative linkage between shocks in EPU and financial innovation in the long-run but short-run effects is insignificant. Furthermore, financial innovation measured by R&D investment exhibits positive linked with shocks in EPU, implying that uncertainty induces innovation in the economy. Refers to directional causality estimation, the study revealed evidence supporting the *feedback hypothesis* between EPU and financial innovation in all sample countries.

Keywords: Financial Innovation; Economic Policy Uncertainty; ARDL; NARDL, Toda-Yamamoto

JEL classifications: G23; D04; D81

I. Introduction

We hypnotized Economic Policy Uncertainty hereafter EPU influences financial innovation; however, their association yet to explore in the empirical literature. Therefore, it is essential to examine this hypothesis due to the significance and critical role of financial innovation in the economy, especially in the financial sector. Finance scholars, including Miller [1] and Merton [2], advocated the importance of innovative financial products and services to achieve an efficient financial sector in the economy. They

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posit that financial innovativeness is critical not only for financial institutions' sustainability but also for economic progress. Financial innovation expands the existing financing opportunities by lowing the cost of funds and efficient financial intermediation.

Financial innovation in the empirical literature is one of the discussant facts since Schumpeter [3]. Over the past few decades, researchers and academicians invest considerable efforts in gauging the effects of financial innovation and produce substantial evidence such as financial innovation accelerate economic growth (Bara, Mugano [4], Jianguo and Qamruzzaman [5], Bara and Mudxingiri [6], Laeven, Levine [7], Laeven, Levine [8], Michalopoulos, Laeven [9], Qamruzzaman and Wei [10], Ajide [11], financial sector development [12-14], foreign direct investment [15]; financial inclusion [10]. Another line of findings are also available in the empirical literature, i.e., harmful or advise effects base on firm-specific and country-specific investigation see, for instance, Smith, Smithson [16] point to increasing volatility; however, the positive impact from financial innovation is more prominent than a negative one. Tufano [17] established that financial innovations are crucial for global financial integration and diversification and allow financial institutions in the home country to mitigate perceived risk in the financial system by utilizing innovative financial produce ad services. Financial innovation is a tool for investment risk mitigation through diversification.

In recent time, a vast number of studies appeared in literature dealing with the impacts of economic policy uncertainty, hereafter EPU, on a financial system such as credit expansion ([18-21]), financial stability ([22, 23]), banking activities [21, 24, 25]. It suggests that the financial system's key players are vulnerable to the changes in the present state of EPU in the economy. Hence, the powerful effects of EPU can hinder the average speed of financial development. Furthermore, empirical literature also revealed diverse outcome dealing with EPU impact on stock market volatility [26], the stock price [27, 28], financial market [29-32], exchange rate volatility [33], firm-level investment [34, 35], unemployment [36], stock return [37, 38], capital structure [39] and so no.

The **novelty** of the study relies on the following aspects. First, with our best knowledge, for the first time, the nexus between financial innovation and economic policy uncertainty has investigated focusing BRIC nations by using monthly data over the period 2004M1-2018M12. Second, empirical findings with a single proxy measuring financial innovation may not produce enthralling results as such, and this study considers three widely used proxies for measuring the presence of financial innovation in the empirical equation. Third, to gauge the possible association between EPU and financial innovation, the study applied advanced econometrical methodology such as other than the conventional unit root test. We also applied the nonlinear unit root test proposed by Kapetanios, Shin [40], and Kruse [41]. The study performed Autoregressive Distributed Lagged (ARDL) initiated by Pesaran, Shin [42], and Nonlinear-ARDL proposed by Shin, Yu [43]. And their possible directional causality investigated by performing the Non-granger causality test proposed by Toda and Yamamoto [44].

Conventional unit root test revealed mixed order of integration that is few variables are statutory at a level and few after first difference. Furthermore, the unit root test with nonlinearity established that nonlinear stationary processes follow variables. The cointegration test with ARDL confirmed long-run cointegration between EPU and financial innovation since the null hypothesis of "no-cointegration" is rejected in Fpss, Wpss and tBDM tests. This verdict is suitable for all model estimations. Referring to long-run elasticity from EPU to financial innovation, The study disclosed a statistically significant adverse association, implying that economic uncertainty deters financial innovation growth in the financial system. Asymmetry effects are established with empirical model excitation following a nonlinear framework by Shin, Yu [43]. Furthermore, the standard Wald test ascertains the long-run and short-run asymmetry impact

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running from EPU to finical innovation in all three proxy measures. Finally, the directional causality test unveils bidirectional causal effects running between EPU and financial innovation.

The remaining sections apart from the introduction are Section II, dealing with the literature survey. The motivation of the study is explained in Section III. Bribable definitions and econometrical methodology are described in detail in Section IV. Empirical model estimation and interpretation are inserted in Section V. Finally, study finding and conclusion reports in Section VI.

II. Literature review

After the financial crisis of 2008s, to recover from the financial distress world economy feel the importance of effective and stable economic policy. Stability in the economy eliminates adverse shocks in macro fundaments and accelerates the movement towards economic sustainability. However, global economic integration and macro complexity produce economic uncertainty and adverse shocks in economic activities both in the long run and short-run. Krol [33] documented that economic uncertainty positively correlated with the market economy due to macro fundamentals behaviour are intertwined and complex. Uncertainty in monetary policy, according to Baker and Martin [45], shake economic activities both at the macro and micro level and reduce confidence in the economy with the perspective of domestic and foreign investors. Besides, from an investment viewpoint, firms avail benefits from uncertainty by delaying investment on the ground of higher cost and costly workforce to run the project [46].

A. Effects of financial innovation

The well functioned financial sector is pivotal for economic sustainability due to capital accumulation, reallocation, and economic resources mobilization expatiate domestic progress. Therefore, regulatory bodies persistently seek to formulate and implement effective monetary and fiscal policies to ensure financial efficiency. In particular financial efficiency demands diversifications in financial services and products so that a larger population can be served with ease. In the study of Miller [1], innovative financial products intensify the financial sector's growth, in particular financial markets. They explained that diversified financial assets assist in transferring risk, higher returns from tax-deductible security, and investor accumulation in the market.

Financial innovation in the modern economy was positively and negatively accepted through the financial sector channel. Regarding the positive side of financial innovation, the world economy observed global financial integration and expansion of existing financial assets and services in past decades. Financial sectors expand their scope by adapting and diffusing innovative products and services to the economy, especially people who were not enlisted into the formal financial system earlier. To some extent, financial innovation works for financial inclusion by offering risk diversified financial products and services in the financial system. Financial innovation accelerates financial progress establishing capital adequacy, investment opportunity, and intermediation through fetching efficiency in the capital market. Institutional development, i.e., the contribution from other than bank-based financial institutions such as non-bank financial institutions, leasing companies, insurance companies, and so on, in the process of financial innovation. The developing economies' financial region incorporates commercial banks, leasing institutions, insurance companies, and specified financial institutions, such as financial markets, informal financial companies, and house building finance corporations.

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Financial literature, especially finance-growth, postulated that financial innovation contributes to macro and micro development, such as economic growth, efficient financial intermediation, financial diversification, economic resources reallocation, and financial inclusion. The role of financial innovation established in empirical literature in a diversified manner such as, increases the value of financial products and facilities [47], raising the capital growth and distribution practices [48, 49], advances the practices of financial development [50] and upsurges the efficacy of financial institutions [51].

Over the past decades, financial innovation has contributed to enormous evolvement in the hunt for financial inclusion. Possibly the most prominent example of this is the accomplishment of mobile money transfer and banking service. In this vein, a growing number of studies are found in the empirical literature. For instance, In the study of Qamruzzaman and Wei [10], they advocated that the process of financial inclusion has been augmented by the diffusion of innovative financial products and services in the economy. In the study of Arslanian and Fischer [52], they suggested that financial innovation, particularly technological advancement in providing financial services, results in easy access to the unbanked population's formal financial system.

Further evidence was observed in the study [53-55]. Financial inclusion with financial innovation augments integrating the unbans population into the formal financial system by allowing the unbanked rural population to access financial services at their ease. So it is potential to believe that financial innovation broke the Chain of demographic and social attribute issues dragging people to avail financial benefits.

In Dunne and Kasekende [56] study, findings revealed money demand in Sub-Saharan Africa adversely influenced financial innovation both in the long-run and short-run. They advocated that financial innovation induced people to move away from liquidating currency to electronic currency in their daily transactions. Further evidence available in the study of Dooley and Spinelli [57], Arrau and De Gregorio [58], Arrau, De Gregorio [59], Hafer and Kutan [60], Adil, Hatekar [61], and Dlamini and Mabuza [62]. Literature advocated that financial innovation plays a critical role in money demand functions. It is also established that transactional efficiency is one of the financial sector results due to the adaption of innovative financial services, hence financial innovation. In a study, Malik and Aslam [63] postulated that financial innovation brings changes in the financial sector and banking industry reform and substantially influences money demand.

Another vain, i.e., financial innovation and financial stability. Financial innovation is the act of creating and then popularizing new financial instruments and new financial technologies, institutions, and markets. In a study, Xin [64] advocated that financial assets' innovation demands effective regulatory establishment, financial risk possible increased in the financial system. However, risk diversification with efficiency is one of the benefits of financial innovation, which plays a critical role in establishing financial stability. Lüke and Gaowang [65] revealed several variables' financial stability, including assets price in the financial market, economic uncertainty, economic shocks, and banking institutions' behavior. They also detected that financial market capacity, investor's preference, and financial assets performance immensely rely on financial stability.

B. Effects of Economic Policy uncertainty

Over the past decades, economic policy uncertainty becomes one of the key issues in investigating its impact on the economy; with this note, a growing number of empirical studies have already been

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performed concentrating on macro fundamentals. For instance, EPU impact on stock market volatility [26], stock price [27, 28], financial market [29-32], exchange rate volatility [33], firm-level investment [34, 35], unemployment [36], stock return [37, 38], capital structure [39]. Another line of findings was also available in the empirical literature: macro factor effects on EPU see, for instance, oil price shocks [66], gold and Bitcoin [67].

In a study, Nguyen, Le [18] revealed the adverse effects of EPU on credit growth in both advance and developing nations. However, coefficient magnitude revealed that emerging economies are more vulnerable than advanced economies. In another study conducted by Phan, Iyke [22], study findings unveil adverse effects from economic policy uncertainty to financial stability. Furthermore, they postulated that the impact of EPU on financial stability is stronger for countries with higher competition, lower regulatory capital, and smaller financial systems.

Also, Chi and Li [21] revealed that EPU induces loan defaulter in Chain's financial institution. They argued that EPU increases credit risk in the financial system, which discourages reducing loan size. Panousi and Papanikolaou [68] document that high EPU can increase financing costs and risk aversion among top managers, which depresses the investment size. Besides, the depressing effect of EPU on investments is more significant in firms with higher irreversibility in investing that are more dependent on government public expenditure [69]

III. The motivation of the study and hypothesis development

No conclusive pronouncement regarding the nexus between economic policy uncertainty and financial innovation is yet to establish in the empirical literature. Considering, however, their impact on macro fundamentals, it is apparent that both variables play a deterministic role but with diverse direction. Financial innovation augments financial development offering versatile financial products and services to the economy, especially for unbanked pollution. It is suggesting that financial inclusion is one of the results that can be observed in the economy. On the other hand, economic policy uncertainty induces financial instability with fragile financial systems, discouraging people from involving the formal financial system. In a study by Li and Zhong [23], EPU shocks are adversely linked to financial market volatility. They documented that EPU increases financial volatility through interest rate movement, exchange rate fluctuation, stock price declination, and housing price reduction.

Furthermore, the vain of financial innovation and financial volatility exposed negative associations, referring that risk diversification is one of the benefits of adopting innovation in the financial sector. However, Xin [64] documented that excessing financial innovation is the curse for the financial sector. Furthermore, LI and ZHANG [70] revealed that investor irrational behavior causes financial instability in the long-run.

Considering the indirect approach to establish interlinked between financial innovation and EPU, one common verdict can be observed in the financial sector, i.e., rules and regulations about the financial system influences both. Hence, we can presume that it may be an empirical association available between financial innovation and EPU.

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IV. Data and methodology of the study

The study utilizes monthly time series data for the period from 2004M1 to 2018M12 of BRIC countries. The selection of countries and study period purely rely on data availability. All the variables were extracted from Interfacial financial statistics (IFS) published IMF except the index of EPU.

Financial innovation

Lewis and Mizen [71] posit innovation in the financial system appeared in product development and process development. Product innovation entails advancement in financial assets through modification or adaption of improved financial assets such as mutual funds, sweep accounts, and pension funds. Process innovation postulates development in fund accumulation and reallocation processes such as automated teller machines, point-of-sale terminals, and electronic funds transfer.

There is no consensus proxy available in empirical literature because measuring financial innovation in the empirical studies research used several proxy variables. Such variation was subject to data availability and the way of estimation along with countries' socioeconomic status. However, bring into line with the prevailing literature, in this study, we considered three proxy measures that are widely used in the various empirical study see, for instance,

The first proxy is the Broad-to-narrow money (M2/M1) affects the demand for real cash balances, the income, and interest elasticity for money demand. [72]; Bara, Mugano [4], [6] [73] Qamruzzaman and Jianguo [15], Qamruzzaman and Jianguo [74], Qamruzzaman and Jianguo [75], Qamruzzaman and Wei [76]; Arrau and De Gregorio [58]. For the second measure of financial innovations (FI), we employed the ratio of M3 to M1 [56, 77] [11] [78]. Third, following empirical literature such as Bernier and Plouffe [79], Beck, Chen [80], Ajide [11], financial innovation measured by financial sector R&D expenditures.

Economic Policy uncertainty

Baker et al. (2013) measured EPU for major countries and regions globally, and the data can be obtained from the Economic Policy Uncertainty database. It includes uncertainties regarding tax, spending, monetary and regulatory policy by the government that is calculated from 3 components: the frequency that economic policies appear in the newspaper, the number of expired code, and the extent of forecaster disagreement over future inflation and government purchases. Policy uncertainty

For control variables, by following empirical studies dealing with assessing financial innovation effects, see, for instance, Dunne and Kasekende [56]. In this study, we considered three control variables: GDP growth rate, Gross savings as % of GDP, Non-performing loans. All data are transformed by taking natural logarithms to correct for potential Heteroskedasticity. Descriptive statistics and pairwise correlation exhibit in Table I.

Estimation techniques

In the study, we perform several econometric techniques for unveiling certain types of information. Investigating variables the order of integration, we applied both traditional unit root test, namely, ADF: Dickey and Fuller [81], P-P: Phillips and Perron [82], and KPSS: Kwiatkowski, Phillips [83] assuming linear stationary process (see, *Table I*). Furthermore, the study of Galadima and Aminu [84] and Qamruzzaman

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and Karim [85] advocated performed nonlinear unit root tests following Kapetanios, Shin [40] and Kruse [41] for observing the presence of nonlinear process (see Table II &Table III). Furthermore, the Brock-Dechert-Scheinkman-BDS [86] nonlinearity test and the nonlinear ordinary least squares (NOLS) estimation techniques were also employed, confirming the presence of a nonlinear relationship between financial innovation and EPU. The coefficient of nonlinear effects is positive and negative shocks of EPR on financial innovation estimates by applying nonlinear Autoregressive Distributed Lagged propose by Shin, Yu [43]. And finally directional causal relationship also investigate with symmetric and asymmetric effects from remittance inflows in the equation by following Granger non-causality test proposed by Toda Toda and Yamamoto [44]

`*The Kapetanios-Shin-Snell (2003) test*

Performance of Conventional unit root test is under stress due to conflict between theoretical prediction and test statistics, i.e., present form of linear unit root test incapacity to detect theoretical prediction and failed to establish it [87, 88]. With the motivation to mitigate dissatisfaction with conventional unit root test, Kapetanios-Shin-Snell (2003) familiarized with a nonlinear exponential smooth transition autoregressive (ESTAR) process globally stationary.

Therefore, following Kapetanios, Shin [40]; Liu and He [89]; Anoruo and Murthy [90]; and Galadima and Aminu [84], we specify the ESTAR model as

$$\Delta Y_t = \beta Y_{t-1}\{1 - exp(-\theta Y_{t-1}^2)\} + \varepsilon_t \qquad t = 1,2 \dots T \quad (1)$$

Where, Y_t is the time series of interest, β and θ is an unidentified factor, the term$\{1 - exp(-\theta Y_{t-1}^2)\}$ Specify the test to characterize the nonlinear adjustment, ε_t is the stochastic term with a zero mean and a constant variance.

Hence from equation (1), we test the following hypothesis

$$H_0: \theta = 0 \quad (2)$$

And

$$H_1: \theta > 0 \quad (3)$$

In addition to the reparameterization of equation (1), obtain a first-order Talyor series approximation to the ESTAR model under the null, and get the auxiliary regression.

$$\Delta Y_t = \delta Y_{t-1}^3 + error \qquad (4)$$

This is suggesting that it is easy to get the value of t-statistics for $\delta = 0, against\ \delta < 1$ as,

$$t_{NL} = \frac{\hat{\delta}}{s.e.(\hat{\delta})} \qquad (5)$$

Where $\hat{\delta}$ is the ordinary least squares (OLS) estimate of d and $s.e.(\hat{\delta})$ is the standard error of the^ d. Nonetheless, it is noteworthy that the t_{NL} the statistic does not follow an asymptotic standard normal distribution.

The Kruse (2011) test.

Kapetanios, Shin [40] proposed ESTAR based nonlinear unit root test to assume that the location parameter c in the smooth transition function is equal to zero (see equation 1) for empirical study and became popular among researchers. However, a growing number of studies observed the coefficient of c is significant to see, for example, Michael, Nobay [91]; Sarantis [92]; Taylor, Peel [88]; and Rapach and Wohar [93]. Kruse [41] argued that the exclusion of basic assumptions leads to the nonstandard testing problem. Therefore, modified test statistics are used by following Abadir and Distaso [94] to mitigate the location parameter issue. Eventually, the following modified ESTAR specification was proposed.

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$$\Delta Y_t = \alpha Y_{t-1} + \delta Y_{t-1}\{1 - exp(-\theta(Y_{t-1} - c)^2\} + \varepsilon_t \qquad t = 1,2 \dots T \quad (6)$$

Where $\varepsilon_t \sim$ iid(0, σ^2). If the smoothness parameter γ approaches zero, the ESTAR model becomes a linear AR(1) model, i.e. $Y_t = \alpha Y_{t-1} + \varepsilon_t$ that is stationary if $-2 < \alpha < 0$.Nonlinear OLS. Hence, the modified ADF regress is;

$$\Delta Y_t = \sum_{j=1}^{p} \alpha_j Y_{t-j} + \gamma_1 Y_{t-1}^3 + \gamma_2 Y_{t-1}^2 + \varepsilon_t \qquad t = 1,2 \dots T \quad (7)$$

In the equation, the null hypothesis $H_0: \theta = 0$ turn out $\gamma_1 = \gamma_2 = 0$ with the alternative hypothesis of $\gamma_1 < 0; \gamma_2 \neq 0$, where γ_2 stems from the fact that the location parameter 'c' is allowed to take nonzero values.

Linear ARDL

Conventional cointegration tests possess certain limitations, and therefore, the researcher's persistently seeking alternative ways of establishing the long-run association in empirical studies. *[42]* familiarized OLS based cointegration test with variables different order of integration. Additionally, the short-run adjustment speed in the long run also originates using the linear transformation *[95]*.

A simplified ARDL model (see *[96]* for these variables X, Y, and Z can be expressed as;

$$\Delta y_t = \emptyset_1 + \gamma_1 y_{t-1} + \gamma_2 x_{t-1} + \gamma_3 z_{t-1} + \theta_1 \sum_{i=1}^{n} \Delta y + \theta_2 \sum_{i=1}^{n} \Delta x + \theta_3 \sum_{i=1}^{n} \Delta z + \varepsilon_{1t} \quad (7)$$

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 $\theta_1, \theta_2, \theta_3$ denote short-run coefficients.

The generalized ADRL model for assessing the nexus between economic policy uncertainty and financial innovation as follows:

$$\Delta FI^1{}_t = \alpha_0 + \beta_i FI^1{}_{t-1} + \beta_2 \text{EPU}_{t-1} + \beta_3 \text{BL}_{t-1} + \beta_4 GS_{t-1} + \beta_5 \text{Y}_{t-1} + \sum_{j=1}^{m1} \lambda_0 \Delta FI^1{}_{t-j} + \sum_{j=1}^{m2} \lambda_1 \Delta EPU_{t-j} + \sum_{j=0}^{m3} \lambda_2 \Delta BL_{t-j} + \sum_{j=0}^{m4} \lambda_3 \Delta GS_{t-j} + \sum_{j=0}^{m5} \lambda_4 \Delta Y_{t-j} + \varepsilon_t \quad (8)$$

Where, α is an intercept, the long-run coefficients of the empirical model represented by $\beta_1 \dots \dots \dots \beta_6$, the short-run coefficients exhibited by $\lambda_0 \dots \dots \dots \lambda_5$,ε_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).

To implement the ARDL model, the ordinary least square (OLS) method is used to estimate equation 8, and then cointegration between the variables can be established in three different ways, first, using the F-test of Pesaran, Shin [97] with the null hypothesis of no-cointegration ($H_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$) against the alternative of cointegration ($H_0 = \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq 0$). Second, Second, a Wald-test (*W*PSS), which also tests the above joint null. Third, the tBDM-test statistic of Banerjee, Dolado [98] with the null hypothesis of no-cointegration ($H_0: \beta_1 = 0$) against the alternative of cointegration

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(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

Nonlinear ARDL

To gauge the asymmetric effect of EPU on banking institutions' financial innovation, we employed nonlinear ARDL proposed by shin and considered the following asymmetric long-run regression.

$$FI_t = (\beta^+ EPU_{1,t}^+ + \beta^- EPU_{1,t}^-) + \delta_i X_i + \varepsilon_t \quad (9)$$

Where $\beta^+, \beta^- and\ \delta_i$ associated with long-run pavements. β^+, β^- measure the effects of positive and negative shocks in EPU on financial innovation and δ_i measures the effects of control variables in the equation.

Since, a proposed new concept in estimating both long-run and short-run, a growing number of empirical studies extensively applying in their respective studies see, for example [15, 75, 99, 100]. The positive and negative shocks in EPU represent in the equation by$E_{1,t}^+ + E_{1,t}^-$, which is calculated by using the following equations.

$$\begin{cases} POS(E)_{1,t} = \sum_{k=1}^{t} lnE_k^+ = \sum_{K=1}^{T} MAX(\Delta lnE_k, 0) \\ NEG(E)_t = \sum_{k=1}^{t} lnE_k^- = \sum_{K=1}^{T} MIN(\Delta lnE_k, 0) \end{cases} \quad (10)$$

Shin, Yu [43] show that the linear model (9) can be transformed into nonlinear ARDL by incorporating EPU variables' decomposition in the following equation.

$$\Delta \mathrm{FI}_t = \partial \mathrm{U}_{t-1} + (\beta^+ EPU_{1,t-1}^+ + \beta^- EPU_{1,t-1}^-) + \beta_3 inf_{t-1} + \beta_4 \mathrm{Y}_{t-1} + \beta_5 fd_{t-1} + \sum_{j=1}^{m-1} \lambda_j \Delta FI_{t-j} + \sum_{j=1}^{n-1} (\pi^+ EPU_{1,t-1}^+ + \pi^- EPU_{1,t-1}^-) + + \sum_{j=0}^{m-1} \lambda_4 \Delta fd_{t-j} + \sum_{j=0}^{m-1} \lambda_5 \Delta y_{t-j} + \varepsilon_t \quad (11)$$

The equation (11) can be rewritten in the following manner,

$$\Delta \mathrm{FI}_t = \partial \mathrm{e}_{t-1} + \sum_{j=1}^{k-1} \lambda_j \Delta FI_{t-m} + \sum_{m=1}^{k-1} (\pi^+ EPU_{1,t-1}^+ + \pi^- EPU_{1,t-1}^-) + + \sum_{m=0}^{k-1} \lambda_4 \Delta fd_{t-m} + \sum_{m=0}^{m-1} \lambda_5 \Delta y_{t-m} + \varepsilon_t \quad (12)$$

Where $\mathrm{e}_{t-1} = \mathrm{FI}_{t-1} - (\delta^+ EPU_{1,t-1}^+ - \delta^- EPU_{1,t-1}^-) - \theta inf_{t-1} - \vartheta \mathrm{Y}_{t-1} - \tau fd_{t-1}$ is the nonlinear error correction term with $\delta^+ = \frac{-\beta^+}{\partial}$; $\delta^- = \frac{-\beta^-}{\partial}$; $\theta = \frac{-\beta_3}{\partial}$; $\vartheta = \frac{-\beta_4}{\partial}$; $\tau = \frac{-\beta_5}{\partial}$ are the long-run parameters.$\partial = \sum_{j-1}^{m} \varphi_j - 1, \lambda_j = \sum_{i=j+1}^{m} \varphi_i\ for\ j = 1 \ldots., m.\ \delta^+ = \sum_{j=0}^{p} \delta_j^+$; $\delta^- = \sum_{j=0}^{q} \delta_j^-$. The short-run adjustments to positive and negative EPU changes are captured by π^+; π^-. To gauge the asymmetric relationship between EPU and financial innovation, the following NARDL is considered:

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$$\Delta \mathrm{FI}_t = \alpha + \partial \mathrm{FI}_{t-1} + \beta^{+} EPU^{+}_{1,t-1} + \beta^{-} EPU^{-}_{1,t-1} + \beta inf_{t-1} + \beta \mathrm{Y}_{t-1} + \beta fd_{t-1} + \sum_{j=1}^{m1} \lambda_j \Delta FI_{t-j} + \sum_{j=0}^{m2} (\pi^{+} EPU^{+}_{1,t-1}) + \sum_{j=0}^{m3} \pi^{-} EUP^{-}_{1,t-1} + + \sum_{j=0}^{m6} \lambda_4 \Delta fd_{t-j} + \sum_{j=0}^{m7} \lambda_5 \Delta y_{t-j} + \varepsilon_t \quad (13)$$

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 ($H_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = 0$) against the alternative of cointegration ($H_0 = \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq 0$) 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 ($H_0: \beta_1 < 0$). Where nonlinear cointegration is confirmed, the next step is to assess long-run symmetry, i.e. ($\beta^{+} = \beta^{-}$) and short-run (additive) symmetry, i.e. ($\sum_{j=1}^{n-1} (\pi^{+} E^{+}_{1,t-1}) = \sum_{j=1}^{n-1} \pi^{-} E^{-}_{1,t-1}$) using a standard Wald test.

Toda Yamamoto causality test

To established directional causality between financial innovation, money supply, interest rate, remittance and stock price, we applied the non-causality test proposed by Toda and Yamamoto [44]. Because traditional casualty tests are based on F-statistics in a regression context for determining whether some parameters in the model jointly zero (a stable VAR model) is not valid with variables are integrated. To overcome existing limitations in the traditional causality test, Toda and Yamamoto [44] proposed a causality test utilizing the Modified Wald test to restrict a VAR(*k*). The Toda and Yamamoto [44] causality test is based on the idea of Vector autoregressive at level *(P=K+D$_{max}$)* with correct VAR order *K* and *d* extra lag, where *d* represents the maximum order of integration of time series.

Toda and Yamamoto's non-causality test, according to Zapata and Rambaldi [101], possess certain advantages over the traditional Granger causality test. First, assessing causality with a non-causality test does not require cointegration properties in the system equation. Second, in the mixed order of variables integration that is either I (0) and I (1), the MWALD test can investigate existing causality between variables.

$$FI^1{}_t = \alpha_0 + \sum_{i=1}^{k} \beta_{1i} FI^1{}_{t-i} + \sum_{j=k+1}^{d_{max}} \beta_{2j} FI^1{}_{t-j} + \sum_{i=1}^{k} \gamma_{1i} EPU_{t-i} + \sum_{j=k+1}^{d_{max}} \gamma_{1j} EPU_{t-j} + \sum_{i=1}^{k} \varphi_{1i} Y_{t-i} + \sum_{j=k+1}^{d_{max}} \varphi_{1j} Y_{t-j} + \sum_{i=1}^{k} \delta_{1i} BL_{vol_{t-i}} + \sum_{j=k+1}^{d_{max}} \delta_{2j} BL_{vol_{t-j}} + \sum_{i=1}^{k} \theta_{1i} GS_{t-i} + \sum_{j=k+1}^{d_{max}} \theta_{2j} GS_{t-j} + \varepsilon_{1t} \quad (14)$$

$$FI^2{}_t = \alpha_0 + \sum_{i=1}^{k} \beta_{1i} FI^2{}_{t-i} + \sum_{j=k+1}^{d_{max}} \beta_{2j} FI^2{}_{t-j} + \sum_{i=1}^{k} \gamma_{1i} EPU_{t-i} + \sum_{j=k+1}^{d_{max}} \gamma_{1j} EPU_{t-j} + \sum_{i=1}^{k} \varphi_{1i} Y_{t-i} + \sum_{j=k+1}^{d_{max}} \varphi_{1j} Y_{t-j} + \sum_{i=1}^{k} \delta_{1i} BL_{vol_{t-i}} + \sum_{j=k+1}^{d_{max}} \delta_{2j} BL_{vol_{t-j}} + \sum_{i=1}^{k} \theta_{1i} GS_{t-i} + \sum_{j=k+1}^{d_{max}} \theta_{2j} GS_{t-j} + \varepsilon_{1t} \quad (15)$$

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$$FI^3{}_t = \alpha_0 + \sum_{i=1}^{k} \beta_{1i} FI^3{}_{t-i} + \sum_{j=k+1}^{d_{max}} \beta_{2j} FI^3{}_{t-j} + \sum_{i=1}^{k} \gamma_{1i} EPU_{t-i} + \sum_{j=k+1}^{d_{max}} \gamma_{1j} EPU_{t-j} + \sum_{i=1}^{k} \varphi_{1i} Y_{t-i} + \sum_{j=k+1}^{d_{max}} \varphi_{1j} Y_{t-j} + \sum_{i=1}^{k} \delta_{1i} BL_{vol}{}_{t-i} + \sum_{j=k+1}^{d_{max}} \delta_{2j} BL_{vol}{}_{t-j} + \sum_{i=1}^{k} \theta_{1i} GS_{t-i} + \sum_{j=k+1}^{d_{max}} \theta_{2j} GS_{t-j} + \varepsilon_{1t} (16)$$

V. Model estimation and interpretation

Unit root test:

The results of conventional unit root test, i.e., ADF and P-P *with the null hypothesis of data is no stationary and KPSS with the null hypothesis of data is stationary,* exhibit in Table I. Results established mixed order of integration, suggesting that few variables are stationary at a level I(0) and few become stationary after first difference I(1). This verdict is pertinent to all three unit root tests.

Table I Results of Unit root test

Panel-A; unit root test with ADF test with Constant and Constant &Trend								
F1	-1.195	-1.634	-1.5538	-4.9181a	-1.6843	-2.5556	-1.0544	-1.3315
F2	1.060	-2.115	-1.7975	-4.3213a	-0.9434	-3.0366	-1.3586	-2.0036
F3	-1.109	-2.081	-2.7188c	-2.681c	-1.9415	-1.867	-0.7783	-3.5142
PE	-5.521a	-6.807a	-0.5695	-1.4188	-5.3406c	-10.5372a	-0.7783	-3.5142
GS	0.378	-1.61	-1.7027	-1.9103	-0.6817	-0.7999	-1.6604	-2.1438
BL	-6.429a	-6.006a	-1.5585	-1.3578	-2.2964	-2.7459	-0.9544	-1.4258
Y	-3.158b	-3.142c	-1.0159	-1.9113	-1.5256	-1.1931	-1.0927	-1.7894
ΔF1	-13.369a	-13.369a	-9.9007a	-9.888a	-2.6452c	-2.9395	-16.738a	-16.6967a
ΔF2	-16.570a	-16.770a	-9.3819a	-9.3663a	-2.8235c	-2.8185	-16.5838a	-16.5418a
ΔF3	-26.155a	-25.993a	-16.2264a	-16.1997a	-4.9243a	-4.9323a	-16.6503a	-16.721a
ΔPE	-9.383a	-9.611a	-8.607a	-11.553a	-12.7147a	-12.6809a	-16.6503a	-16.721a
ΔGS	-9.388a	-9.378a	-3.9476a	-3.9581a	-4.8759	-4.7731	-7.2555a	-7.3222a
ΔBL	-7.377a	-7.642a	-11.2416a	-11.2518a	-12.8795a	-12.8622a	-12.9304a	-12.8961a
ΔY	-12.394a	-12.466a	-13.1588a	-13.1214a	-12.3637a	-12.3936a	-13.3755a	-13.34a
Panel-A; unit root test with P-P test								
F1	-1.115	-0.789	-1.8059	-3.7685b	-1.5895	-3.9059	-1.0278	-1.761
F2	1.228	-1.943	-1.4592	-3.4191c	-0.7535	-2.705	-1.0629	-1.7907
F3	-0.804	-2.318	-5.4896a	-5.4781a	-2.7561	-2.6363	-1.8064	-3.1007
PE	-5.536a	-6.673a	-0.6575	-1.1768	-8.6796a	-10.6338a	-1.8064	-3.1007
GS	0.359	-1.722	-1.6101	-1.7191	-2.1408	-2.1264	-1.4114	-1.8368
BL	-2.553	-2.538	-1.8614	-1.8949	-2.5342	-2.9893	-0.9887	-1.5366

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Y	-3.234b	-3.154c	-1.0301	-1.9809	-1.5896	-1.4463	-1.0927	-1.8108a
ΔF1	-12.911a	-12.946a	-19.2999a	-20.8224a	-21.3488a	-23.1544a	-16.3426a	-16.3092a
ΔF2	-17.054a	-17.273a	-14.6161a	-14.8512a	-19.1089a	-19.0616a	-16.2266a	-16.1916a
ΔF3	-14.049a	-14.011a	-29.0398a	-29.2885a	-9.8576a	-9.8993a	-17.3203a	-17.5537a
ΔPE	-5.455a	-5.711a	-6.8023a	-6.7969a	-49.7774	-49.6033	-17.3203a	-17.5537a
ΔGS	-3.937a	-3.892a	-6.2778a	-6.2535a	-7.9756a	-8.3661a	-7.7609a	-7.7825a
ΔBL	-5.196a	-5.149a	-11.6485a	-11.6459a	-12.8791a	-12.862a	-12.9335a	-12.8993a
ΔY	-8.443a	-8.541a	-13.1588a	-13.1214a	-12.4736a	-12.4603a	-13.3756a	-13.341a
Panel-A; unit root test with KPSS test								
F1	1.585a	0.112	1.5383a	0.1895b	1.6741a	0.1467b	1.2791a	0.1507b
F2	1.637a	0.329a	1.5517a	0.1545b	1.6258a	0.1247c	1.2812a	0.156b
F3	1.443a	0.080	1.3027a	0.2936a	1.1605a	0.089	1.1161a	0.1729b
PE	0.840a	0.145c	1.2799a	0.1537b	1.497a	1.0937a	1.1161a	0.1729b
GS	1.260a	0.262a	1.2107a	0.1098b	1.092b	1.0781a	1.0617a	0.1367b
BL	0.393a	0.149b	1.2681a	0.2653a	0.4262	0.1498b	1.3069a	0.2501a
Y	0.947a	0.089	1.3755a	0.1695b	1.1033a	0.2653a	1.4003a	0.1944b
ΔF1	0.136	0.107	0.1902	0.1812b	1.2131a	0.3796a	0.1078	0.1072
ΔF2	0.398c	0.087	0.1543	0.1392	0.0766	0.0773	0.0941	0.0938
ΔF3	0.067	0.050	0.1451	0.108	0.0966	0.0487	0.2648	0.0846
ΔPE	0.242	0.043	0.2018	0.184b	0.0418	0.0416	0.2648	0.0846
ΔGS	0.068	0.053	0.0939	0.0929	0.2689	0.0758	0.1146	0.0524
ΔBL	0.363	0.1641b	0.1036	0.0478	0.0612	0.0298	0.1424	0.1355
ΔY	0.178	0.064	0.0918	0.092	0.1593	0.0679	0.0941	0.0885

Table II reports the nonlinear unit root test result with Kapetanios, Shin [40]. The test utilizes three cases, such as raw data (Case 1), the demeaned data (Case 2), and the de-trended data (Case 3) for the series of financial annotations, EPU, gross saving, non-performing loan, and economic growth. We observed that the linear unit root test's null hypothesis is rejected for all the variables in either case. Hence, we can conclude that the series of financial innovation, EPU, gross savings, non-performing loans, and economic growth follow nonlinear stationary processes.

Table II Results of KSS nonlinear unit root test

Series		FI[1]	FI[2]	FI[2]	EPU	BL	GS	Y
Case -1	Brazil	-4.751a	-0.718	-2.157	-4.323a	-3.006a	-3.013a	-3.134a
	Russia	-2.751	-3.124a	0.126	-1.376	-4.034a	-1.935	-4.561a
	India	-6.277a	-3.112a	-6.726a	-1.141	-1.388	-5.297a	-4.335a

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	China	-6.522a	3.246a	-2.898a	-3.378a	-3.043a	-1.008	-1.121
Case -2	Brazil	-2.517c	-6.774a	-9.654	-1.642	-4.951a	-4.406a	-3.978a
	Russia	-2.728c	-3.373	-7.528	-3.268c	-3.171	-4.806a	-2.57
	India	-6.142a	6.849a	-1.672a	-3.408b	-4.873a	-1.818	-1.277
	China	-6.142a	6.214a	-2.638	-1.574	-5.651a	-5.145a	-3.414b
Case - 3	Brazil	-4.517a	-6.782a	-9.124a	-2.21	-1.033	-1.29	-1.767
	Russia	-2.013	-3.171b	-9.210a	-2.32	-1.781	-4.145a	-4.577a
	India	4.032a	7.363a	-1.890	-4.911a	-5.455a	-4.408a	-1.78
	China	4.032a	7.634a	-6.811a	-3.514b	-4.859a	-1.175	-2.089
Critical value Kapetanios, Shin [40]								
	level	Case-1	Case-2	Case - 3				
	1%	-2:82	−3:48	−3:93				
	5%	−2:22	−2:93	−3:40				
	10%	−1:92	−2:66	−3:13				

Table III displays the results of Kruse [41] nonlinear unit root test. The results signpost that the linear unit root test's null hypothesis is rejected either 1% or 5% level of significance, implying that the series of financial innovation, economic policy uncertainty, gross saving, Bad loan, and economic growth follow nonlinear stationary processes.

Table III Results of Kruse nonlinear unit root test

Series		FI^1	FI^2	FI^2	**EPU**	**BL**	**GS**	Y
Case -1	Brazil	24.943a	0.921	11.634a	12.066a	7.949	4.077	13.266a
	Russia	35.526a	18.064a	10.929c	18.654a	15.454a	12.236a	5.51
	India	12.841a	14.575a	15.115b	7.749	5.353	10.927a	9.268
	China	9.874b	38.126a	5.664	17.914a	18.391a	18.021a	6.203
Case -2	Brazil	14.009a	13.064a	17.198a	10.863b	10.446b	6.328	19.438a
	Russia	11.267a	16.524a	9.383	18.014a	17.364b	8.665c	4.945
	India	5.947	3.280	13.954b	3.358	10.091c	2.437	8.925c
	China	15.748a	13.046a	6.286	17.126a	18.541a	9.881c	17.102a
Case -3	Brazil	16.952a	12.243a	16.048b	11.224a	12.775a	7.276	3.199
	Russia	30.948a	5.748	7.150	14.395a	14.125a	9.911	19.491a
	India	11.287a	3.780	3.101	7.881	15.546a	19.947a	7.685
	China	14.214a	11.332a	5.807	14.327a	8.445	15.025a	9.629
Asymptotic Critical Values of t-statistic								
		Case-1	Case-2	Case -3				
	1%	13.15	13.75	17.10				

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	5%	9.53	10.17	12.82				
	10%	7.85	8.60	11.10				

*Notes: The critical values are from Kruse (2011). A denotes the optimal lag length selected by the SBC. The estimation and tests were conducted using a program code written in "R" produced by Kruse. ***, ** and * denote the rejection of a unit root's null at the 1, 5, and 10% significance level, respectively. Nonlinearity test*

In the following, the study investigates both long-run and short-run relationships between financial innovation, EPU, gross savings, non-performing loans, and economic growth of BRIC nations performing equation (8). Table IV displays the results, including long-run cointegration test in Panel-A; long-run coefficients in Panel – B; short-run coefficients reports in Panel –C, and residual diagnostic tests result in Panel –D.

Panel-A of Table IV reports the results of the long-run cointegration test performing three statistics. First, the modified F-test (FPSS), advanced by Pesaran, Shin [97]. Second, a standard Wald-test (WPSS), which is the above joint null hypothesis, and Third, a t-test (tBDM) proposed by Banerjee, Dolado [98]. We observed that the null hypothesis of no co-integration is rejected by a significant 1% level, suggesting that test statistics of F_{pss}, $W_{pss,}$ and t_{BDM} are higher than the critical value at a 1% level significance. Once the long-run association documented, we move to assess both long-run and short-run magnitudes running from economic policy uncertainty to financial innovation

Table IV of Panel B reports long-run coefficients and found negatively associate with financial innovation. Results display in Col [1] for Brazil, a coefficient of -0.029, [4] for Russia, a coefficient of -0.081, [7] for India, a coefficient of -0.073, and [10] for China, a coefficient of -0.074, where financial innovation measured by M2/M1 in the empirical equation. Furthermore, financial innovation measured N3/M1 by results exhibits in Col [2], a coefficient of -0.026 for Brazil, Col [5] a coefficient of -0.028 for Russia, col [8] a coefficient of -0.064 for India, and col [11] a coefficient of -0.053 for china. Furthermore, the empirical model outcome with investment in R&D as a proxy for financial innovation exhibits in Col [3] for Brazil, a coefficient of -0.069, col [6] for Russia, a coefficient of 0.073, col[9] for India, a coefficient of -0.012, and col [12] for China, a coefficient of -0.029, respectively. The noticeable fact is that all the coefficients are statistically significant at a 1% level of significance.

Panel-C of Table IV reports the Short-run coefficients of the empirical model. The study documented that the error correction term is negative and statistically significant at a 1% level. The coefficients specify the speed of adjustment toward long-run equilibrium due to prior period shocks. Regarding EPU's effects on financial innovation, the study revealed similar associations like the long-run, i.e., adverse impact. More precisely, financial innovation proxy by M2/M1 revealed a coefficient of -0.034 for Brazil, a coefficient of -0.023 for Russia, a coefficient of -0.325 for India and a coefficient of -0.285 for China. Based on coefficient elasticity, India and China's financial system are more responsive than other selected nations.

On the other hand, col [2], [5], and [8] display the magnitudes of EPU on financial innovation, which is measured by M3/M1. Due to a 10% increase in EPU, results declined the speed of financial innovation embellishment by 0.475 in Brazil, by 0.91% in Russia, by 2.91% in India by 2.88% in China. Findings suggest that financial innovation in the form of M3/M1 response more promptly in India and China due to movement in EPU. So, it established that reducing EPU by implementing control mechanisms in the economy, both India and China, can maximize Brazil and Russia's potential benefits.

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Column [3], [6]. [9], and [12] of panel –C in Table IV exhibits EPU effects on financial innovation measured by investment in R&D by the financial institution. The study established a positive relationship, i.e., a coefficient of 0.179 for Brazil, a coefficient of 0.123 for Russia, a coefficient of 0.015 for India, and a coefficient of 0.073 for China. These findings suggest that EPU financial institutions expand their investment in innovating and developing financial services and producing to mitigate the adverse effects. Such expenditure assists financial institutions to grab investment opportunities and reallocation of economic resources inefficient manner.

For control variables, in the long-run, we observed that the coefficients of non-performing Load negatively impact financial innovation, while gross savings and economic growth emerged as a motivating factor for adaptation and evolution of innovative financial products and services in the financial system. Furthermore, the short-run model documented that gross saving plays a positive role in further developing financial innovation. While non-performing loans and economic growth exhibit adverse influences on financial innovation, their elasticity to financial innovation is statistically insignificant.

Panel –D of Table IV presents the result of diagnostic tests. The associated p-value of test statistics is statistically insignificant, implying that empirical models are free from serial correlation, residuals are normally distributed, and internal consistency is also established.

Table IV Linear ARDL estimation results

	Brazil			Russia			India			China		
Panel- A: Long-run cointegration												
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
F_{pss}	6.482a	15.623a	7.677a	19.771a	4.79a	5.362a	8.44a	12.102a	12.518a	11.919a	16.761a	9.511a
W_{pss}	12.331a	12.98a	9.609a	10.211a	19.951a	8.96a	19.8a	19.774a	5.101a	11.109a	12.857a	18.106a
t_{BDM}	-11.397a	-10.824a	-5.562a	-7.03a	-8.234a	-11.584a	-9.077a	-5.233a	-4.712b	-8.698a	-7.402a	-9.061a
Panel-B: long-run coefficients												
β	-0.029a	-0.026a	-0.069a	-0.081b	-0.028a	-0.111a	-0.073a	-0.064a	-0.012	-0.074a	-0.053a	-0.029
γ	-0.158a	-0.305a	0.273a	-0.285b	0.182a	-0.331a	0.067b	0.204b	-0.029	-0.019a	-0.115a	0.027a
δ	0.369a	0.145b	0.549a	0.103b	0.089c	0.611c	0.135a	0.681a	0.005	0.045a	0.066a	0.016b
λ	0.172a	0.166b	0.152b	0.154b	0.241b	0.397a	0.139a	0.274a	0.034	0.012a	0.191a	-0.006
Panel –C: Short-run coefficients												
Constant	-0.341c	0.935c	1.145a	-0.096a	0.098	-0.221	-0.495a	-1.037	-0.015	0.604a	0.201	-0.042
Trend	0.025a	0.104b	-0.04a	0.025a	-0.035	0.013	0.034a	0.019	-0.016	0.061a	0.016	0.242
λ1	-0.034a	0.047b	0.179a	-0.023a	-0.091a	0.123c	-0.325a	-0.291	0.015c	-0.285a	-0.288c	0.073c
λ2	0.016	-0.026b	0.079	0.462	0.913	-0.25	0.021	-0.314	-0.016	0.215a	-0.003	-0.015
λ3	0.038b	0.142a	0.029b	0.145a	0.126a	-0.004	0.015b	0.053c	0.003a	0.081a	0.002	0.006
λ4	-0.014a	-0.014	0.054b	0.213a	-0.196	-0.021	0.001	0.014	-0.011	0.012a	-0.014	-0.004
ζ	-0.104a	-0.084a	-0.091a	-0.123a	-0.081	0.416	-0.317c	-0.314	-0.091	-0.143a	-0.378	-0.053
Panel –D: residual Diagnostic test												
R2	0.583	0.618	0.146	0.504	0.153	0.439	0.789	0.792	0.329	0.287	0.132	0.747
F-test	11.251a	25.315a	.14.884a	25.015a	75.024a	18.254a	10.384a	10.667a	45.054a	12.587a	15.294a	14.035a
$x^2_{sR.corr}$	0.729	0.83	0.446	0.558	0.748	0.66	0.011	0.557	0.271	0.31	0.785	0.237

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x^2_{Nor}	0.543	0.877	0.22	0.41	0.117	0.305	0.368	0.424	0.894	0.942	0.409	0.174
x^2_{hete}	0.53	0.749	0.331	0.353	0.751	0.155	0.235	0.078	0.473	0.891	0.714	0.445
RESET	0.918	0.13	0.593	0.321	0.58	0.966	0.584	0.877	0.285	0.152	0.135	0.123

Next, the asymmetric effects of EPU on financial innovation investigated executing nonlinear ARDL and result in reports in Table V.

Panel-A of Table V displayed the results of Fpss, Wpss, and tBDM for the cointegration test and rejected their respective null hypothesis at a 1% level of significance. Next, the long-run and short-run Wald test results rejected the null hypothesis of symmetry at a 1% level of significance. These findings suggest that positive and negative economic policy uncertainty variations do not indicate the linear trend observed in financial innovation. Therefore, applying NARDL in assessing the long-run and short-run effects of EPU on financial innovation allows a better fit model in empirical estimation.

Move to assess nonlinear effects of EPU, i.e., positive and negative shocks of EPU, on financial innovation, and the results exhibit in Panel –B of Table V for the long run. The study established a negative linkage between positive and negative shocks in EPU and financial innovation regarding their linkage. These findings suggest that the increase of EPU in the economy adversely caused the development and evolution of financial innovation in the financial system; on the other hand, financial stability through reducing EPU acts as a catalyst role and encourages financial institutions to adapt and offer innovative financial product and services in the economy.

Furthermore, short-run nonlinear effects display in Panel –C of Table V. Study revealed several statistically insignificant coefficients. However, we observed that statistically significant positive and negative shocks established negative linkage with financial innovation. These findings suggest that EPU can halt the smooth process of financial innovation in the financial system in the short run due to policy uncertainty increase financial vitality in the financial system and cause regulatory development.

The results of the long-run and short-run symmetry exhibit in Panel-D of Table V. Both long-run and short-run asymmetry investigated through the standard Wald test with the null hypothesis of "long-run and short-run symmetry". The test statistics reject the null hypothesis at a 1% level of significance and confirmed asymmetry running from EPU to financial innovation. These findings suggested that positive and negative shocks in EPU do not cause in the same direction with the same magnitudes. Furthermore, residual diagnostic tests confirm model stability and efficiency for empirical estimation.

Table V results of Asymmetric model estimation

	Brazil			Russia			India			China		
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12
Panel –A: Long-run Cointegration test												
F_{pss}	13.898	14.822	7.544	9.74	9.656	9.999	18.748	5.525	8.606	10.873	12.676	17.40
W_{pss}	13.813	7.353	17.515	7.468	11.08	17.714	16.338	8.303	17.592	10.283	18.387	5.98
t_{BDM}	**-7.789**	**-8.058**	**-11.435**	**-8.777**	**-5.588**	**-4.155**	**-7.896**	**-9.861**	**-7.583**	**-10.861**	**-8.378**	**-12.2**
W^{EPU}_{LR}	17.668	16.669	8.279	16.006	11.791	18.535	18.961	8.864	8.978	14.461	11.557	19.80
W^{EPU}_{LR}	17.668	16.669	8.279	16.006	11.791	18.535	18.961	8.864	8.978	14.461	11.557	19.80
Panel –B: Long-run coefficients												
γ^+	-0.132[a]	-0.041 [a]	-0.033 [a]	-0.102 [a]	-0.312 [a]	-0.196 [a]	-0.195 [b]	-0.004 [a]	-0.108 [a]	-0.013 [a]	-0.101 [a]	-0.04
γ^-	-0.023[a]	-0.025 [a]	-0.041 [a]	-0.111 [a]	-0.051[b]	-0.059 [a]	-0.356 [a]	-0.015[a]	-0.045 [a]	-0.052[b]	-0.107[a]	-0.02

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λ	0.348a	0.149b	0.038b	0.091b	-0.486b	-0.27b	0.069b	0.002b	0.195a	-0.106c	-0.031c	0.014
β	0.174a	0.075b	-0.433b	-0.015b	0.232b	0.114a	-0.127a	0.089b	1.807b	0.135b	0.048a	-0.01
μ	-0.086b	0.187b	0.031a	0.023a	-0.316a	-0.149	0.159a	-0.17b	-0.481	-0.215a	-0.035c	-0.00
Panel –C: Short-run coefficients												
Constant	-0.07	-0.02	7.897	0.464	0.671	-0.251	0.969	0.037	0.943	-0.358	0.204	0.13
Trend	0.006	0.073	-0.024	0.013	-0.002	0.002	-0.081	0.005	-0.024	0.032	0.048	0
δ^+	-0.016a	0.031a	0.371	0.011	-0.012a	-0.041b	0.012c	-0.292c	-0.033a	-0.023a	-0.024a	0.209
δ^-	0.029	0.078a	0.107	-0.035a	-0.051a	-0.262a	0.098c	0.024c	-0.082a	0.635	-0.011a	0.014
λ	0.043	0.933	0.011	-0.038	0.046	-0.26	0.067	-0.041	-0.864	0.149	-0.015	-0.01
β	0.022	0.125	0.03	0.292	-0.053	0.127	-0.098	-0.003	0.072	-0.119	0.028	0.005
μ	-0.011	-0.193	-0.029	0.058	0.22	0.086	-0.015	0.005	-0.002	0.182	-0.011	-0.00
ζ	-0.123a	-0.24a	-0.373a	-0.306a	-0.194a	-0.133a	-0.262a	-0.094a	-0.328a	-0.128a	-0.091a	-0.08
Panel –D: Diagnostic test												
W_{LR}^{EPU}	17.668	16.669	8.279	16.006	11.791	18.535	18.961	8.864	8.978	14.461	11.557	19.80
W_{SR}^{EPU}	9.504	5.229	9.616	18.987	6.52	14.332	9.77	4.377	3.502	12.241	8.216	10.72
x_{Auto}^2	0.343	0.582	0.187	0.063	0.715	0.148	0.699	0.215	0.589	0.494	0.906	0.059
x_{Het}^2	0.511	0.259	0.168	0.401	0.072	0.29	0.401	0.347	0.907	0.023	0.718	0.535
x_{Nor}^2	0.431	0.691	0.866	0.233	0.978	0.342	0.914	0.525	0.212	0.764	0.072	0.859
x_{RESET}^2	0.057	0.534	0.168	0.572	0.615	0.493	0.316	0.658	0.427	0.285	0.177	0.177

The following directional relationship is examined by performing a causal equation [14-16], and results shown in Table VI, Table VII, and Table VIII, respectively. The study established several directional causalities; however, the study focus on causality between EPU and financial innovation.

In Table VI, we observed that the *feedback hypothesis* explains the causality between EPU and financial innovation [EPU←→FI] in Brazil, Russia, and India. Findings are suggesting that shocks, in either case, both variables are subjects to the response. Therefore, development in financial innovation should appropriately regulate and evolve in the financial system. Additionally, unidirectional causal effects are running from EPU to financial innovation [EPU→FI]. Furthermore, the directional association between financial innovation and control variables. We observed that bidirectional causality between non-performing loans and economic growth, i.e. [BL←→FI; Y←→FI] and unidirectional causality running from gross savings, i.e. [GS→FI].

Table VI Results of causality test: Financial innovation measured by M_2/M_1

	FI	EPU	BL	GS	Y	Causal relationship
Panel-A: Brazil						
FI	-	12.761a	13.036a	6.745b	6.268C	EPU←→FI; BL←→FI; GS→FI; Y←→FI; BL←→EPU; Y→EPU; EPU→GS; BL→GS; BL→Y
EPU	15.746a	-	16.666a	2.979	12.19a	
BL	7.324b	7.608b	-	3.554	1.907	
GS	3.839	11.021a	11.407a	-	0.607	
Y	14.41a	3.563	11.453a	2.358	-	
Panel – B: Russia						
FI	-	8.132b	11.388a	0.011	1.357	EPU←→FI; BL←→FI;
EPU	9.942a	-	0.879	0.975	0.689	
BL	10.463a	0.973	-	0.829	3.242	
GS	3.664	2.093	3.437	-	3.755	
Y	2.195	2.476	3.101	0.735	-	

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Panel –C: India						
FI	-	13.832a	4.833	6.317c	6.722c	EPU←→FI; GS→FI; Y←→FI; BL→EPU; Y←→EPU; FI→BL; Y→BL; EPU→GS; Y←→GS;
EPU	9.075b	-	6.837c	2.258	12.021a	
BL	8.827b	0.577	-	0.911	6.924c	
GS	1.245	6.995c	3.717	-	10.887a	
Y	18.231a	7.173c	5.293	11.606a	-	
Panel-D: China						
FI	-	12.516a	7.764c	9.257b	4.873	EPU→FI; BL←→FI; GS→FI; BL←→EPU; GS→BL; EPU→Y
EPU	2.145	-	6.569c	0.593	2.016	
BL	12.145a	6.569c	-	8.593b	3.016	
GS	1.096	0.97	0.152	-	1.54	
Y	3.899	5.967c	0.455	3.53	-	

Table VII presents causality test results where M3/M1 measures financial innovation. The study revealed bidirectional causality between EPU and financial innovation [EPU←→FI] in Brazil, Russia, and China. Additionally, unidirectional causality running from EUP to financial innovation [EPU→FI] India. Referring to causality between financial innovation and control variables, the study disclosed that bidirectional causality is running between economic growth and financial innovation [Y←→FI] and non-performing loan and financial innovation [BL←→FI] Brazil, Russia, and India, and gross savings to financial innovation [GS←→ FI] in china. Furthermore, unidirectional causality revealed running from gross savings to financial innovation [GS→FI] in India.

Table VII Results of causality test: Financial innovation measured by M_3/M_1

	FI	EPU	BL	GS	Y	Causal relationship
Panel – A: Brazil						
FI		13.595a	6.325c	3.565	8.304b	EPU←→FI; BL←→FI; Y←→FI;BL←→EPU; Y→EPU; GS←→BL; FI→GS; EPU→GS; BL→Y;
EPU	18.823a		21.303a	3.47	18.845a	
BL	9.846b	8.293b		6.461c	1.114	
GS	7.382c	10.835a	12.549a		0.635	
Y	6.779c	3.49	12.491a	5.028		
Panel – B: Russia						
FI		6.021c	8.353b	4.066	3.492	EPU←→FI; BL←→FI;GS→EPU; Y→BL; FI→GS; EPU→Y; GS→Y
EPU	8.047b		1.287	11.078a	0.815	
BL	15.877a	0.383		0.317	7.029c	
GS	10.944a	2.025	5.012		3.147	
Y	3.989	11.675 a	5.336	10.497 a		
Panel – C: India						
FI		12.142a	15.594a	7.249c	8.072b	EPU→FI; BL←→FI; GS→FI; Y←→FI;GS←→ EPU; Y←→ EPU; Y→BL; Y→GS;
EPU	5.799		7.094c	2.026	13.381a	
BL	6.119c	0.591		1.08	6.114c	
GS	0.839	6.733c	3.46		9.963b	
Y	20.626a	6.737c	5.689	11.822a		
Panel – D: China						
FI		14.279a	10.95a	10.225a	4.996	
EPU	6.562c		7.427c	1.446	1.234	

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BL	1.422	1.058		0.067	1.486	EPU←→FI; BL→FI; GS←→FI; BL→EPU; BL→Y
GS	1.519	6.392c	0.459		0.632	
Y	0.537	1.33	11.852a	0.693		

Causality results with financial innovation measured by investment in the R&D report in Table VIII. Study findings support the presence of *feedback hypothesis* available between EPU and financial innovation [EPU←→FI], i.e., bidirectional causality established. This verdict applies to all sample countries. Furthermore, the control variable's causal effects on financial innovation revealed bidirectional causality between non-performing loans and financial innovation [BL←→FI] in Brazil. On the other hand, unidirectional causality running from non-performing loans to financial innovation [BL→FI] in Russia and India, gross savings to financial innovation [GS→FI] in Russia and China.

Table VIII Results of causality test: Financial innovation measured by R&D investment by financial institutions

	FI	EPU	BL	GS	Y	Causal relationship
Panel – A: Brazil						
FI		6.299c	8.494b	1.86	0.374	EPU←→FI; BL←→FI; BL←→EPU; Y→EPU; EPU→GS; BL→GS; BL→Y
EPU	12.132a		10.335a	5.042	8.972b	
BL	11.209a	8.916b		4.741	2.018	
GS	0.765	14.857a	14.667a		3.504	
Y	0.985	5.968	15.757a	4.528		
Panel – B: Russia						
FI	-	11.113a	6.716c	11.758a	1.026	EPU←→FI; BL→FI; GS→FI; BL→GS; EPU→Y
EPU	11.367a	-	1.671	1.757	0.159	
BL	1.442	0.574	-	1.128	4.228	
GS	4.406	1.897	7.066c	-	2.277	
Y	1.175	10.698a	3.485	0.472	-	
Panel – C: India						
FI	-	12.858a	10.008a	2.29	0.864	EPU←→FI; BL→FI; GS→EPU; Y→EPU; GS→BL; FI→GS; BL→Y
EPU	12.618a	-	3.774	7.155c	13.333a	
BL	0.543	4.095	-	7.479c	3.524	
GS	11.64a	0.945	5.715	1.24	1.31	
Y	1.115	3.009	13.89a	4.749	-	
Panel – D: China						
FI	-	11.999a	0.462	10.661a	10.257a	EPU←→FI; GS→FI; Y→FI; BL→EPU; GS→BL; Y→BL; EPU→GS; FI→Y
EPU	11.883a	-	6.556c	0.819	4.493	
BL	4.732	2.609	-	8.345a	7.649a	
GS	0.59	16.029a	10.756a	-	0.247	
Y	9.934b	0.42	0.174	3.788	-	

VI. Findings and conclusion

The paper has examined the nexus between EPU and financial innovation in BRIC countries for the period 2004M1-2018M12. The key finding of the study are as follows:

First, detecting variables order of integration, we performed both conventional and nonlinear unit root tests. Conventional unit root test established mixed order of integration, i.e., few variables are

stationary at a level, and few become stationary after first difference. Result of nonlinear unit root tests disclosed variables become stationary by following nonlinear process. Such a variable order of integration induces further estimation following a nonlinear framework in the empirical study.

Second, empirical model estimation with ARDL established a long-run association between economic policy uncertainty and financial innovation in selected countries. The long-run coefficient exhibits a negative association with different financial innovation proxies, which is obvious in all 12 (twelve) models. Besides, in the short run, we observed EPU effects on financial innovation are mostly statistically insignificant.

Third, the standard Wald test's test statistics confirmed that the asymmetric effects are running from EPU to financial innovation both in the long-run and short-run. In the long-run, both positive and negative variations in EPU display negative linkage with financial innovation in all empirical models. Considering their elasticity on financial innovation, it appears that negative shocks in EPU are more vibrant than positive shocks in EPU, nevertheless. In the short run, positive and negative shocks in EPU established a statistically insignificant impact on financial innovation; however, statistically significant coefficients are negatively associated with financial innovation.

Finally, the directional causality test holds the *feedback hypothesis* of explaining the causal effects between EPU and financial innovation. These findings suggesting that in the long-run, anything happened in either variable, i.e., financial innovation and EPU, the obvious effects will have appeared respectively. Referring to control variables' causal effects toward financial innovation, the study established unidirectional effects running from control variables to financial innovation in most cases.

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