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How does economic policy uncertainty influence the innovation activities: Empirical evidence from BRICS

Mosab I. Tabash [a,1], Umar Farooq [b,f,*,2], Mujeeb Saif Mohsen Al-Absy [c], Omar Fayez Albzour [d], Osama Arafat Mahmoud [e]

[a] College of Business, Al Ain University, Al Ain, United Arab Emirates
[b] School of Economics and Finance, Xi'an Jiaotong University, Xi'an, Shaanxi, PR China
[c] Accounting and Financial Science Department, College of Administrative and Financial Science, Gulf University, Sanad 26489, Kingdom of Bahrain
[d] An-Najah National University, Palestine
[e] HikmaRe Reinsurance Brokerage, Amman, Jordan
[f] Research Fellow, University of Religions and Denominations, Qom, Iran

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ABSTRACT

This study investigates the relationship between Economic Policy Uncertainty (EPU) and innovation activities within the context of the BRICS countries (Brazil, Russia, India, China, and South Africa) over the period from 2000 to 2019. Focusing on the interplay between economic policy uncertainty and innovation, this research aims to provide empirical evidence regarding the potential impact of EPU on innovation efforts within these emerging economies. By employing FMOLS (fully modified ordinary least square) and controlling for other relevant factors, the study seeks to isolate the specific influence of economic policy uncertainty on innovation outcomes across the BRICS countries. The findings of the study reveal a significant and negative relationship between EPU and innovation activities. The empirical evidence suggests that heightened levels of economic policy uncertainty tend to stifle innovation efforts across these economies. This negative effect underscores the potential hindrance that uncertain economic environments can impose on research, development, and the implementation of new ideas and technologies. The implications of these findings are important for policymakers, businesses, and researchers. Policymakers can use this evidence to recognize the importance of providing stable and predictable economic policy frameworks to foster innovation. In conclusion, this study contributes to the existing literature by shedding light on the intricate relationship between EPU and innovation activities. The empirical evidence presented herein underscores the need for policy measures that promote stability and predictability in economic environments to facilitate sustained innovation and economic growth.

1. Introduction

In today's rapidly evolving landscape, where technology and economies are intricately intertwined, the relationship between economic policy uncertainty (EPU) and innovation has emerged as a compelling area of study. EPU, often stemming from fluctuations in government policies, geopolitical events, and economic conditions, casts a shadow of unpredictability over markets and economic growth (Gu et al., 2021). The rising uncertainty in economic policies has an adverse impact on various firm-level decisions including investment, leverage (Almustafa et al., 2023), capital structure (Athari and Bahreini, 2023), energy consumption (Borozan and Borozan, 2022), and earning management (Cui, et al., 2021a, 2021b), etc., In addition to these, the literature provides the evidence on adverse effect of EPU on firm-level innovation activities (Q. Nguyen and Trinh, 2023; M.H. Nguyen and Trinh, 2023). Innovation represents the driving force behind societal progress, economic growth, and the transformation of industries, and therefore has a vital role in overall economic development. The intricate interplay between EPU and innovation is a dynamic process that merits exploration, as it holds the potential to shape the trajectory of economies, influence

* Corresponding author at: School of Economics and Finance, Xi'an Jiaotong University, Xi'an, Shaanxi, PR China.
E-mail addresses: mosab.tabash@aau.ac.ae (M.I. Tabash), umerrana246@gmail.com (U. Farooq), dr.mujeeb.saif@gulfuniversity.edu.bh (M.S.M. Al-Absy), omarbzoor69@gmail.com (O.F. Albzour), o.arafat@hikmare.com (O.A. Mahmoud).
[1] ORCID: 0000-0003-3688-7224.
[2] ORCID: 0000-0002-5772-5243.

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business strategies, and redefine the boundaries of technological advancement. This exploration delves into the multifaceted connections between EPU and innovation, shedding light on how uncertainty can both stifle and catalyze innovation efforts, thereby paving the way for a comprehensive understanding of their intricate relationship.

In the study conducted by Baker et al. (2016), an index was developed to assess the overall situation of economic uncertainty in a country. Many studies have emerged showing the impact of EPU on firm-level R&D (research and development) activities (Q. Nguyen and Kim, 2023; M.H. Nguyen and Trinh, 2023). However, the frequency of literature exploring the impact of EPU on macro-level score of innovation activities is low. In addition to firm-level innovation activities, EPU can influence the overall innovation performance of a country. Economic policy uncertainty can have significant effects on research and development (R&D) activities within an economy. When economic policy uncertainty is high, businesses and individuals often become cautious and hesitant about making long-term investments, including those in R&D. Similarly, high levels of economic policy uncertainty can lead to reduced investment in R&D. Businesses may delay or cut back on their R&D projects because they are unsure about the future economic conditions, regulatory environment, and government policies (Athari et al., 2023a). Uncertainty can make it difficult for firms to allocate resources towards innovative activities. EPU can make it challenging for governments and businesses to effectively allocate resources for R&D. They might prioritize preserving liquidity and ensuring their survival in uncertain times over-allocating funds for longer-term projects that may not yield immediate returns (Cui, et al., 2021a, 2021b; Athari, 2021).

Discussing the situation of EPU in BRICS countries, economic uncertainty in the BRICS nations has been driven by a mix of internal and external factors, including political instability, structural challenges, global economic dynamics, and policy decisions. While these countries have made significant progress in improving their economies, they continue to face various economic uncertainties that require ongoing attention and strategic planning. Brazil has a history of economic uncertainty stemming from factors such as high inflation, political instability, and external debt. In the 1980s and early 1990s, hyperinflation was a significant challenge for the Brazilian economy. Russia's economic history has been marked by significant shifts, particularly after the dissolution of the Soviet Union. The transition from a centrally planned economy to a market-oriented one led to economic uncertainty in the 1990s, characterized by hyperinflation, economic contraction, and social turmoil. India has faced economic uncertainties related to fiscal deficits, inflation, and structural challenges. The country underwent economic reforms in the early 1990 s to liberalize its economy and open it up to global markets. China's economic transformation over the past few decades has been remarkable, but it has not been without uncertainty. The country's shift from a planned economy to a market-based one led to rapid growth, but also challenges related to overinvestment, environmental degradation, and a debt buildup. Similarly, South Africa's history of economic uncertainty is tied to its complex political and social landscape. The apartheid era had a profound impact on the country's economy, leading to international sanctions and isolation. The end of apartheid in the 1990s brought hope, but the subsequent years saw challenges such as high unemployment, inequality, and political uncertainty (Buthelezi, 2023).

The current analysis aims to explore the empirical relationship between EPU and macroeconomic innovation performance. We arrange the empirical analysis on BRICS countries over the period 2000–2019 and check the regression by employing the FMOLS (fully modified ordinary least square) model. In this study, the innovation performance was assessed by two proxies including R&D expenditures and number of trademark applications. Similarly, economic uncertainty was proxied by the EPU index. The analysis reveals that EPU has an adverse effect on both R&D activities and trademark applications. In addition, the analysis infers the significant positive effect of control variables including financial sector development, FDI inflow, government subsidies, and corruption on innovation activities. The negative effect of EPU on innovation activities can be defined as EPU deferring the government earnings and therefore less likely to be involved in R&D projects. Moreover, a high EPU shows the imbalanced economic situation and discontinuity of economic policies. Both factors have a negative spillover impact on the innovation performance of a country. In addition, EPU can impact a country's global competitiveness. If uncertainty leads to decreased R&D activities, it can hinder a country's ability to keep up with technological advancements on the global stage.

This study contributes in the following ways: First, this study extends the empirical literature by exploring the nexus between EPU and macroeconomic innovation activities. Most studies were limited to providing empirical evidence on EPU-firm-level innovation activities. This study considers the macroeconomic innovation performance of the country and checks how it is influenced by uncertain economic situations. Second, we employ a range of pre-estimation techniques including the cross-section dependence test, unit root test, and cointegration test for checking the validity of the adopted technique i.e., the FMOLS model. This study offers an unbiased empirical estimation of results. Third, the analysis advocates the role of EPU in the innovation performance of a country and therefore recommends an important policy regarding the focus on economic stability. As innovation plays a vital role in economic development, it is necessary to ensure policy stability for harvesting better results on innovation performance. It is recommended to exercise significant efforts for ensuring the long-term viability of economic policies as such stability will not only result in overall economic prosperity but will also accelerate the innovation activities.

Other parts of the paper contain the following sections: Section 2 explains the review of literature, Section 3 describes the data and methods, and Section 4 contains the empirical analysis of the study. In Section 5, we explain the results and summarize the whole discussion in Section 6 named conclusion and policies.

2. Literature review and hypothesis

Theoretically, the real option theory justifies the link between EPU and innovation performance (Bloom et al., 2007). According to underlying notions of real option theory, enterprises adopt the wait-and-see strategy during highly uncertain economic conditions, and therefore overall innovation performance of a country remains at the lowest level. Moreover, uncertain economic situations weaken government efforts e.g., subsidies, indirect appreciation of innovation activities like rewards, and protection of copyrights, etc., necessary for accelerating the innovation activities within the country. Owing to this, the innovation performance of a country declines to an unexpected level. In support, Tajaddini and Gholipour (2021) found the validation of real option theory while investigating the empirical linkages between EPU, R&D expenditures, and innovation outputs. Similarly, resource dependence theory emphasizes that firms' innovation activities are influenced by their access to external resources and the uncertainty surrounding these resources. Economic policy uncertainty can disrupt resource availability, affecting firms' innovation capabilities (Irani et al., 2022). In the same vein, institutional theory vows that EPU can alter the institutional environment in which firms operate, affecting the legitimacy and feasibility of innovation activities. Firms may adapt their innovation strategies to align with the changing institutional context. The study of Xu (2020) supports both resource dependence theory and institutional theory while examining the empirical relationship between EPU, cost of capital, and firm-level innovation. A similar effect of EPU on country-level innovation can be expected.

In addition to theoretical support, some empirical studies also provide evidence on EPU-innovation linkages. For instance, Khan et al. (2020) attempted to explore the empirical relationship between EPU and R&D investment in the case of Chinese enterprises. They observe that a high level of EPU discourages R&D investment and this negative influence was stronger across the industries working in a competitive

environment. In contrast, Tajaddini and Gholipour (2021) found a positive relationship between EPU and R&D expenditures across 19 countries. Their study asserted that high EPU leads to enhancing the R&D investment to effectively respond the uncertain economic conditions. Lou et al. (2022) investigated the impact of EPU on the innovation performance of China's A-listed companies and found that EPU has an adverse effect on firm innovation. This negative effect of EPU was more obvious in firms having risk-averse executives. MengDie et al. (2023) arranged an empirical analysis for checking the impact of EPU on R&D investment of Chinese enterprises. In addition, their study aimed to explore the moderating role of government subsidies in the EPU-R&D investment nexus. The findings of their study vow that EPU dampens the R&D investment while government subsidies moderate this relationship, inferring that high EPU worsens the R&D situation within the country.

Similarly, M.H. Nguyen and Kim (2023); Q. Nguyen and Kim (2023) also observe the negative impact of EPU on R&D intensity of enterprises from seven countries. Based on the resource endowment view, the study of Xu and Yang (2023) asserted that high EPU first accelerates the green innovation within a threshold level. However, when EPU transcends a certain level, it hampers the green innovation of enterprises. In another study, Zhou et al. (2023) conjectured that high EPU perception substantially hampers corporate innovation performance. However, this negative impact of EPU on innovation becomes insignificant after the inclusion of macroeconomic variables in the analysis. They further found that the adverse effect of EPU on innovation become weak across the enterprises having independent board of directors. The findings of these show the adverse effect of EPU on firm-level innovation performance. However, the frequency of literature exploring the EPU-macroeconomic innovation performance is very low. This literature gap can be fulfilled by exploring the following hypothesis.

H_1. : Economic policy uncertainty has a negative and statistically significant relationship with innovation activities.

Literature suggests some other factors that influence the innovation activities within a country. For instance, Athari et al. (2022) asserted that EPU enhances the inflation which further has a negative effect on innovation activities. Carreras (2023) found the positive role of the Development Bank in fostering the innovation activities of the Brazilian manufacturing sector. The study reveals the crowding-in effect of funds provided by Development Bank on the R&D intensity of enterprises. Xiong et al. (2023) examined the positive role of digital inclusive finance (reflecting the development status of the banking sector) on R&D activities of enterprises. Similarly, Yue (2022) aimed to explore the microeconomic impact of FDI inflow on innovation performance of Chinese enterprises. The findings depict the improving role of FDI inflow on innovation performance and this positive effect was stronger across capital-intensive, non-coastal, high-productive, and non-state-owned enterprises. The study of Garcia et al. (2023) relates the FDI inflow with regional innovation efficiency measured by patent outputs of Brazilian companies. The analysis reveals that FDI inflow enhances the innovation efficiency of local enterprises and this positive effect of FDI inflow on innovation was reinforced by regional diversity of enterprises. Sun and Fan (2023) found the positive impact of Chinese outward FDI flow on innovation performance of host country. Chinese foreign investment accelerates technological development and promotes the overall innovation performance of the host countries.

Prolonging the discussion, Xu et al. (2023) found the inverted U-shape relationship between government subsidies and innovation performance of Chinese listed enterprises. Government support in the shape of subsidies has complementary and substitution effect and therefore play both crowding-in and crowding-out effect on innovation investment. Zuo and Lin (2022) also asserted that the effect of government subsidies varies across industrial heterogeneity and depends upon the characteristics of recipient firms. They found that government subsidies have a favorable effect on the innovation performance of enterprises measured by patent outputs. Xu et al. (2023a) observed that government subsidies promote innovation performance through the channel of R&D investment as it mediates the relationship. The government's financial support encourages R&D activities which further boosts the overall technological innovation. In the same vein, the findings of Xie et al. (2019), and Viglioni et al. (2022) mutually agreed on the hampering role of corruption in the innovation activities of enterprises. The conduct of corruption practices dampens innovation activities. This conjecture was also supported by Wen et al. (2023) who argued that corruption hurt green innovation at global level. Wu et al. (2022) documented the significance of anti-corruption compaigns in accelerating the green innovation in China. In short, it can be conjectured that corruption control boosts the innovation activities.

3. Data and methods

3.1. Sample and data source description

For empirical analysis, we utilize the 20 years of data over the period 2000–2019 of BRICS (Brazil, Russia, India, China, and South Africa) economies. We selected this span due to the availability of data for this specific span. Moreover, we limit the span to the year 2019 due to COVID-19 spread in the year 2020 which may create biases regarding the effect of EPU on innovation activities. Economies have adopted varying strategies during this span (Iqbal, 2021; Saliba et al., 2023), and therefore it is more useful to limit the span to the year 2019. Similarly, we select the BRICS countries as these are the largest and fastest-growing countries in the world. Moreover, BRICS countries are excelling in innovation (Mussaiyib and Pradhan, 2023), and therefore it is insightful to check the effect of EPU on the innovation performance of BRICS countries. BRICS countries are among the largest and fastest-growing economies in the world. They represent a substantial portion of global GDP and have a significant impact on global economic dynamics. This makes them an interesting group to study as changes in their economic policy uncertainty can have broad-reaching implications. In addition, BRICS countries are diverse in terms of culture, geography, political systems, and stages of economic development. This diversity can provide valuable insights into how economic policy uncertainty affects innovation in various contexts. The statistical information on the EPU index was collected from an online site[3] developed by Baker et al. (2016) while the data of other variables were collected from WDI (World Development Indicators), The World Bank.

3.2. Variables of study

In this study, innovation performance is a dependent variable, assessed with two proxy variables named research and development expenditures and trademark applications. Research and development expenditure (% of GDP) is a key indicator that reflects the amount of a country's economic resources devoted to research and development (R&D) activities relative to its overall economic output. This metric is often used to gauge the level of investment a country makes in innovation and technological advancement. R&D Expenditure refers to the total amount of money spent on research and development activities by both public and private sectors within a country during a specific period. A higher R&D expenditure as a percentage of GDP generally indicates a greater emphasis on innovation and technological advancement, which can lead to increased competitiveness, economic growth, and improvements in various sectors such as healthcare, energy, agriculture, and manufacturing (Sarpong et al., 2023). Similarly, "trademark applications, resident, by count" is a term used in intellectual property and legal contexts to refer to the number of trademark applications filed by residents or entities within a specific jurisdiction or country. These are formal requests submitted to a government agency or trademark office

[3] https://www.policyuncertainty.com/about.html

to register a unique sign, symbol, word, or phrase that distinguishes the goods or services of one entity from those of others. Trademark registration provides legal protection and exclusive rights to use the trademark in commerce (Mussaiyib and Pradhan, 2023). Some recent studies have utilized similar variables to measure the innovation performance of a country (Olaoye et al., 2021; Tajaddini and Gholipour, 2021; Ahmad and Zheng, 2022).

Economic policy uncertainty is the main explanatory variable, measured with an EPU index developed by Baker et al. (2016). EPU index reflects the degree of uncertainty that businesses, investors, and policymakers perceive in relation to current and future economic policies, which can include fiscal policy, monetary policy, trade policy, and regulatory measures. This index is usually calculated based on various indicators, such as media coverage, economic forecasts, policy-related uncertainty, and stock market volatility. We aggregate the monthly index into annually to make it align with other variables whose data were in annual frequency. Similar measurement of EPU was also observed in the studies conducted by Tajaddini and Gholipour (2021), and Q. Nguyen and Trinh (2023); M.H. Nguyen and Trinh (2023). In addition to EPU, the analysis contains some control variables including financial sector development, FDI inflow, government subsidies, and corruption control. Financial sector development is a percentage of domestic credit provided by the banking sector to the private sector of an economy. A high percentage shows that a country has a developed financial sector and vice versa (Zhu et al., 2020). Similarly, FDI (foreign direct investment) inflow refers to the investment made by a company or individual from another country to the host country. It involves acquiring a significant ownership stake (usually more than 10 %) in a foreign business entity, such as a company or a factory, with the intention of exerting a lasting influence on the entity's operations and management (Farooq, 2023).

We measure the subsidies as a percentage of total expenses which refers to financial assistance provided by a government to support certain industries, organizations, or activities. They are intended to reduce the financial burden and encourage growth or sustainability. Subsidies can be provided in various forms, such as direct cash payments, tax breaks, reduced interest rates on loans, or grants. Lastly, corruption control was measured by a index which assess the efforts and mechanisms put in place by governments, institutions, and societies to prevent and combat corruption. Corruption is the abuse of entrusted power for personal gain, and it can have detrimental effects on economies, social cohesion, and political stability. It's important to note that the effectiveness of anti-corruption efforts can vary widely depending on the specific context of each country. Factors such as political will, the strength of institutions, cultural norms, and socioeconomic conditions can all influence the success of control of corruption initiatives. We follow the studies of Boeing et al. (2022), and Dokas et al. (2023) as base studies for the measurement and selection of underlying control variables. Table 1 provides description of the variables.

Table 1
Variables of study.

Acronym	Variables	Role	Measurement	References
RND	Research and development	Dependent	Research and development expenditure (% of GDP)	(Olaoye et al., 2021; Udeagha and Breitenbach, 2021; Sarpong et al., 2023)
TMK	Trademark applications	Dependent	Trademark applications, resident, by count	(Ahmad and Zheng, 2022; Tajaddini and Gholipour, 2021; Mussaiyib and Pradhan, 2023)
EPU	Economic policy uncertainty	Independent	EPU index	(Tajaddini and Gholipour, 2021; Nguyen and Trinh, 2023)
FSD	Financial sector development	Control	Domestic credit to private sector by banks (% of GDP)	(Zhu et al., 2020)
FDI	Foreign direct investment inflow	Control	Foreign direct investment, net inflows (% of GDP)	(Farooq, 2023)
SUB	Subsidies	Control	Subsidies and other transfers (% of expense)	(Boeing et al., 2022)
COC	Control of corruption	Control	Control of Corruption Index	(Dokas et al., 2023)

Note: This tables shows the measurement of variables. Source: previous studies.

3.3. Research models

The relationship among variables can be presented in the form of following equations.

$$Innovation = f(EPU, FSD, FDI, SUB, COC)$$

$$RND_{it} = \beta_{\circ} + \alpha_1 EPU_{it} + \gamma_1 FSD_{it} + \gamma_2 FDI_{it} + \gamma_3 SUB_{it} + \gamma_4 COC_{it} + \varepsilon_{it} \quad (1)$$

$$TMK_{it} = \beta_{\circ} + \alpha_1 EPU_{it} + \gamma_1 FSD_{it} + \gamma_2 FDI_{it} + \gamma_3 SUB_{it} + \gamma_4 COC_{it} + \varepsilon_{it} \quad (2)$$

Eq. (1) shows the impact of EPU (economic policy uncertainty) on RND (research and development) expenditures. This equation also includes a list a control variables including FSD (financial sector development), FDI (foreign direct investment) inflow, SUB (subsidies), and COC (control of corruption). Similarly, Eq. (2) mainly shows the impact of EPU on another proxy of innovation i.e., TMK (trademark application). In these equations, β is a constant, showing the intercept of the regression line. At the same time, α is a vector of coefficient for explanatory variable and γ is a vector for control variables. In addition, α, and γ manifest the degree of change in the dependent variable due to the change in explanatory variables. The subscript I is for cross-section and t is for time-effect. The symbol of ε shows the error term.

4. Empirical results

4.1. Descriptive and correlation analyses

In Table 2, we present the descriptive analysis. The mean value of RND (research and development) is 0.532, showing the percentage of expenditures made on R&D activities by the central government. TMK (trademark) registration has a mean value of 5.345 which is the log value of total number of patents registered by resident individuals during a year. The mean value of EPU is 132. 825, showing the intensity of policy uncertainty in sample countries. For control variables, FSD has a mean value of 65.536 which is the percentage of private credit offered by the banking sector to the private sector of an economy. Similarly, the mean value of FDI is 2.599, showing the % (of GDP) inflow of FDI during a year. The mean value of SUB is 54.570, demonstrating the percentage contribution of expenditures made in the shape of subsidies by the central government. COC has a mean value of − 0.488 which is skewed towards the negative end, showing the bad situation in terms of corruption control in underlying BRICS countries. In addition to mean values, we also calculate the median, maximum, minimum, standard deviation, skewness, and kurtosis values for all variables of the study. Table 3 shows the correlation analysis between the variables. As shown in column 2 of Table 3, most variables have normal correlation values (below 0.70), conjecturing that there is no issue of multicollinearity among the variables. Fig. 1 shows the trend of variables across the sample span.

4.2. Pre-estimation analysis

For regression analysis, we employ the FMOLS (fully modified

Table 2
Descriptive analysis.

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis
RND	0.532	0.535	0.987	0.020	0.291	0.126	1.871
TMK	5.345	5.202	6.879	4.256	0.540	1.208	4.060
EPU	132.825	115.885	363.358	50.443	69.308	1.450	4.971
FSD	65.536	51.867	165.390	13.647	39.592	1.187	3.185
FDI	2.599	2.568	5.033	0.502	1.124	0.138	2.062
SUB	54.570	58.855	71.209	25.496	10.861	-0.981	3.065
COC	-0.488	-0.452	0.168	-1.141	0.341	-0.208	2.192

Acronyms: RND = research and development, TMK=trademark applications, EPU=economic policy uncertainty, FSD=financial sector development, FDI=foreign direct investment inflow, SUB=subsidies, COC=control of corruption **Note:** This table shows the panel descriptive analysis. **Source:** self-estimation.

Table 3
Correlation analysis.

Variables	RND	TMK	EPU	FSD	FDI	SUB	COC
RND	1.000						
TMK	0.016[a]	1.000					
EPU	-0.109[b]	0.241[a]	1.000				
FSD	0.069[a]	0.659[c]	0.199[a]	1.000			
FDI	-0.035[c]	0.013[b]	-0.080[a]	0.117[a]	1.000		
SUB	-0.012[a]	0.218[b]	0.299[c]	0.220[a]	0.285[a]	1.000	
COC	-0.066[b]	0.117[b]	-0.021[c]	0.171[c]	0.084[b]	-0.099[a]	1.000
VIF	3.132	3.091	2.098	4.888	4.009	2.998	3.910

Acronyms: RND = research and development, TMK=trademark applications, EPU=economic policy uncertainty, FSD=financial sector development, FDI=foreign direct investment inflow, SUB=subsidies, COC=control of corruption **Note:** This table shows the correlation analysis. **Source:** self-estimation. **Note:** a shows the significance at 1 %, b shows the significance level at 5 %, and c shows the significance level at 10 %.

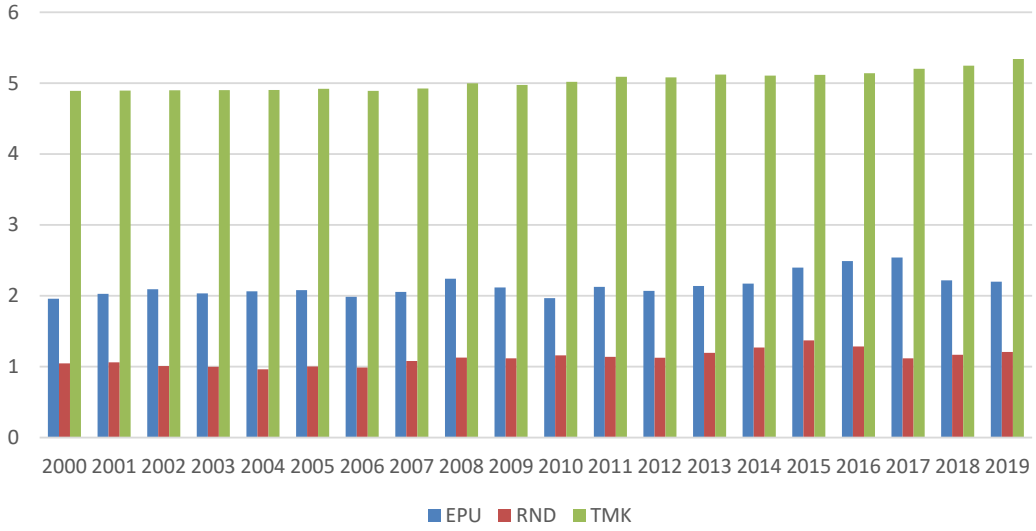

Fig. 1. Trend of Variable. Source: self-estimation. Acronyms: EPU = economic policy uncertainty, RND = research and development, TMK = trademark applications Note: This figure shows the trend of variables.

ordinary least square) model and check the robustness through the RLS (robust least square) model. However, the selection of both models is based upon the statistical suggestions offered by some pre-estimation techniques including cross-section dependence test, unit root test, and cointegration test. As the analysis was conducted on a panel of 5 countries, there are more chances of cross-sectional dependence of series. To test this assumption, we employ a series of techniques named Breusch-Pagan LM test (Breusch and Pagan, 1980), Pesaran scaled LM test, and Pesaran CD test (Pesaran, 2004), and report the analysis in Table 4. The significant p-values of underlying techniques reject the null hypothesis i.e., no cross-section dependence, and assume the existence of a CD (cross-section dependence) issue. In the presence of a CD issue, we check the stationarity of data by employing the second-generation unit root test (Pesaran, 2007), and report the analysis in Table 5. The reported values in Table 5 show that all the variables are stationary at level 1(I(I), conferring to employ the cointegration test. For cointegration, we employ the Johansen Cointegration test (Johansen, 1988), and report the analysis in Table 6. The significant p-value of the Kao-residual

Table 4
Cross-section dependence test.

Test	Statistics	D.F	Probability
Breusch-Pagan LM	43.646	6	0.000
Pesaran scaled LM	10.867	-	0.000
Pesaran CD	-1.215	-	0.224

Note: The significant p-values probe the existence of CD (cross-section dependence) issue. Source: self-elaboration.

Table 5
Second-generation unit root testing.

	(CIPS)		(CADF)	
Variables	At Level	At first difference	At level	At first difference
RND	(−3.450)	(−0.182)	(−4.206)	(−3.182)
	0.221	0.000	0.050	0.000
TMK	(−1.871)	(−2.660)	(−2.371)	(−2.220)
	0.121	0.000	0.990	0.000
EPU	(−1.222)	(−1.242)	(−2.351)	(−2.221)
	0.178	0.000	0.186	0.000
FSD	(−0.190)	(−0.221)	(−1.620)	(−1.480)
	0.223	0.000	0.202	0.000
FDI	(−1.845)	(−2.610)	(−1.692)	(−2.592)
	0.117	0.000	0.118	0.000
SUB	(−3.345)	-	(−0.730)	(−3.885)
	0.000		0.181	0.000
COC	(−2.351)	(−2.561)	(−1.842)	(−2.391)
	0.199	0.000	0.188	0.000

Acronyms: RND = research and development, TMK=trademark applications, EPU=economic policy uncertainty, FSD=financial sector development, FDI=foreign direct investment inflow, SUB=subsidies, COC=control of corruption **Note:** The reported values probe the stationarity level of variables. **Source:** self-estimation.

Table 6
Cointegration analysis (Kao Residual Cointegration Test).

Null Hypothesis: No cointegration		
Test name	t-statistics	Probability
ADF	-3.622	0.001
Residual variance	0.003	-
HAC variance	0.004	-

Note: The significant value of ADF probes the existence of cointegration. Source: self-estimation.

technique assumes the existence of cointegration which conferred the implication of the FMOLS technique. Based on the statistical findings of pre-estimation techniques, we employ the FMOLS model argued by Phillips and Hansen (1990) as a regression estimation technique. This model has the capacity to estimate the coefficients over long by resolving the issues of multicollinearity, endogeneity, and un-observed heteroscedasticity. For robustness, we employ the RLS model which provides an accurate measurement of regression even in the presence of an outlier effect.

Table 7
Effect of economic policy uncertainty on innovation.

	FMOLS (Fully Modified Ordinary Least Square)			
	RND as a dependent Variable		TMK as a dependent Variable	
Variables	Coefficients	Probability	Coefficients	Probability
EPU	-0.539***	0.023	-0.002***	0.046
FSD	0.008***	0.000	0.014***	0.000
FDI	-0.036	0.188	0.011**	0.063
SUB	0.014***	0.002	0.008**	0.055
COC	0.194***	0.026	0.206***	0.017
Adjusted R-squared	0.686		0.656	
S.E. of regression	0.137		0.109	
Long-run variance	0.027		0.019	

Acronyms: RND = research and development, TMK=trademark applications, EPU=economic policy uncertainty, FSD=financial sector development, FDI=foreign direct investment inflow, SUB=subsidies, COC=control of corruption **Note:** The reported values probe the stationarity level of variables. **Source:** self-elaboration **Note:** ***, **, * indicate the significance level at 1 %, 5 %, and 10 % relatively.

4.3. Regression analysis

We report the regression analysis in Table 7 and the robustness findings in Table 8. As shown in Table 7, the coefficient value of EPU is − 0.539 and − 0.002 in the case of RND and TMK relatively. Both values show the significant but negative impact of EPU on RND and TMK. These values state that a one-unit increase in EPU hampers the R&D expenditures by 53.9 % and trademark registration by 2 % relatively. All control variables including FSD, FDI, SUB, and COC have positive and statistically significant coefficient values, inferring the positive role of underlying control variables in determining the innovation activities. We find the robustness of analysis (shown in Table 8) as all variables show a consistent relationship with innovation activities as shown in Table 7.

5. Discussion

This study aims to find out the impact of EPU on innovation activities. To achieve this aim, we employ the FMOLS model and report the analysis in Table 7. The findings show that EPU has a negative effect on innovation activities including R&D and trademark registration. High EPU can lead to a cautious approach among businesses and investors. When economic policies are uncertain, companies may hold back on making significant investments in research and development (R&D) and new technologies. This reduced investment can hinder overall innovation. In addition, innovation often requires long-term planning and commitment by the central government. High EPU can disrupt government and companies' ability to engage in long-term strategic planning, which is essential for fostering a culture of innovation. Uncertain economic policies can discourage collaboration between different players in the economy. This lack of collaboration can limit the exchange of ideas, knowledge, and resources necessary for fostering innovation. Uncertain economic policies can lead to delayed decision-making among businesses. Companies might postpone important strategic choices, including those related to innovation until they have more clarity about the regulatory and economic environment. In an environment of uncertainty, companies tend to be more risk-averse. Innovation inherently involves taking risks, and when businesses are unsure about the economic policies that might affect their innovations, they might opt for safer, more conservative strategies instead. This negative effect of EPU on innovation was also evidenced in the studies conducted by Xu (2020), Lou et al. (2022), and Q. Nguyen and Trinh (2023); M.H. Nguyen and Trinh (2023). However, their studies were limited to the firm-specific

Table 8
Robustness analysis (effect of economic policy uncertainty on innovation).

	RLS (Robust Least Square)			
	RND as a dependent Variable		TMK as a dependent Variable	
Variables	Coefficients	Probability	Coefficients	Probability
Constant	0.110***	0.038	0.486***	0.000
EPU	-0.006**	0.092	-0.002***	0.033
FSD	0.007***	0.000	0.013***	0.000
FDI	-0.016	0.495	0.048***	0.005
SUB	0.009***	0.000	0.001	0.576
COC	0.038**	0.060	0.057***	0.027
Adjusted R-squared	0.446		0.456	
Akaike info criterion	116.231		216.030	
Schwarz criterion	125.133		105.179	
Prob. (Rn-squared stat.)	0.000		0.000	

Acronyms: RND = research and development, TMK=trademark applications, EPU=economic policy uncertainty, FSD=financial sector development, FDI=foreign direct investment inflow, SUB=subsidies, COC=control of corruption **Note:** The reported values probe the stationarity level of variables. **Source:** self-elaboration **Note:** ***, **, * indicate the significance level at 1 %, 5 %, and 10 % relatively.

innovation effect of EPU while the current analysis aims to check the impact of EPU on the macroeconomic innovation performance of a country.

In contrast to EPU, FDI inflow, financial sector development, government subsidies, and corruption control have positive effects on innovation activities. The positive effect of FDI inflow can be explained as FDI can lead to partnerships between local and foreign firms, fostering collaboration and knowledge exchange. Such collaborations can catalyze innovation by bringing together complementary expertise and resources. FDI often brings in capital and financial resources that can be used to support local startups and innovative projects. This access to funding can accelerate the growth of innovative ventures. FDI can lead to the creation of clusters of related industries and research institutions. This concentration of economic activity fosters knowledge spillovers, where knowledge and ideas are shared between firms, universities, and research centers. Sun and Fan (2023) asserted the positive effect of FDI on innovation performance of Belt & Road economies. Similarly, a developed financial sector provides better access to various sources of funding, including venture capital, angel investment, and loans. This increased access to capital can help startups and innovative companies secure the funds they need to develop new products and technologies. In addition, financial institutions themselves can drive innovation by adopting cutting-edge technologies. For example, the use of fintech solutions, blockchain, and AI in financial services can lead to increased efficiency and improved services, indirectly benefiting innovation in other sectors. Carreras (2023) highlighted the similar impact of the Development Bank on the innovation performance of a country.

Government subsidies can provide financial incentives for businesses and organizations to invest in R&D activities. This, in turn, can lead to the development of new technologies, products, and processes that drive innovation and economic growth. By offering subsidies, governments can encourage private companies to allocate more funds towards innovation-related projects. This can help businesses overcome the high upfront costs and risks associated with research and development, making innovation more attractive (Boeing et al., 2022). Lastly, corruption control positively influences a country's innovation performance by creating an environment conducive to fair competition, attracting investment, fostering R&D, promoting a culture of innovation, protecting intellectual property, facilitating efficient government spending, encouraging entrepreneurship, improving global competitiveness, and enhancing collaboration. Countries with lower corruption levels tend to have a more favorable business environment. This improved business environment enhances a country's global competitiveness. As innovation becomes a key driver of competitiveness, reducing corruption indirectly supports innovation efforts (Wu et al., 2022).

In summary, it can be conjectured that EPU has an unfavorable impact on the innovation performance of a country while FDI inflow, financial sector development, government subsidies, and corruption control have a favorable impact on innovation performance.

6. Conclusion and policies

Despite the of abundance literature exploring the impact of EPU on firm-level innovation activities, the current study investigates the impact of EPU on the macroeconomic innovation performance of the country. To check this impact, we arrange the empirical analysis on BRICS countries and employ the FMOLS model for regression analysis. The empirical findings reveal that high EPU dampens both R&D activities and trademark registration, conferring the negative impact of EPU on overall innovation performance. High EPU discourages enterprises and individuals to involved in any long-term research projects and therefore overall innovation performance remains poor. In addition, high EPU defers the government's efforts to accelerate the innovation culture within the country. This can lead to waive-off financial support to private individuals for conducting R&D activities and weak control over the protection of copyrights. Thereby, it can be conjectured that a country is unable to achieve the desired level of innovation in the presence of EPU. We further find the positive effect of all control variables including FDI inflow, financial sector development, government subsidies, and corruption control on innovation performance. The analysis supports the alternative hypothesis (H1) and yields the following policy outcomes.

6.1. Policy outcomes and limitations

As EPU has a negative impact on innovation, therefore it is necessary to provide a clear and stable regulatory environment that gives businesses confidence in their ability to plan and execute innovative projects. Frequent changes in regulations can disrupt long-term innovation plans and discourage R&D investments. Therefore, governments should commit to long-term policies that support innovation, such as providing consistent funding for R&D, maintaining tax incentives for research, and fostering collaboration between academia and industry. In addition, ensuring adequate funding for innovation initiatives, both from government sources and private investment, can help offset the uncertainty created by EPU. Funding can support R&D, technology commercialization, and startup incubators. Governments should communicate their policy intentions clearly to the public and the business community. Transparency in policy formulation and decision-making can help reduce uncertainty and enable businesses to make informed decisions. In addition, encouraging international collaboration in innovation and R&D through inviting more FDI can provide access to a broader range of expertise and resources, making the innovation ecosystem more resilient to domestic economic uncertainty.

Similarly, the banking sector can also be invited to promote the innovation culture. In this essence, governments can create mechanisms to enhance the cooperation between the banking sector and the real sector of an economy which can reduce the financial risks associated with innovation, such as providing insurance against project failures or offering guarantees for loans taken to fund innovative projects. Providing more subsidies and control of corruption are suggested to accelerate the innovation.

Similar to other studies, the current analysis has some limitations: This study is unable to consider the country heterogeneity while checking the impact of EPU on innovation. Each country may have a different level of response to the EPU. This shortcoming can be incorporated into future studies. Moreover, future studies can be conducted by introducing some strategical variable like governance quality as a moderating variable in the relationship between EPU and innovation activities.

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Not applicable.

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Mosab I. Tabash: Supervision, drafting, original-paper writing, Methodology. **Umar Farooq:** Conceptualization, Data curation, Writing – original draft. **Mujeeb Saif Mohsen Al-Absy:** Writing – review & editing, Methodology. **Omar Fayez Albzour:** Data curation, Writing-revised draft preparation. **Osama Arafat Mahmoud:** Formal analysis, Conceptualization, Software.

Data Availability

Data that support the findings of this study available at public domains named World Development Indicators, The World Bank.

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