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# How Do Economic Policy Uncertainty and Financial Development Affect Green Innovation? Evidence from G7 and BRIC Countries

**Abstract.** *The aim of the study is to reveal the relationship between economic policy uncertainty and green innovation for developed and developing countries. Additionally, the aim is to examine the relationship between financial development and green innovation for developed and developing countries. This study investigates the impact of economic policy uncertainty and financial development on green innovation for G7 and BRIC countries via Panel ARDL method. The time period taken for this study covers the years from 1990-2020. The panel ARDL test results for the G7 countries revealed that over the long term, there was a significant and negative relationship between GI and EPU. In the long-run analysis results in this study for the G7 countries, a significant and positive relationship was found between GI and FD. In earlier research, the relationship between FI and GI has been ignored in favour of investigating the relationship between EPU and GI. Furthermore, the relationship between GI and EPU for both developing and developed countries has not been investigated or compared in earlier studies. Therefore, we created two models in the study and analysed two groups of countries separately to fill the gap in the literature.*

**Keywords**: *green innovation, financial development, economic policy uncertainty, panel data analysis, ARDL methods.*

**JEL Classification:** O3, P34, G00.

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|---|---|---|

## 1. Introduction

The increasing environmental pollution and the constraints on natural resources have global effects. In particular, rapid industrialisation and urbanisation lead to increased water, air, and soil pollution. Over the last few decades, climate change, the COVID-19 pandemic, and global and regional disasters have caused disruptions in ecological systems (McNeely, 2021). This circumstance has raised environmental concerns among households/consumers and directed governments and businesses toward developing environmentally focused strategies. To attract the attention of consumers, the use of environmentally friendly technologies, the development of

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green marketing strategies, government incentives for green innovations, and cost reduction efforts are directing businesses towards green innovation activities (Şenocak & Mohan, Bursalı 2018). Green innovation is a concept derived from traditional innovation theory that emphasises sustainable economic development and green ecological concepts and is a process to improve green efficiency and innovation efficiency (Peng et al., 2023).

The concept of green innovation (GI) can be defined as the significant reduction in environmental impacts of new products and processes. Moreover, it is also expressed through different concepts such as environmental innovation, eco-innovation, and sustainable innovation. Initially introduced as a subset of sustainable development, the term "green innovation" was defined by Chen et al. (2006). Similar to "green innovation," "eco-innovation" describes innovation that reduces the use of natural resources and the production of hazardous waste. GI involves the development of novel ideas, products, and processes for significantly reducing environmental damage and promoting sustainable development (Xu & Yang, 2023). GI practices address issues such as waste recycling, food production, and water usage, while also encompassing the reprocessing of recycled materials, green products, renewable energy, and green management approaches. EPU has an important impact on corporate GI. Roper and Tapinos (2016) claimed that the EPU increases the instability in this environment, arguing that external factors constitute the main hazards to green innovation. In this context, it can be argued that there is a strong relationship between the risks associated with institutional GI and the uncertainties surrounding economic policy. Moreover, ambiguous trade policies increase the cost of raw materials or cause supply shortages. This increases the cost of transition to GI. Increasing costs and the resulting financing constraints stand as a major obstacle to innovation. An increase in EPU may lead to unexpected results in market conditions. This situation will prevent innovation by making financing difficult (Tajaddini & Gholipour, 2021).

Financial development (FD) plays an important role in increasing and encouraging GI by businesses (Tamazian et al., 2009; Abid et al., 2022). Financial development, well-functioning capital markets, and banking systems provide businesses with convenient access to capital. This situation provides great convenience in financing research and development activities, especially related to green technologies (Tajaddini & Gholipour, 2021). Financial development also includes state support and international financing mechanisms. Governments provide incentives, subsidies, and grants to encourage businesses to invest in GI. International organisations contribute to maintaining global sustainability by providing financial support to research and development projects in developing countries (Huang et al., 2019). In the GI process, long-term investments are realised as research and development and market adaptation spread over a long period of time. Financial institutions that adopt sustainable finance support projects with long payback periods. As a result, financial development plays an important role in providing enterprises with the necessary capital, reducing risks, and creating conditions favourable to sustainable business practices. This situation increases GI.

Moreover, GI exploits the full potential of financial development through strong cooperation between financial institutions, businesses, governments and international organisations. Thus, this study aims to reveal the relationship between EPU and GI for developed and developing countries. Furthermore, it was intended to reveal the relationship between financial development and the GI of developed and developing countries. To address these theoretical and practical issues, this study seeks answers to the following questions:

*Q1 Is there a relationship between GI and EPU in both developed and developing countries? If so, what is the direction of that relationship?*

*Q2 Is there a relationship between GI and FD in both developed and developing countries? If so, what is the direction of that relationship?*

The remainder of the research is as follows: In Section 2, the theoretical analysis and hypotheses are presented; in Section 3, the econometric model is explained; in Section 4, the estimation results are reported; in Section 5, the study's conclusions are compared and contrasted with previous research, and some policy implications for G7 and BRIC countries are suggested.

## 2. Literature review

### *2.1 Economic Policy Uncertainty and Green Innovation*

The first strand of the literature focuses on the relationship between some studies mainly include macroeconomic variables and analyses involving stock market indexes. In such studies, indicators such as exchange rate, oil, cryptocurrencies, investments, exports, innovation, unemployment, and energy have been used in general as macroeconomic variables (Nguyen, 2022). As mentioned above, EPU have a destabilising effect on GI (Roper & Tapinos, 2016). This uncertainty can impact investment decisions, research and development funding, and market dynamics, which in turn can influence the pace and direction of GI. Although the EPU is increasing, businesses may be reluctant to invest in long-term, innovative green technologies due to the unpredictable economic environment. Therefore, reducing the EPU can positively impact the development and adoption of GI practices (Bhattacharya et al., 2017; He et al., 2020; Cui et al., 2021). This is why we investigated the relationship between EPU and GI. Considering this background, Hypothesis 1 and Hypothesis 2 are proposed as follows:

*H1a. Economic policy uncertainty negatively affects GI.*

*H1b. The effects of economic policy uncertainty on GI are different between developed and developing countries.*

### *2.2 Financial Development and Green Innovation*

A great deal of studies analysing the relationship between FD and GI have started to increase in recent years (Nicolaisen et al., 1991). Financial development, which includes the current situation regarding financial resources, opportunities for

investments, and ease of access to capital, plays an important role in GI development (Abid et al., 2022). Financial development is important in providing the financing and investment support needed for research and development, which is important in green technology investments. In addition, financial development can also influence the adoption of GI, as it provides financing for the utilisation of green technologies in business activities. This, in turn, encourages businesses to use environmentally friendly technologies and removes these barriers. A well-functioning financial development supports the transition to a more sustainable and environmentally friendly economy. In their study, Tamazian et al. (2009) revealed the importance of financial development in achieving sustainability goals and facilitating environmental progress. According to the authors, financial development has a significant impact on whether environmental progress is facilitated or impeded. Another study by Tamazian and Rao (2010) backed the impact of financial development in hastening the adoption of improved environmental practices and raise the environmental standards. Financial development as a tool to cause environmental deterioration, studies that supported financial development as a vital aspect for environmental sustainability are included above. The literature that is currently in publication focuses on financial innovation and development strategies for advancing both technology innovation in general and green technology innovation. With this in mind, the following are the proposed hypotheses:

*H2a: Financial development positively affects GI.*

*H2b. The effects of financial development on GI are different between developing and developed countries.*

According to the results of the literature review, the expected relationship between the variables in this study is presented in Table 1.

**Table 1. Direction of the Expected Relationship**

| Dep. Variable | Indep. Variables | Direction of the expected relation | Studies |
|---|---|---|---|
| Green Innovation | EPU | - | Bhattacharya et al. (2017), He et al. (2020), Cui et al. (2021), Li, Hu, and Zhang (2021), Cui, et al. (2023) |
| | FD | + | Pham (2019), Huang et al. (2019), Yu et al. (2021) |
| | FDI | + | Abid et al. (2022), Peng et al. (2023) |
| | GDP | + | Abid et al. (2022), Razzaq et al. (2023) |
| | CO2 | - | Ganda (2020), Umar and Safi (2023) |
| | R&D | + | Abid et al. (2022), Xu and Yang, (2023) |

*Source*: Authors' processing.

## 3. Research Motivation

Researchers have mainly focused on the factors that are influential on GI. First, at the corporate level, Brunnermeier and Cohen (2003) proposed the view that that the investment of firms in environmental management costs positively affects their green patents. Profit is a decisive factor for firms in green product innovation (Peng et al., 2023). This is because businesses consider environmental issues and

competitive priorities such as cost reduction when embracing green innovations. Contrary to the widespread belief that the implementation of GI practices increases business costs, when companies adopt these practices, they trigger innovative activities that decrease production costs, increase input efficiency, and enhance the value of products, thereby increasing competitiveness by balancing environmental costs with added value. On the other hand, this study focuses on macro factors rather than micro factors that influence GI. In particular, the study highlights the impact of financial development (FD) and economic policy uncertainty (EPU), which are considered important for GI. Furthermore, the comparability of studies and results from both developing and developed countries highlights the originality of this research. Therefore, this study will contribute to the literature.

## 4. Data and Methods

In this section of the study, details on the econometric model, data, and econometric methods applied are given.

### *4.1 Econometric Model*

This paper aims to investigate the effects of EPU on GI via the Panel ARDL Bound Test. This model was based on the studies conducted by Xu and Yang (2023) and Cui et al. (2023).

$$GI_{i,t} = \beta_0 + \beta_1 EPU_{i,t} + \beta_2 GDP_{i,t} + \beta_3 R\&D_{i,t} + \beta_4 FDI_{i,t} + \beta_5 CO2_{i,t} + \varepsilon_{i,t} \quad (1)$$

GI in the equation 1 above shows patented environment-related technologies, EPU is economic policy uncertainty, and the control variables are as follows: GDP is per capita real gross domestic product; R&D is research and development expenditure (% of GDP); FDI is foreign direct investment, net inflows (% of GDP); $CO_2$ is per capita carbon emissions, and the error term is given by ε.

$$GI_{i,t} = \alpha_0 + \alpha_1 FI_{i,t} + \alpha_2 GDP_{i,t} + \alpha_3 R\&D_{i,t} + \alpha_4 FDI_{i,t} + \alpha_5 CO2_{i,t} + \varepsilon_{i,t} \quad (2)$$

GI in the equation 2 above shows patented environment-related technologies, FI is the Financial Development Index, and the control variables are as follows: GDP is per capita real gross domestic product; R&D is research and development expenditure (% of GDP); FDI is foreign direct investment, net inflows (% of GDP); $CO_2$ is per capita carbon emissions, and the error term is given by ε.

The factors in the equation above were chosen based on the solid theoretical background of previous studies (Bhattacharya et al.,2017; Pham 2019; Huang et al., 2019; He et al., 2020; Cui et al., 2021; Cui et al., 2023). In previous research, the relationship between FI and GI has been ignored in favour of investigating the relationship between EPU and GI. Furthermore, the relationship between GI and EPU for both developing and developed countries has not been investigated or compared in earlier studies. Therefore, we created two models in the study and analysed two groups of countries separately to fill the gap in the literature.

### *4.2 Sample and Data*

This study examines the impact of EPU and FI on GI in the presence of GDP, R&D, FDI, and CO2 for G7 (Germany, USA, UK, France, Italy, Japan, Canada) and BRIC (Brazil, Russia, India, China) countries. The time period taken for this study covers the years from 2000 to 2020. We took this specific time period into account because the data were easily accessible.

**Dependent variable:**

 Green Innovation: GI was calculated as patented environment-related technologies (% of total patented technologies), and data for GI were obtained from the OECD database. The same dataset was used by Abid et al. (2022), Anwar et al. (2023), Chen et al. (2022), and Umar and Safi (2023).

**Independent variables:**

 Economic Policy Uncertainty Index: This is an index of three different types of underlying components to quantify economic uncertainty related to policy. Newspaper coverage of economic uncertainty related to policy is quantified in the first and most flexible component. The bulk of other topic- and country-specific indexes hosted on the website where the index was accessed also employ this newspaper-based methodology.

 Financial Development Index: A measure of a nation's depth, accessibility, and effectiveness in terms of its financial markets and institutions is called the Financial Development Index. The literature generally refers to financial development using credit to the private sector or monetary aggregates like M1/M2/M3 (Chen et al., 2022; Anwar et al., 2023).

**Control variables:** To reduce any bias arising from the omission of variables, we introduce several control variables into the model (Feng & Zheng, 2022).

 Foreign Direct Investment: The net amount of money invested to obtain a long-term management stake (10% or more of voting stock) in a business that operates in an economy other than the investor's country is known as foreign direct investment. (World Bank (WB), 2024; Fernandes et al., 2021; Abid et al., 2022).

 Gross Domestic Product: The gross domestic product divided by the population at midyear yields GDP per capita. (WB, 2024). The data are expressed in US dollars as of 2015 (Fernandes et al., 2021; Abid et al., 2022; Chen et al., 2022).

 Carbon Dioxide Emissions: Carbon dioxide emissions are produced when fossil fuels are burnt and cement is made. These values consist of the carbon dioxide released during gas flaring and the consumption of solid, liquid, and gas fuels (WB, 2024; Oguzturk & Ozbay, 2022).

 Research and Development: This variable refers to research and development (R&D) spending on the basis of GDP. The four primary sectors of business activity, government, higher education, and private non-profit comprise both capital and ongoing expenditures. Basic, applied, and experimental research categories are all

included in R&D (WB, 2024; Tamazian et al., 2009; Abid et al., 2022). The symbols, short definitions, and sources of all the included variables are given in Table 2.

**Table 2. Definitions of Variables**

| Symbol | Variables | Definition | Source |
|---|---|---|---|
| GI | Green Innovation | Patented environment-related technologies (% of total patented technologies) | OECD |
| EPU | Economic Policy Uncertainty Index | An index of three types of underlying components. | www.policyuncertainty.com |
| FD | Financial Development | Financial Development Index | International Financial Statistics (IFS) |
| FDI | Foreign Direct Investment | Foreign direct investment, net inflows (% of GDP) | WB |
| GDP | Gross Domestic Product | Per capita real gross domestic product (Constant 2015 US$) (used to proxy economic growth) | WB |
| CO2 | Carbon dioxide emissions | Per capita carbon dioxide emissions (Metric tons) (used to proxy environmental impact) | WB |
| RD | Research and Development | Research and development expenditure (% of GDP) | WB |

*Source*: Authors' processing.

### *4.3 Cross-Sectional Dependence (CSD) Test*

The Breusch-Pagan LM (1980) statistic is among the cross-sectional dependence tests used in the case of T>N. Under the null hypothesis of no cross-sectional dependence, the LM statistic is asymptotically distributed as chi-squared with N(N-1)/2 degrees of freedom:

$$CD_{LM} = T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}^2 \tag{3}$$

$\hat{\rho}_{ij}^2$ denotes the sample correlation coefficient between the error terms obtained from the individual OLS estimation equation. Pesaran, Ullah, and Yamagata (2008) presented the Breusch-Pagan LM statistic scaled for balanced and large panels. The CD test statistic is asymptotically standard normally distributed under the null hypothesis of cross-sectional independence, as both the cross-section dimension (N) and the time dimension (T) go to infinity (N → ∞ and T → ∞).".

$$LM_{scaled} = \sqrt{\frac{1}{N(N-1)}}\left[\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}(T\hat{\rho}_{ij}^2 - 1)\right] \tag{4}$$

$$LM_{adj} = \sqrt{\frac{2}{N(N-1)}}\left[\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\frac{(T-k)\hat{\rho}_{ij}^2 - \mu_{Tij})}{\vartheta_{Tij}}\right] \tag{5}$$

$$LM_{adj} \sim dN(0,1) \quad (6)$$

The determination of the tests to be used in assessing the presence of CSD is related to the time dimension studied in the model and the number of cross sections included in the model. In this study, these parameters were T=21 (time), N=4 (BRIC), and N=7 (G7) (cross-section). In other words, in the determination of the cross-sectional dependence test to be used here, approaches that are based on the T>N condition should be used.

### *4.4 Unit Root Test*

According to the results of the CSD test, the Bai-Ng (2004) PANIC unit root test, which is a second-generation unit root test, was used in the study to test the stationarity of the series. This test allows testing common factors and error terms separately (Bai and Ng, 2010). The deterministic component $D_{it} = \sum_{j=0}^{p} \delta_i \, t^j$ is an individual-specific fixed effect of the form $D_{it} = \delta_i$ when $p = 0$ and an individual-specific time trend when $p = 1$. When there is no deterministic term, $p = -1$. Therefore, the data creation process can be expressed as follows (Bai & Ng, 2010):

$$X_{it} = D_{it} + \lambda_i' F_t + e_{it} \quad (7)$$

$$(1 - L)F_t = C(L)\eta_t \quad (8)$$

$$e_{it} = \rho_{it} e_{it-1} + \varepsilon_{it} \quad (9)$$

In equations (7), (8), and (9), $F_t$ is the vector of common factors in $rx1$ dimensions that trigger correlation between cross-sectional units. $\lambda_i$ is the vector of factor loadings in $rx1$ dimensions. $e_{it}$ is the error term, and $C(L)$ is the $r \times r$ matrix containing the polynomials of the lag operator, which can be expressed as $C(L) = \sum_{j=0}^{\infty} C_j L^j$. In the PANIC tests, the first difference of equations (7), (8), and (9) was taken and is expressed as follows (Bai & Ng, 2010):

$$\Delta X_{it} = \lambda_i' \Delta F_t + \Delta e_{it} \quad (10)$$

### *4.5 Panel ARDL*

The ARDL model, which is preferred over the single cointegration approach for a number of reasons, is used to determine whether the provided time series data demonstrate long- and short-run equilibria (Pesaran et al., 2001). The panel ARDL model concurrently gives long- and short-term coefficients. In light of these benefits, we used the panel ARDL approach to validate potential long- and short-term relationships between GI, EPU, and FD. The long-run and short-run models are based on panel ARDL and are represented in equations (11) and (12), respectively (Topaloğlu and Bayrakdaroğlu, 2024):

$$Y_{it} = \sum_{j=1}^{p} \lambda_{ij} Y_{i,t-j} + \sum_{j=0}^{p} \delta_{ij}' X_{i,t-j} + \varepsilon_{it} \quad (11)$$

$$\Delta Y_{it} = \phi_i(Y_{it-1} - \Theta_t' X_{it}) + \sum_{j=1}^{p-1} \lambda_{ij}^* + \Delta Y_{it-j} + \sum_{j=0}^{p-1} \delta_{ij}^* + \Delta X_{it-j} + \varepsilon_{it} \quad (12)$$

In Equations 9 and 10 $i$, N denotes the cross-sectional dimension, $t = 1,2,3 \ldots \ldots$ T denotes the time dimension, $k\,x1$ denotes the vector of explanatory variables, $\delta_{it}, kx1$ denotes the vectors of coefficients, $\lambda_{ij}$, denotes the scales, $\phi_i$ denotes the error correction mechanism and $\varepsilon_{it}$ denotes the error term.

## 5. Results

Descriptive statistics offer safety advice along with succinct scenarios. The variables of skewness, kurtosis, mean, median, mode, and standard deviation were included as descriptive statistics in this study. The descriptive statistics of the variables of the study are given in Table 3.

**Table 3. Descriptive Statistics**

| **G7 Countries** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **LNEPU** | **FD** | **FDI** | **LNCO** | **LNGDP** | **LNGI** | **RD** |
| Mean | 4.901 | 0.817 | 2.184 | 2.227 | 10.578 | 2.358 | 2.211 |
| Median | 4.859 | 0.814 | 1.710 | 2.205 | 10.552 | 2.405 | 2.191 |
| Maximum | 6.296 | 0.955 | 12.731 | 3.018 | 11.013 | 2.756 | 3.422 |
| Minimum | 3.627 | 0.669 | -1.164 | 1.374 | 10.287 | 1.742 | 1.003 |
| Std. Dev. | 0.500 | 0.075 | 2.274 | 0.431 | 0.173 | 0.243 | 0.668 |
| Skewness | 0.392 | -0.019 | 2.286 | 0.156 | 0.606 | -0.71 | 0.033 |
| Kurtosis | 2.995 | 1.656 | 9.429 | 1.985 | 2.605 | 2.764 | 1.842 |
| Jarque-Bera | 3.767 | 11.070 | 381.236 | 6.904 | 9.975 | 12.691 | 8.232 |
| Probability | 0.151 | 0.003 | 0.000 | 0.031 | 0.006 | 0.001 | 0.016 |
| Observations | 147 | 147 | 147 | 147 | 147 | 147 | 147 |
| **BRIC Countries** | | | | | | | |
| | **LNEPU** | **FD** | **FDI** | **LNCO** | **LNGDP** | **LNGI** | **RD** |
| Mean | 4.814 | 0.570 | 2.513 | 1.261 | 8.417 | 2.240 | 1.156 |
| Median | 4.757 | 0.527 | 2.553 | 0.948 | 8.834 | 2.297 | 1.087 |
| Maximum | 6.377 | 0.797 | 5.033 | 2.475 | 9.245 | 2.725 | 2.406 |
| Minimum | 3.886 | 0.416 | 0.502 | -0.12 | 6.627 | 1.383 | 0.655 |
| Std. Dev. | 0.556 | 0.125 | 1.159 | 0.885 | 0.843 | 0.278 | 0.408 |
| Skewness | 0.709 | 0.516 | 0.109 | 0.109 | -0.876 | -0.90478 | 1.286 |
| Kurtosis | 3.383 | 1.794 | 1.974 | 1.490 | 2.210 | 3.657 | 4.177 |
| Jarque-Bera | 7.566 | 8.814 | 3.848 | 8.142 | 12.939 | 12.972 | 28.023 |
| Probability | 0.022 | 0.012 | 0.145 | 0.017 | 0.001 | 0.001 | 0.000 |
| Observations | 84 | 84 | 84 | 84 | 84 | 84 | 84 |

*Source*: Authors' processing.

As seen in Table 3 for G7 countries, all variables except for FD and GI were skewed to the right. According to the Jarque-Bera (JB) probability value ($p<0.05$), which shows whether a series is normally distributed. It was determined that the EPU

series among the series in the models constructed for the G7 countries had a normal distribution, and the series for the other variables did not have a normal distribution. The number of observations for the G7 countries was 147. For BRIC countries, all variables except for GDP and GI were skewed to the right. According to the JB probability value ($p<0.05$), which shows whether a series is normally distributed. Among the series in the models for the BRIC countries, it was determined that the FDI variable had a normal distribution, and the other variables did not have a normal distribution. The number of observations for the BRIC countries was 84.

Since there were non-normally distributed series in the model, Spearman's correlation analysis was preferred when creating the correlation matrix. According to the result of this analysis, a high level of correlation ($r>0.90$) between variables constitutes a multicollinearity problem. In a regression analysis, the presence of multicollinearity indicates that the independent variables are related to each other. For this reason, Spearman's correlation coefficients and the Variance Inflation Factor (VIF) results were also analysed in this study. If a critical value calculated according to VIF is greater than 10, this indicates that there may be a multicollinearity problem. Spearman's correlation analysis test results are shown in Table 4.

**Table 4. Correlation Matrix Results**

| **G7 Countries** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **LNEPU** | **FD** | **FDI** | **LNCO** | **LNGDP** | **LNGI** | **RD** | **RESID01** |
| LNEPU | 1.000 | | | | | | | |
| FD | 0.125 | 1.000 | | | | | | |
| FDI | -0.002 | 0.092 | 1.000 | | | | | |
| LNCO | -0.265 | 0.374 | 0.122 | 1.000 | | | | |
| LNGDP | 0.339 | 0.629 | 0.405 | 0.475 | 1.000 | | | |
| LNGI | 0.609 | -0.010 | -0.165 | -0.181 | 0.149 | 1.000 | | |
| RD | 0.014 | 0.047 | -0.275 | 0.337 | 0.141 | 0.307 | 1.000 | |
| RESID01 | 0.730 | 0.191 | -0.005 | -0.370 | 0.426 | 0.770 | -0.018 | 1.000 |
| **BRIC Countries** | | | | | | | | |
| | **LNEPU** | **FD** | **FDI** | **LNCO** | **LNGDP** | **LNGI** | **RD** | **RESID01** |
| LNEPU | 1.000 | | | | | | | |
| FD | 0.334 | 1.000 | | | | | | |
| FDI | 0.002 | 0.461 | 1.000 | | | | | |
| LNCO | 0.324 | 0.443 | 0.141 | 1.000 | | | | |
| LNGDP | 0.678 | 0.406 | 0.144 | 0.726 | 1.000 | | | |
| LNGI | 0.351 | 0.115 | 0.082 | 0.297 | 0.460 | 1.000 | | |
| RD | 0.396 | 0.804 | 0.352 | 0.571 | 0.546 | 0.148 | 1.000 | |
| RESID01 | 0.650 | 0.509 | -0.031 | 0.443 | 0.756 | 0.485 | 0.689 | 1.000 |

*Source*: Authors' processing.

The correlation matrix results, as seen in Table 4, showed that not all variables were strongly correlated. The CSD test results are shown in Table 5.

**Table 5. CSD Test**

| G7 | | | | BRIC | | | |
|---|---|---|---|---|---|---|---|
| **Variables** | **Statistic** | **Prob.** | **Variables** | **Statistic** | **Prob.** | **Variables** | **Statistic** |
| LNGI | Breusch-Pagan LM | 375.833 | 0.000 | LNGI | Breusch-Pagan LM | 29.012 | 0.000 |
| | Pesaran scaled LM | 54.752 | 0.000 | | Pesaran scaled LM | 6.643 | 0.000 |
| LNEPU | Breusch-Pagan LM | 246.283 | 0.000 | LNEPU | Breusch-Pagan LM | 35.585 | 0.000 |
| | Pesaran scaled LM | 34.762 | 0.000 | | Pesaran scaled LM | 8.540 | 0.000 |
| FD | Breusch-Pagan LM | 105.212 | 0.000 | FD | Breusch-Pagan LM | 34.340 | 0.000 |
| | Pesaran scaled LM | 12.994 | 0.000 | | Pesaran scaled LM | 8.181 | 0.000 |
| LNGDP | Breusch-Pagan LM | 302.227 | 0.000 | LNGDP | Breusch-Pagan LM | 104.892 | 0.000 |
| | Pesaran scaled LM | 43.394 | 0.000 | | Pesaran scaled LM | 28.548 | 0.000 |
| LNCO | Breusch-Pagan LM | 314.891 | 0.000 | LNCO | Breusch-Pagan LM | 56.543 | 0.000 |
| | Pesaran scaled LM | 45.348 | 0.000 | | Pesaran scaled LM | 14.590 | 0.000 |
| FDI | Breusch-Pagan LM | 54.080 | 0.000 | FDI | Breusch-Pagan LM | 14.871 | 0.021 |
| | Pesaran scaled LM | 5.104 | 0.000 | | Pesaran scaled LM | 2.561 | 0.010 |
| RD | Breusch-Pagan LM | 239.783 | 0.000 | RD | Breusch-Pagan LM | 32.578 | 0.000 |
| | Pesaran scaled LM | 33.759 | 0.000 | | Pesaran scaled LM | 7.672 | 0.000 |
| MODEL A (EPU) | Breusch-Pagan LM | 228.299 | 0.000 | MODEL A (EPU) | Breusch-Pagan LM | 30.660 | 0.000 |
| | Pesaran scaled LM | 31.987 | 0.000 | | Pesaran scaled LM | 7.119 | 0.000 |
| MODEL B (FD) | Breusch-Pagan LM | 306.468 | 0.000 | MODEL B (FD) | Breusch-Pagan LM | 25.706 | 0.000 |
| | Pesaran scaled LM | 44.049 | 0.000 | | Pesaran scaled LM | 5.689 | 0.000 |

*Source*: Authors' processing.

Considering both CSD test results in Table 5 for the G7 and BRIC countries, it is understood that the hypothesis 'Ho: there is no CSD' was rejected since the values calculated on both the variable and model bases were smaller than the critical value (0.05). In other words, there was CSD on both the variable and the model bases. According to this result, the PANIC unit root test, which is a second-generation unit root test that takes into account CSD, was used. The results of this test are given in Table 6.

**Table 6. PANIC Unit Root Test**

| G7 Countries | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Level | | | | First Difference | | | |
| | | Constant | | Constant + Trend | | Constant | | Constant + Trend | |
| Variables | Test | T-Stat. | p-value | T-Stat. | p-value | T-Stat. | p-value | T-Stat. | p-value |
| LNGI | PCe_Choi | -1.060 | 0.856 | -0.480 | 0.684 | 7.409 | 0.000 | 7.409 | 0.000 |
| | Pce_MW | 8.389 | 0.868 | 9.650 | 0.647 | 53.204 | 0.000 | 53.204 | 0.000 |
| LNEPU | Pce_Choi | -0.909 | 0.818 | -0.682 | 0.752 | 6.495 | 0.000 | 4.937 | 0.000 |
| | Pce_MW | 9.189 | 0.819 | 10.393 | 0.733 | 48.368 | 0.000 | 40.123 | 0.000 |
| FD | Pce_Choi | 5.835 | 0.000 | 5.532 | 0.000 | - | - | - | - |
| | Pce_MW | 44.877 | 0.000 | 43.272 | 0.000 | - | - | - | - |
| LNGDP | Pce_Choi | 6.217 | 0.000 | 7.031 | 0.000 | - | - | - | - |
| | Pce_MW | 46.897 | 0.000 | 51.204 | 0.000 | - | - | - | - |
| LNCO | Pce_Choi | 6.767 | 0.000 | 4.494 | 0.000 | - | - | - | - |
| | Pce_MW | 49.806 | 0.000 | 37.780 | 0.001 | - | - | - | - |
| FDI | Pce_Choi | 3.971 | 0.000 | 2.604 | 0.005 | - | - | - | - |
| | Pce_MW | 35.010 | 0.002 | 27.778 | 0.015 | - | - | - | - |
| RD | Pce_Choi | 6.586 | 0.000 | 3.698 | 0.000 | - | - | - | - |
| | Pce_MW | 48.852 | 0.000 | 33.570 | 0.002 | - | - | - | - |
| **BRIC Countries** | | | | | | | | | |
| Variables | Test | T-Stat. | p-value | T-Stat. | p-value | T-Stat. | p-value | T-Stat. | p-value |
| LNGI | PCe_Choi | -0.637 | 0.738 | -1.428 | 0.923 | 4.301 | 0.000 | 4.952 | 0.000 |
| | PCe_MW | 5.452 | 0.708 | 2.290 | 0.971 | 25.204 | 0.001 | 27.806 | 0.001 |
| LNEPU | PCe_Choi | -0.504 | 0.693 | 1.378 | 0.084 | 1.993 | 0.023 | 3.014 | 0.001 |
| | PCe_MW | 5.983 | 0.649 | 13.512 | 0.095 | 15.973 | 0.043 | 20.056 | 0.010 |
| FD | PCe_Choi | -1.572 | 0.942 | -1.361 | 0.913 | 3.316 | 0.001 | 2.350 | 0.009 |
| | PCe_MW | 1.711 | 0.989 | 2.557 | 0.959 | 21.263 | 0.007 | 17.398 | 0.026 |
| LNGDP | PCe_Choi | 2.270 | 0.012 | 2.606 | 0.005 | - | - | - | - |
| | PCe_MW | 17.078 | 0.029 | 18.426 | 0.018 | - | - | - | - |
| LNCO | PCe_Choi | -1.665 | 0.952 | -0.744 | 0.771 | 4.000 | 0.000 | 2.116 | 0.017 |
| | PCe_MW | 1.341 | 0.995 | 5.026 | 0.755 | 24.000 | 0.002 | 16.464 | 0.036 |
| FDI | PCe_Choi | 2.988 | 0.001 | 4.379 | 0.000 | - | - | - | - |
| | PCe_MW | 19.951 | 0.011 | 25.514 | 0.001 | - | - | - | - |
| RD | PCe_Choi | -0.886 | 0.812 | 1.089 | 0.138 | 2.276 | 0.011 | 4.000 | 0.000 |
| | PCe_MW | 4.458 | 0.814 | 12.355 | 0.136 | 17.105 | 0.029 | 24.000 | 0.002 |

Note: *PCe_MW:* Maddal and Wu (1999); *PCe_Choi:* Represents statistics proposed by Choi (2001). The maximum number of common factors for the PANIC unit root test is 2, and the delay lengths are 4. ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

*Source*: Authors' processing.

According to the results of the test, as seen in Table 6, the hypothesis 'H0: There is a unit root in the series' was rejected since the calculated values of LNGI and LNEPU used in the model including the G7 countries were greater than the critical

value (0.05), and when the first-order differences of the series were taken, it was found that the series were stationary at the I(1) level. Since the values calculated for the other variables used in the model were smaller than the critical value (0.05), the hypothesis 'H0: There is a unit root in the series that could not be rejected. In other words, the series were stationary at the I(0) level. In the test results for the BRIC countries, it was found that the variables LNGI, LNEPU, FD, LNCO, and RD were stationary at the I(1) level, while LNGDP and FDI were stationary at the I(0) level. Considering that the series of the included variables had different degrees of stationarity, the Panel ARDL bounds test was used to calculate the long- and short-run coefficients. The panel ARDL bounds test results are presented in Table 7.

**Table 7. Panel ARDL**

| **G7 Countries** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **MODEL A** | | | | | **MODEL B** | | | | |
| **Long-Run Equation** | | | | | **Long-Run Equation** | | | | |
| Variable | Coefficient | Std. Error | t-Stat. | Prob. | Variable | Coefficient | Std. Error | t-Stat. | Prob. |
| LNGDP | 1.105*** | 0.323 | 3.420 | 0.001 | LNGDP | -1.306*** | 0.164 | -7.980 | 0.000 |
| FDI | 0.329** | 0.130 | 2.533 | 0.014 | LNCO | 3.138*** | 0.526 | 5.966 | 0.000 |
| RD | 0.429 | 0.268 | 1.603 | 0.115 | FDI | -0.068*** | 0.007 | -9.322 | 0.000 |
| LNCO | 0.633 | 0.707 | 0.895 | 0.375 | RD | -0.231** | 0.094 | -2.444 | 0.018 |
| LNEPU | -2.311*** | 0.814 | -2.840 | 0.006 | FD | 3.366*** | 0.194 | 17.382 | 0.000 |
| **Short-Run Equation** | | | | | **Short-Run Equation** | | | | |
| COINTEQ01 | -0.044 | 0.009 | -5.136 | 0.000 | CQ01 | -0.523 | 0.420 | -1.246 | 0.218 |
| D(LNGDP) | -1.964** | 0.735 | -2.673 | 0.010 | D(LNGDP) | -1.358 | 1.244 | -1.092 | 0.280 |
| D(FDI) | -0.040* | 0.022 | -1.829 | 0.073 | D(LNCO) | -0.362 | 0.680 | -0.532 | 0.597 |
| D(RD) | -0.385 | 0.231 | -1.668 | 0.101 | D(FDI) | -0.006 | 0.045 | -0.127 | 0.900 |
| D(LNCO) | 0.446 | 0.333 | 1.341 | 0.185 | D(RD) | 0.437 | 0.293 | 1.493 | 0.142 |
| D(LNEPU) | 0.103*** | 0.035 | 2.967 | 0.004 | D(FD) | -1.785 | 1.368 | -1.305 | 0.198 |
| C | -2.699 | 0.695 | -3.885 | 0.000 | C | 3.001 | 2.257 | 1.329 | 0.190 |

Note: ***, **, and * represent statistically significant level at 1%, 5%, and 10%, respectively.

*Source*: Authors' processing.

According to the long-run results for Model A (GI and EPU), a significant and positive relationship was found between GI and the variables of GDP and FDI. A one-unit increase in GDP increased GI by 1.10 units, while a one-unit increase in FDI increased GI by 0.32 units. A one-unit increase in EPU decreased GI by 2.31 units. According to the short-run coefficients, a one-unit increase in GDP decreased GI by 1.96 units, while a one-unit increase in EPU increased GI by 0.10 units. According to the long-run results for Model B (GI and FD), a significant and positive relationship was found between GI and the variables of LNCO and FD, while a significant and negative relationship was found between GI and the variables of GDP, FDI, and RD. While a one-unit increase in LNCO increased GI by 3.13 units, a one-unit increase in FD increased it by 0.06 units. On the other hand, one-unit increases in GDP, FDI, and RD decreased GI by 1.30, 0.06, and 0.23 units,

respectively. The short-term coefficients were not found to be significant because the short-term economic or social dynamics may be different from the long-term effects.

**Table 8. Panel ARDL**

| BRIC Countries | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **MODEL A** | | | | | **MODEL B** | | | | |
| **Long-Run Equation** | | | | | **Long-Run Equation** | | | | |
| Variable | Coeff. | Std. Error | t-Stat. | Prob. | Variable | Coeff. | Std. Error | t-Stat. | Prob. |
| LNEPU | 0.389*** | 0.043 | 9.093 | 0.000 | LNCO | 0.179 | 0.178 | 1.007 | 0.323 |
| LNCO | -0.055 | 0.295 | -0.188 | 0.852 | FDI | -0.154*** | 0.023 | -6.665 | 0.000 |
| FDI | 0.094*** | 0.016 | 6.004 | 0.000 | LNGDP | -0.547** | 0.238 | -2.303 | 0.029 |
| LNGDP | 0.589*** | 0.204 | 2.894 | 0.007 | RD | 0.632* | 0.326 | 1.941 | 0.063 |
| RD | 1.333*** | 0.235 | 5.680 | 0.000 | FD | 3.624*** | 0.262 | 13.807 | 0.000 |
| **Short-Run Equation** | | | | | **Short-Run Equation** | | | | |
| COINTEQ01 | -0.338 | 0.262 | -1.287 | 0.208 | CQ01 | -0.766 | 0.452 | -1.696 | 0.101 |
| D(LNEPU) | 0.016 | 0.124 | 0.129 | 0.898 | D(LNCO) | -0.144 | 0.468 | -0.307 | 0.761 |
| D(LNCO) | 0.182 | 0.367 | 0.496 | 0.624 | D(FDI) | 0.042 | 0.091 | 0.461 | 0.648 |
| D(FDI) | -0.020 | 0.014 | -1.480 | 0.149 | D(LNGDP) | -0.589 | 1.318 | -0.447 | 0.659 |
| D(LNGDP) | -1.116** | 0.504 | -2.215 | 0.034 | D(RD) | -2.002** | 0.747 | -2.681 | 0.012 |
| D(RD) | -0.525 | 0.510 | -1.028 | 0.312 | D(FD) | 3.289 | 2.238 | 1.469 | 0.153 |
| C | -1.851 | 1.285 | -1.441 | 0.160 | C | 3.081 | 2.238 | 1.376 | 0.180 |

Note: ***, **, and * represent statistically significant level at 1%, 5%, and 10%, respectively.

*Source*: Authors' processing.

According to the long-run results for Model A (GI and EPU), a significant and positive relationship was found between GI and the variables of EPU, FDI, LNGDP, and RD. A one-unit increase in EPU increased GI by 0.38 units, a one-unit increase in FDI increased GI by 0.09 units, and a one-unit increase in GDP increased GI by 0.58 units. Based on the short-run coefficients, a significant and negative relationship was found between GI and GDP. A one-unit increase in GDP decreased GI by 1.11 units. According to the long-run results for Model B (GI and FD), a significant and negative relationship was found between GI and FDI and GDP, while a significant and positive relationship was found between GI and FD. A one-unit increase in GDP decreased GI by 2.00 units, a one-unit increase in RD decreased GI by 2.00 units, however, a one-unit increase in FD increased GI by 3.62 units. Based on the short-run coefficients, a significant and negative relationship was found between GI and RD. A one-unit increase in RD decreased the GI by 2.00 units.

## 6. Discussion and Conclusions

The purpose of this study was to reveal the relationship between EPU and GI for developed and developing countries. Furthermore, the study intended to

examine the relationship between financial development (FD) and GI for developed and developing countries. Within this framework, first, the horizontal cross-sectional dependency was analysed to decide which test to use. According to the test results, second-generation unit root tests were used. As a result of the unit root tests, it was found that the series in both models were non-stationary on the same level. Therefore, the panel ARDL bounds test method, which takes into account the non-stationarity of a series, was used in the estimation of long- and short-run coefficients. The meanwhile limitation of this study, GI data were included up to the year 2020. The panel ARDL test results for the G7 countries revealed that over the long term, there was a significant and negative relationship between GI and EPU (Model A). We expected that EPU would negatively impact GI. Studies by Bhattacharya et al. (2017), He et al. (2020), Cui et al. (2021), and Ren et al. (2023), using Chinese-listed companies as samples, showed a decline in GI due to EPU, corroborating our findings. Investors become more risk-averse during times of significant EPU. GI projects are less attractive than safer short-term investments since they frequently involve large upfront costs and long payback periods. Businesses and investors may decide to postpone or scale back their investment in green technologies because of the unpredictability of upcoming laws, regulations, and subsidies. Uncertainty in economic policy can potentially tighten credit conditions even in developed countries. Financing for high-risk initiatives like GI may become less accessible as banks and other financial institutions grow more conservative. The cost of capital may rise as a result of the perceived risks connected to policy uncertainty. Due to this issue, borrowing money for green initiatives becomes more costly for businesses, which hinders innovation. There was a significant and positive relationship between GI and the variables of GDP and FDI in this study. We expected that GDP and FDI would positively impact GI. Therefore, the result of this study differed from the results reported by Abid et al. (2022), Razzaq et al. (2023), and Peng et al. (2023). According to the short-run coefficients found in this study, there was a significant and positive relationship between EPU and GI. This result was similar to the results reported by Feng and Zheng (2022), and Peng et al. (2023). This situation may be interpreted as that the effects of short-term uncertainties on the economy would be temporary.

In the long-run analysis results in this study for the G7 countries, a significant and positive relationship was found between GI and FD (Model B). We expected that FD would positively impact GI. This was similar to the reports by Pham (2019), Huang et al. (2019), and Yu et al. (2021). Although EPU generally has a negative impact on GI, in the short term, several dynamics can create a positive relationship. Government interventions, strategic business decisions, increased consumer and investor pressure, and the availability of targeted funding can temporarily boost GI. These short-term incentives and strategic moves can help firms navigate uncertainty while advancing their sustainability goals. Additionally, a significant and positive relationship was found between GI and LNCO. This result was similar to the result given by Oguzturk and Ozbay (2022). However, we expected that LNCO would negatively impact GI. Therefore, this result differed from those reported by Ganda

(2020) and Umar and Safi (2023). A significant and negative relationship was found between GI and the variables of GDP, FDI, and RD. We expected that GDP, FDI, and RD would negatively impact GI. Therefore, this result differed from those reported by Abid et al. (2022), Razzaq et al. (2023), Peng et al. (2023), and Xu and Yang (2023).

According to the results of the panel ARDL test for the BRIC countries, a significant and positive relationship between GI and EPU (Model A) in the long run was found. We expected that EPU would negatively impact GI. This situation differed from the results of studies conducted by Bhattacharya et al. (2017), He et al. (2020), Cui et al. (2021). In developing countries, a positive relationship between EPU and GI may be due to a combination of conditions that encourage innovation even in the face of uncertainty. While EPU often creates challenges for national economies, it can also create a favourable environment for GI. This is due to increased support from government and international organisations, strategic business decisions, new market opportunities, and green finance and investment. In addition, social and environmental imperatives may lead governments to priorities sustainability. This turns the negativity created by uncertainty into a positive situation. In this study, a significant and positive relationship was identified between GI and the variables of EPU, FDI, LNGDP, and RD. We expected that FDI, LNGDP, and RD would positively impact GI. This was similar to the results found by Abid et al. (2022), Peng et al. (2023), Razzaq et al. (2023), and Xu and Yang (2023). Based on the results of the analyses on long-term relationship for Model B (GI and FD), a significant and negative relationship was found between GI, FDI and RD. This situation was different from the studies carried out by Abid et al. (2022) and Razzaq et al. (2023). While a significant and positive relationship was found between GI and FD. This was similar to the reports by Pham (2019), Huang et al. (2019), Yu et al. (2021).

In parallel with the results of the study, some policy recommendations can be made for developed and developing countries. In order to reduce the negative relationship between EPU and GI in developed countries, governments can provide sustainable policy frameworks and various fiscal incentives. They can also provide a safe environment for GI investments by supporting public-private partnerships. In addition, increasing institutional support, mobilising market demand and implementing feedback mechanisms with an effective monitoring mechanism are important for the development of GI despite EPU. In developing countries, some strategies can be mentioned to address the positive relationship between the EPU and GI. These strategies can provide opportunities for the reduction of risks and the development of GI. Stable policy frameworks to be implemented by states, international support and market-oriented solutions, and robust innovation systems to be established play a key role in the development of GI. In addition, new legal regulations and incentives to be created can be recommended to increase funding for the development of green technology, universities or research organisations carrying out studies/projects on this technology. In addition to these, loan package programmes with low-interest loans and public cooperation can be increased in order

to direct investors with entrepreneurial ideas to green innovation projects. Limitation of this study, GI data were included up to the year 2020.

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