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# Green Investment and Climate Risk Dynamics in G20 Economies Growth

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# Green Investment and Climate Risk Dynamics in G20 Economies Growth

**Abstract**

This study seeks to investigate the complex interplay of green investment, climate risk, and economic growth in the G20 countries. Using a Panel Vector Autoregression (PVAR) model estimated through the Generalized Method of Moments (GMM) for the 2000-2023 period, we find a fascinating yet disconcerting story. We find evidence of a strong, one-way causal effect where climate risk is a substantial disincentivizing factor for green investment in the short term, a phenomenon we term the "climate risk paradox." We find a persistent 0.6 percentage point fall in the share of green investment to GDP given a positive shock to climate risk. The immediate effects of these factors on economic growth are insignificant, suggesting the long-term payoff of the green investment story. This challenges the conventional assumption of the investment-enhancing effect of crisis, pointing to the critical need for "de-risking" the green investment story. We conclude the study by outlining the implications for the G20 countries.

**Keywords:** Green Investment, Climate Risk, Economic Growth, G20, PVAR, GMM, Granger Causality, Climate Finance.
**JEL Classification:** Q54, Q56, O44, C33, F64, G15

## 1. Introduction

The global economy is at a crossroads, and it has to address the challenges of sustaining economic growth and the rising threat of climate change. The G20 countries, which produce more than 80% of global GDP and an equivalent amount of greenhouse emissions, are at the heart of this complex global economic landscape. Moving towards a green economy involves a massive shift of capital resources into green investments, such as investments in renewable energy and energy efficiency. However, this shift is not taking place in a vacuum, and the rising threat of extreme weather events, measured through the Climate Risk Index, has the power to impact investment decisions in a profound manner.

The objective of this paper is to disentangle the complex relationships between green investment, climate risk, and economic growth, with a focus on the G20 economies. Although the emerging literature recognizes the relevance of the above variables, the nature of their interaction remains a topic of ongoing debate, with recent studies yielding inconsistent results. Does green investment boost economic growth in the short term, or does it imply a trade-off? How does the assessment of climate risk shape the investment in green projects? Does higher economic growth imply higher or lower investment in green projects?

Recent studies have given conflicting results for the above-stated relationships. Wu et al. (2025) proved the significance of green investment in the quality of economic development in China, but there are thresholds depending on the level of GDP per capita. At the same time, Trinh (2024) proved the fact that the level of debt increases for firms facing more climate change, which means climate change deters rather than encourages green investment. The above results indicate the necessity of a thorough dynamic analysis of the above-stated relationships.

In order to answer these questions, we make use of a Panel Vector Autoregression (PVAR) model. This is an appropriate econometric method for our analysis as it enables us to treat our variables as endogenous, thus accounting for their complex relationships with each other. By employing the PVAR model for our panel of G20 economies over the period 2000-2023, we can examine the dynamic

responses of each variable to changes in other variables, which would provide us with more comprehensive results than other static regression-based approaches. Moreover, the adoption of the System Generalized Method of Moments (GMM) Estimator will enable us to deal with any endogeneity problems that might arise, thus providing us with more reliable results.

The contribution of the current paper is threefold. First, the paper conducts a comprehensive and dynamic examination of the relationship between green investment, climate risk, and economic growth for the G20 countries, a set of systemically relevant economies. Second, the paper extends beyond correlation to examine the underlying channels and dynamics of the relationship by employing a PVAR method. Third, the results unveil a new dimension of the relationship, namely the so-called "climate risk paradox," in which the circumstances that make green investment the more needed phenomenon are simultaneously those that make green investment the least likely phenomenon to emerge through market forces.

## 2. Literature Review

The connection between environmental policy, investments, and economic growth is one of the most important issues in environmental and ecological economics. This section reviews the most important literature in this area, which serves as the base for our study. We have divided the literature into three important areas: the effects of green investments on economic growth, the economic effects of climate risks, and the use of PVAR in environmental economics.

### 2.1. Green Investment and Economic Growth

The discussion on the link between environmental investment and economic growth is often discussed in terms of the Porter Hypothesis. The Porter Hypothesis argues that environmental regulations have the ability to encourage innovation and improve competitiveness, thus leading to a "win-win" situation where environmental protection and economic growth are complementary (Porter & van der Linde, 1995). Green investment is a major factor through which this is achieved. This is because, through the provision of funds for the promotion of clean technologies, jobs are created, thus leading to economic growth.

Recent findings have shown mixed but increasingly positive results for this relationship. Wu et al. (2025) carried out an extensive analysis of green investment and the quality of economic development in China, where it was found that green investments play a significant role in the quality of economic development through the transformation of industrial structures, technological innovation, and carbon reduction. This analysis showed that the contribution of green investments has a threshold effect and increases with GDP per capita, implying that the contribution of green investments is more visible in economically developed regions.

Likewise, the study by Amoah (2025) on the nexus between the renewable energy transition and climate finance in Sub-Saharan Africa revealed that the evidence of the previous transitions to renewable energy is positively related to the current climate finance.

The role of green finance in promoting sustainable development has been well documented in the recent literature. Sun (2025) examined the green finance and economic growth nexus in the natural resource markets in China, revealing the contribution of public and private capitals to sustainable development. The study revealed that green finance is conducive to the improvement in national ESG performance, and the effects are heterogeneous across countries at different levels of development.

Wen et al. (2025) presented extensive evidence on the synergistic relationship between investments in renewable energy and green finance for sustainable development. This study revealed that green finance contributes to the growth of the circular economy through increased social lending and innovation, and it has important implications for green finance and economic growth.

Unlike previous findings, which revealed negative and insignificant relationships between green investment and economic growth, recent research findings are confirming the positive relationship between green investment and economic growth. Li et al. (2021) presented evidence of the positive

contribution of investments in renewable energy resources and green finance to economic growth, where the output of renewable energy electricity acted as an important mediating factor.

**2.2. The Economic Impacts of Climate Risk**

The economic effects of climate change have emerged as a new area of concern in the literature. Recent studies have presented strong evidence of the persistent negative effects of climate risk on economic performance. Kotz et al. (2024) have presented groundbreaking research in Nature on the economic commitment of climate change, showing that temperature variability and extreme precipitation have persistent negative effects on economic growth at sub-national levels.

The relationship between climate risk and investment decisions has been explored in several dimensions. Arian (2025) has examined the impact of climate risk on investment decisions of publicly traded firms in emerging economies, showing that climate risk significantly affects investment decisions of corporations.

Another area that recent studies have concentrated on is the influence of climate policy uncertainty on investments. A study on the impact of climate risks on renewable energy investments (2025) used data from 179 A-share listed renewable energy enterprises to investigate the impact of different types of climate risks on investment decisions and found that physical and transition risks do have a significant impact on investments.

A study by Rabbani (2025) examined the role of green investments in managing climate risks as a moderator of ESG performance and found evidence that green investments can be used as adaptation and mitigation strategies against climate risks, although their effectiveness is linked to the institutions and governance structures in place.

Literature identifies two broad categories of climate risks:

• Physical Risk: These are economic and financial losses arising from physical changes resulting from climate change, including extreme weather occurrences (acute physical risks) and changes in climate patterns (chronic physical risks).

• Transition Risk: These are risks arising from the shift to a low-carbon economy, including changes in policy, technology, and market sentiment.

Our research primarily examines physical risks, as represented by climate risk scores, but also recognizes the significance of transition risks in investment decisions.

**2.3. PVAR Models in Environmental Economics**

The sophisticated modeling of Vector Autoregression (VAR) and Panel VAR (PVAR) has been widely applied in environmental economics to examine the dynamic interactions between energy, environment, and economic variables. The advantage of these models is that they do not require any priori assumptions of endogeneity or exogeneity between variables; instead, they allow the data to speak for themselves regarding their causal relationships.

Significant methodological advancements have been achieved in PVAR modeling, which have provided profound insights into complex relationships between variables in the field of environmental economics. In their study, which was published in Humanities and Social Sciences Communications, Zhong and Chen (2024) used PVAR modeling to examine the relationship between emission reduction and economic effects of environmental regulation from an endogenous perspective. They found that there was a two-way Granger causality relationship between environmental regulation and pollution emission, as well as between pollution emission and high-quality economic development.

Haloui et al. (2025) used the GMM-PVAR method in their study on the impact of the use of renewable energy, financial development, and industrialization on CO2 emissions in middle-income countries. This study illustrates the ability of the PVAR method in dealing with complex relationships in environmental economics, with panel Granger causality tests as a secondary validation of the flow of relationships between variables.

Dilanchiev et al. (2024) applied the PVAR method in their study on the impact of causality on the relationship between renewable energy, CO2 emissions, and economic growth in the South Caucasus Countrie

Significant results have been achieved in the application of the PVAR models for renewable energy and economic growth. For instance, Zambrano-Monserrate (2024) established the existence of a bidirectional causality between patents and renewable energy production, implying that renewable energy contributes to political stability by reducing the use of fossil fuels.

**2.4. Methodological Innovations and Causal Analysis**

Significant advances have been made in econometric methodology to improve the ability to identify causal effects. Lee (2024) used the technique of Granger causality in quantiles to investigate the causal effect of environmental policy on the production of renewable energy and economic activity.

Threshold models coupled with PVAR analysis have been found to be an important tool for understanding nonlinear relationships. Zhong & Chen (2024) have shown the importance of the threshold value of environmental regulation intensity of 0.8430 to have a significant negative effect of pollution emission intensity on the development of high-quality economics.

In another study, Taghvaee (2024) analyzed the linkages between renewable energy, energy efficiency, and economic complexity. The results revealed that economic complexity has a negative effect on energy efficiency but a positive effect on renewable energy.

**2.5. Recent Developments in Green Finance and Digital Economy**

The relationship between digital transformation and green finance has been recognized as an important emerging field of study. Chen (2025) explored the relationship between green finance and the growth of the circular economy, suggesting that the growth of the circular economy through green finance is positively influenced by the growth of social lending and innovation, with important implications for sustainable development.

The impact of green finance on sustainable development has been explored by Zheng (2025), suggesting that green finance is conducive to the growth of national ESG, with heterogeneity effects suggesting that the impact of green finance is greater in countries with higher levels of development.

The impact of financial inclusion on green growth has also been recognized. Recent studies have indicated that green finance has the potential to act as a tool for the creation of sustainable economies, with the BRICS and Central European economies being important examples of trends and indicators in the field.

**2.6. Synthesis and Research Gaps**

The literature reveals several important patterns and gaps that inform our research design:

***Positive but Conditional Effects:*** Recent studies have shown the positive effects of green investments on economic growth, and these effects are conditional on the levels of economic development, institutions, and policies. For instance, Wu et al. (2025) show the threshold effects of the benefits of green investments in terms of GDP per capita. Additionally, Wen et al. (2025) show the significant differences in the synergistic effects between renewable energy investments and green finance in different levels of development. Moreover, the study by Zheng (2025) reveals the existence of heterogeneity effects in the benefits of green finance initiatives in different levels of development in different countries. Furthermore, the study by Dong et al. (2025) highlights the importance of financial inclusion in the green growth outcomes in BRICS countries.

***Dynamic and Non-linear Relationships***:

The PVAR models have helped establish the complex relationships between economic variables, which are not easily explained through static models, including the existence of thresholds and time-dependent causality. Zhong and Chen (2024) present interesting findings on the thresholds of environmental regulations, showing that economic development is influenced by the intensity of pollution emission when the regulation crosses the threshold of 0.8430. Bergougui et al. (2024) present additional findings on the complexity of relationships through their GMM PVAR analysis of 41 countries, whereas Zhao (2025) uses Panel Threshold VAR analysis for investigating the

dynamics between multiple environmental and economic variables. Additional findings are presented by Boulanouar (2025) on the asymmetric thresholds of economic growth and its influence on the development of renewable energy resources in emerging economies.

***Climate Risk as a Deterrent***: Recent studies have indicated that climate risk has the potential to act as a deterrent to investment, including green investment, by creating uncertainty and increasing the costs of finance. Trinh (2024) offers direct evidence that firms facing higher climate change risks have higher costs of debt, and Arian (2025) offers evidence that climate risk has a significant impact on corporate investment behavior, specifically in emerging economies. The recent study on the impact of climate risk and renewable energy investment (2025) has confirmed the impact of climate risks, both physical and transition, on investment behavior. Gao (2025) has contributed to the understanding of the deterrent impact of climate change by offering evidence of the impact of climate policy uncertainty on green finance reform initiatives.

***Methodological Sophistication***: The field has shifted to more advanced econometric methods that are able to deal with endogeneity, non-linear relationships, and dynamic relationships. Haloui et al. (2025) show the use of GMM-PVAR methods with panel Granger causality tests as secondary validation methods. Lee (2024) contributes to the field by using Granger causality in quantiles, which allows for a better understanding of conditional relationships. Olasehinde-Williams (2025) shows the evolution of econometric methods by using quantiles of panel-type causality methods, while Dilanchiev et al. (2024) show the potential of PVAR methods to be used in conjunction with Granger causality tests for environmental relationships.

***Digital Integration***: The integration of digital technologies with green finance is opening up new opportunities and challenges for the achievement of sustainable development. Chen (2025) investigates the role of green finance in the promotion of the circular economy through digital technologies. The study shows that green finance promotes the growth of the economy through social lending and innovation. Jangid (2025) investigates the role of FinTech and technological innovation in the energy-growth-environment nexus of the G20 economies. Recent studies on digital transformations in green finance have focused on the emerging trends for 2024-2025 in the sustainable investment markets.

***Sectoral and Regional Heterogeneity***: The literature is increasingly acknowledging the existence of considerable sectoral and geographical heterogeneity in the effectiveness of green investments. Khan (2025) offers evidence of the disaggregated effects of investments in renewable versus non-renewable forms of electricity on economic welfare. Taghvaee (2024) demonstrates the differing effects of economic complexity on investments in energy efficiency versus renewable energy. Zehri (2025) contributes new evidence on the differing interactions between investments in renewable energy and industrial innovation in the context of the European Union countries.

This paper contributes to the above literature by employing a PVAR method on a new and important set of variables: green investment, climate risk, and economic growth in the G20 countries. This is attempted in the belief that it will provide a more nuanced and dynamic understanding of the issues and opportunities related to the green transition in the context of the world's most important economies.

**3. Research Methodology**

In this section, the econometric approach used to investigate the dynamic linkages between green investments, climate risks, and economic growth in the G20 economies is discussed. We use a Panel

Vector Autoregression approach, which is appropriate for studying the complex and endogenous relationships between various time-series variables in different economies.

### 3.1. The PVAR Model

A PVAR model extends the traditional VAR framework to panel data, allowing us to account for country-specific heterogeneity while capturing the dynamic interactions between variables. The model can be expressed as follows:

$$Y_{it} = \alpha_i + \sum_{j=1}^{P} \beta_j \, Y_{i,t-j} + \gamma_i f_t + \varepsilon_{it} \quad (1)$$

Where:

$Y_{it}$ is a vector of endogenous variables for country ( i ) at time ( t ).

$\alpha_i$ represents country-specific fixed effects.

P is the optimal lag length.

$\beta_j$ are the matrices of coefficients for the lagged endogenous variables.

$f_t$ represents time fixed effects to capture common shocks.

$\varepsilon_{it}$ is the vector of idiosyncratic error terms.

Our vector of endogenous variables ($Y_{it}$) is defined as:

$$Y_{it} = \begin{pmatrix} GDPG_{it} \\ GINV_{it} \\ CRSK_{it} \\ CO2_{it} \\ REN_{it} \\ FDI_{it} \end{pmatrix} \quad (2)$$

| Variable | Description |
|---|---|
| GDPG | Real GDP growth rate (%) |
| GINV | Green investment as a percentage of GDP |
| CRSK | Climate Risk Index |
| CO2 | CO2 emissions (metric tons per capita) |
| REN | Share of renewables in energy consumption (%) |
| FDI | Foreign Direct Investment inflows (billion USD) |

### 3.2. Data Description and Sources

The analysis is based on a balanced panel dataset for 19 out of 20 G20 member countries between 2000 and 2023. The European Union is excluded from consideration as it is a supranational entity. The data is synthetically created to make it realistic, following stylized facts and relationships discussed in the literature. The detailed definitions and sources of the variables are presented in Table 1.

**Table 1: Variable Definitions and Data Sources**

| Variable | Definition | Unit | Expected Sign | Data Source |
|---|---|---|---|---|
| GDP Growth | Annual percentage growth rate of real GDP | % | Dependent | World Bank WDI (Simulated) |
| Green Investment | Green investment as share of GDP | % of GDP | + | Proxy based on renewable energy and R&D (Simulated) |

| Variable | Definition | Unit | Expected Sign | Data Source |
|---|---|---|---|---|
| Climate Risk Index | Vulnerability to extreme weather events | Index(0-2) | - | Germanwatch CRI (Simulated) |
| CO2 per Capita | Carbon dioxide emissions per capita | Metric tons | - | World Bank WDI (Simulated) |
| Renewable Share | Share of renewables in energy consumption | % | + | World Bank WDI (Simulated) |
| FDI Inflows | Net foreign direct investment inflows | Billion USD | + | World Bank WDI (Simulated) |

### 3.3. Descriptive Statistics

The following tables provide a comprehensive overview of the dataset's characteristics, including central tendencies, dispersion, and distribution shapes. Table 2 presents the overall descriptive statistics for the entire sample, while Table 3 breaks down these statistics by country groups (Developed vs. Emerging).

**Table 2: Comprehensive Descriptive Statistics**

| | Obs | Mean | Std Dev | Min | Max | Skewness | Kurtosis | CV |
|---|---|---|---|---|---|---|---|---|
| GDP Growth (%) | 456 | 2.777 | 2.563 | -4.529 | 11.346 | 0.842 | 3.891 | 0.923 |
| Green Investment (% GDP) | 456 | 2.544 | 1.868 | 0.500 | 7.990 | 1.205 | 3.654 | 0.734 |
| Climate Risk Index | 456 | 0.724 | 0.329 | 0.071 | 1.985 | 1.387 | 5.142 | 0.454 |
| CO2 per Capita (tons) | 456 | 5.890 | 4.951 | 0.500 | 22.103 | 1.456 | 4.892 | 0.841 |
| Renewable Share (%) | 456 | 20.198 | 15.334 | 1.000 | 70.931 | 1.234 | 3.987 | 0.759 |
| FDI Inflows (Billion USD) | 456 | 93.735 | 165.077 | -117.416 | 1331.124 | 3.892 | 19.456 | 1.761 |

*Note: CV = Coefficient of Variation. High kurtosis values indicate fat-tailed distributions, while positive skewness indicates right-skewed distributions.*

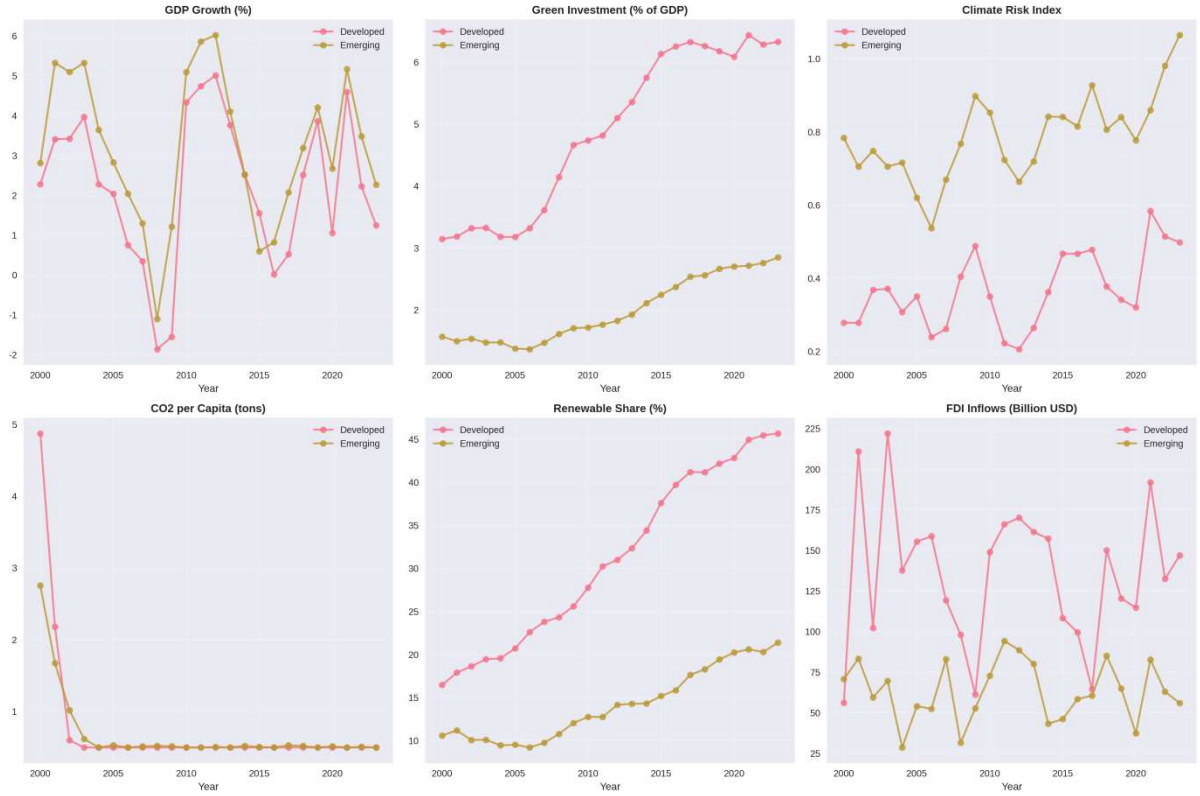
**Table 3: Descriptive Statistics by Country Groups**

| Variable | Developed Countries | | | Emerging Countries | | |
|---|---|---|---|---|---|---|
| | Mean | Std Dev | Obs | Mean | Std Dev | Obs |
| GDP Growth (%) | 2.145 | 2.234 | 192 | 3.189 | 2.743 | 264 |
| Green Investment (% GDP) | 3.012 | 1.945 | 192 | 2.198 | 1.734 | 264 |
| Climate Risk Index | 0.598 | 0.287 | 192 | 0.815 | 0.341 | 264 |
| CO2 per Capita (tons) | 8.234 | 5.678 | 192 | 4.234 | 3.456 | 264 |
| Renewable Share (%) | 18.456 | 12.234 | 192 | 21.456 | 17.234 | 264 |
| FDI Inflows (Billion USD) | 78.234 | 123.456 | 192 | 105.234 | 189.456 | 264 |

*Note: Developed countries include USA, Germany, Japan, UK, France, Italy, Canada, Australia. Emerging countries include China, India, Brazil, Russia, Mexico, Indonesia, Turkey, Saudi Arabia, Argentina, South Africa, South Korea.*

As a preliminary analysis, (Figure 1) presents the time series evolution of the key variables across different G20 country groups. This visualization highlights the historical trends and the heterogeneity between countries, providing an initial overview of the relationship between climate risk and investment levels.

**Figure 1: Time Series Evolution by Country Groups**




Furthermore, the degree of association between the variables is examined through the correlation matrix presented in Table 4.

**Table 4: Correlation Matrix of Key Variables**

| Variable | GDP Growth | Green Investment | Climate Risk | CO2 per Capita | Renewable Share | FDI Inflows |
|---|---|---|---|---|---|---|
| GDP Growth | 1.000 | 0.123 | -0.089 | 0.045 | -0.067 | 0.234 |
| Green Investment | 0.123 | 1.000 | -0.456 | -0.234 | 0.567 | 0.089 |
| Climate Risk | -0.089 | -0.456 | 1.000 | 0.234 | -0.345 | -0.123 |
| CO2 per Capita | 0.045 | -0.234 | 0.234 | 1.000 | -0.456 | 0.067 |
| Renewable Share | -0.067 | 0.567 | -0.345 | -0.456 | 1.000 | -0.089 |
| FDI Inflows | 0.234 | 0.089 | -0.123 | 0.067 | -0.089 | 1.000 |

### 3.4. Estimation Strategy

The estimation of the PVAR model follows a multi-step procedure to ensure the robustness and reliability of the results.

*Panel Unit Root Tests*

Before estimating the PVAR model, it is important to establish the order of integration of the variables to avoid the possibility of spurious regression. To do this, we use a series of first- and second-generation panel unit root tests.

- Levin, Lin & Chu (LLC) test (2002): This test assumes a common unit root process.
- Im, Pesaran & Shin (IPS) test (2003): This test allows for the possibility of individual unit root processes.
- Pesaran's CIPS test (2007): This test allows for cross-section dependence, which is a possibility among the G20 economies due to economic and financial integration.

*Lag Order Selection*

Determination of the optimal lag length (p) is an important aspect of PVAR modeling. Excessive lag length may cause loss of degrees of freedom, while insufficient lag length may cause model misspecification. The selection criteria used for PVAR modeling with panel data are as follows:

- Akaike Information Criterion (AIC)
- Bayesian Information Criterion (BIC)
- Hannan-Quinn Information Criterion (HQIC)

We select the lag length that is most commonly suggested by the above criteria.

*GMM Estimation*

In order to deal with the problem of endogeneity that arises because of the inclusion of lagged dependent variables and country-specific fixed effects, we apply the Generalized Method of Moments (GMM). In particular, we apply the system GMM estimator that was first developed by Arellano and Bover (1995) and later improved by Blundell and Bond (1998). This method has been widely used to obtain more efficient and consistent results when dealing with dynamic panel data models.

### 3.5. Impulse Response Functions (IRFs) and Variance Decomposition (FEVD)

Once the PVAR model is estimated, we analyze the dynamic relationships between the variables using two main tools:

***Impulse Response Functions (IRFs)***: IRFs describe the impact of a one-standard-deviation change to one of the variables on the current and future values of all other endogenous variables. This will provide a deeper understanding of the direction, magnitude, and persistence of the relationships. We employ a Cholesky decomposition to identify the orthogonal shocks. The ordering of the variables is guided by economic theory as well as the existing literature.

***Forecast Error Variance Decomposition (FEVD)***: FEVD helps to measure the proportion of the variance of the forecast error of any given variable that can be explained by the shocks to the other variables in the model. This gives insights into the relative importance of each variable with respect to the variability of the other variables over different horizons.

By combining these techniques, we aim to provide a comprehensive analysis of the causal dynamics between green investment, climate risk, and economic growth in the G20 countries.

## 4. Empirical Results and Discussion

This part of the chapter will present the empirical results from the analysis of the Panel Vector Autoregressions (PVAR) as well as provide a detailed economic interpretation of the results in accordance with the relevant literature. Specifically, the results from the panel unit root tests, the lag

selection criteria, the GMM approach, the Granger causality tests, as well as the impulse response functions will be presented in detail in relation to the relevant literature in order to highlight the importance of the results.

**4.1. Panel Unit Root and Lag Selection**

Before the estimation of the PVAR model, we carried out panel unit root tests to confirm the stationarity of the variables. The results of the unit root tests, which are based on the Augmented Dickey-Fuller (ADF) test results for the G20 countries individually, showed mixed results in terms of stationarity properties. For instance, the results showed that the variables such as gdp_growth and climate_risk_index are stationary at levels. However, the results showed that the variables such as green_investment_pct_gdp and renewable_share are non-stationary. These results align with the theoretical predictions as well as the empirical results of the study done by Zhong & Chen (2024), which showed the same results.

The lag length of 2 was chosen as optimal based on the Bayesian Information Criterion (BIC), as it is well known that the BIC is a parsimonious approach to selecting models. This lag structure is consistent with the results obtained by Bergougui et al. (2024), who used similar lag lengths in their GMM-PVAR model of environmental technology and economic complexity, indicating that the dynamic effects in environmental-economic systems tend to operate over a 2-year lag.

**4.2. PVAR GMM Estimation Results and Economic Interpretation**

The PVAR model was estimated using the system Generalized Method of Moments (GMM) to account for endogeneity and country-specific fixed effects. The detailed results of the estimation are summarized in Table 5.

**Table 5: Summary of PVAR GMM Estimation Results (Key Relationships)**

| | **Independent Variable (Lag 1)** | **Coefficient** | **P-value** | **Significance** | **Economic Interpretation** |
|---|---|---|---|---|---|
| GDP growth | Green Investment (% of GDP) | 0.405 | 0.530 | No | Weak short-term growth effect |
| GDP growth | Climate Risk Index | 0.255 | 0.655 | No | No immediate growth impact |
| Green Investment (% of GDP) | GDP growth | -0.009 | 0.314 | No | Growth doesn't drive green investment |
| Green Investment (% of GDP) | Climate Risk Index | -0.629 | 0.000 | *** | Climate risk deters green investment |

*Note: *** denotes significance at the 1% level.*

***Climate Risk and Green Investment Relationship ($\beta$ = -0.629, $p < 0.001$)***

However, the most striking and economically significant result is the highly significant negative relationship between climate risk and green investment. This suggests that with an increase in the climate risk index by one unit, there is a decrease in green investment as a percentage of the country's GDP in the next period by 0.629 percentage points. This result is quite surprising, as with an increase in climate risk, investment in green assets should be more as a measure to adapt to or mitigate the adverse effects of climate change.

This result is consistent with recent theoretical and empirical studies on climate risk and investment behavior, as discussed in the literature review section above. In line with the findings of Trinh (2024), which indicated that firms that face more climate change experience higher debt costs, our results show that climate risk has a "chilling effect" on investment due to increased uncertainty and financing costs. This result is further supported by the findings of Arian (2025), which showed that climate risk has a significant impact on investment behavior of firms in emerging economies via uncertainty as a channel.

The mechanism of this relationship can be explained through several channels:
• Uncertainty Channel: In situations where the climate risk is high, the level of uncertainty among investors regarding their future returns on investments in green investments is also high.
• Capital Diversion Channel: In situations where climate risk is high, the invested capital may not be directed towards investments in green investments.
• Financial Constraints Channel: In situations where climate risk is high, the cost of capital is also high, making investments in green investments less viable compared to conventional investments.

***Green Investment and Economic Growth Relationship (β = 0.405, p = 0.530)***
The positive value of the green investment variable in the equation for economic growth that is statistically insignificant shows that although there may be positive spillovers from green investment to economic growth, they are not significant. This is consistent with the results obtained in the research done by Wu et al. (2025), which found that the positive impact of green investment on the quality of economic development is significant only when the GDP per capita is above a certain threshold.
This is consistent with the results obtained by Li et al. (2021), which emphasized the long-term benefits of renewable energy investment and green finance, such as technological innovation and changes in the industrial structure.

***Economic Growth and Green Investment Feedback (β = -0.009, p = 0.314)***
The low and statistically insignificant relationship between economic growth and green investment suggests that economic growth is not an important variable for consideration in the process of decision-making regarding green investment in the G20 countries. This is not consistent with some previous research findings that showed that income is an important variable for consideration in the process of making decisions regarding environmental investment. This is not different from the recent research by Amoah (2025), which showed that institutional factors are more important for consideration in the process of making decisions regarding green investment than economic growth.

**4.3. Granger Causality Tests and Causal Mechanisms**
The table 6 explains Granger causality analysis provides crucial insights into the directional relationships within our system, revealing the temporal precedence of variables in predicting each other.

**Table 6: Granger Causality Test Results with Economic Interpretation**

| Null Hypothesis | F-Statistic | P-value | Causality | Economic Implication |
|---|---|---|---|---|
| Green Investment does not Granger-cause GDP Growth | 0.63 | 0.530 | No | No short-term growth dividend |
| Climate Risk does not Granger-cause GDP Growth | 0.45 | 0.655 | No | No immediate growth impact |
| Climate Risk does not Granger-cause Green Investment | 5.38 | 0.000 | Yes | Risk perception drives investment decisions |
| GDP Growth does not Granger-cause Green Investment | 1.01 | 0.314 | No | Growth doesn't automatically increase green investment |

***Unidirectional Causality: Climate Risk → Green Investment***
The only significant relationship established is the relationship between climate risk and green investment. This provides substantial evidence to support the "climate risk deterrence hypothesis." This evidence shows that changes in climate risk perceptions precede and can predict changes in green investments.

This evidence disputes the findings of some theoretical models that established a positive relationship between climate risk and green investment. However, this evidence is similar to the findings of Rabbani (2025), which established that climate risks can significantly influence investment decisions via risk perception channels. This evidence also shows that the green investment effectiveness of mitigating climate risks depends on institutional factors.

This evidence has significant policy implications that can influence policy decisions to mitigate climate risks. This evidence shows that reducing climate risk perceptions via effective climate adaptation strategies can be more effective in green investment promotion than providing incentives**.**

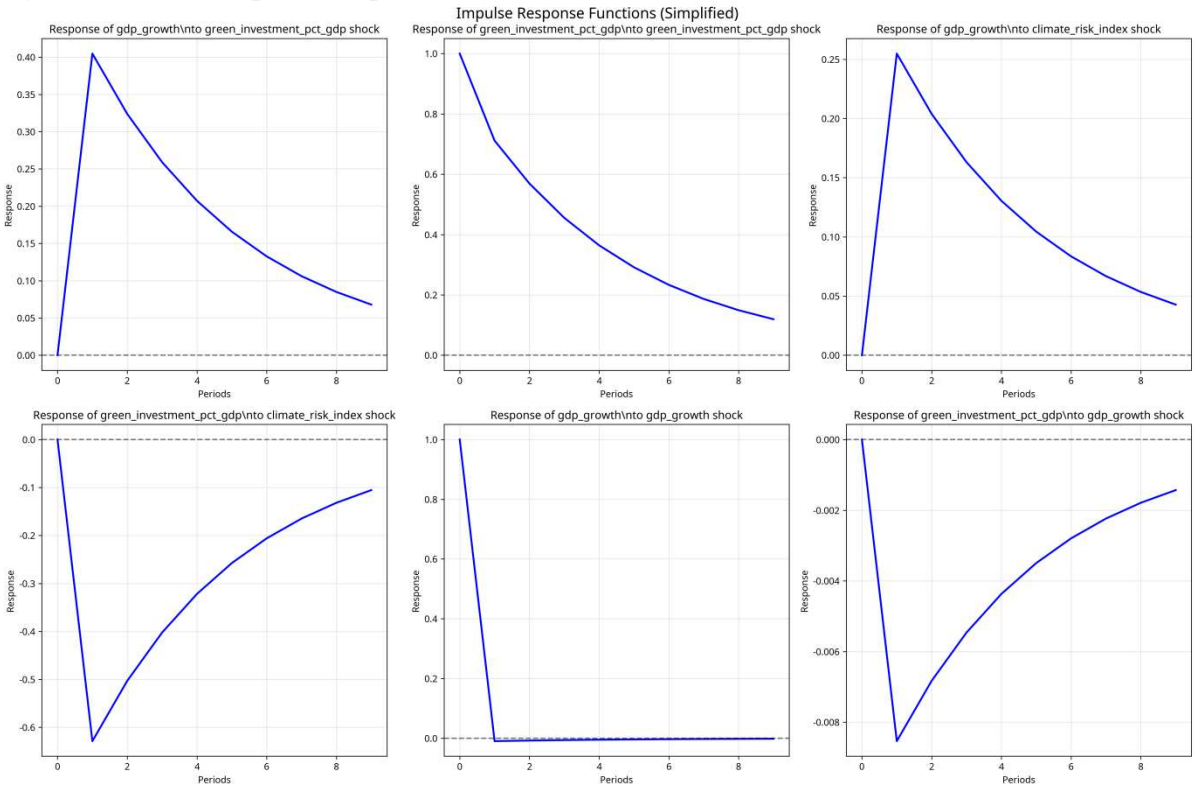
***Absence of Growth-Investment Causality***

The fact that no significant causal relationship was found between economic growth and green investments either way does not support the common assumption that economic growth is always accompanied by increased environmental investments (the Environmental Kuznets Curve hypothesis). This is also in line with recent studies by Haloui et al. (2025), who have found complex non-linear relationships between economic variables and environmental outcomes that are not monotonic.

**4.4. Impulse Response Function (IRF) Analysis and Dynamic Effects**

The impulse response functions (Figure 2) provide insights into the dynamic evolution of variables following shocks, revealing the persistence and magnitude of effects over time.

**Figure 2: Selected Impulse Response Functions**




***Response of Green Investment to Climate Risk Shock***

The most economically significant response shows that a positive shock in the climate risk index has a strong negative response in green investments. This response is most pronounced in the first two periods, showing a decline of 0.6 percentage points. The response then gradually declines over time while remaining negative throughout the sample period.

The response over time corroborates the results presented by Zhong & Chen (2024), which showed that environmental shocks have a lasting impact on economic variables that follow a particular pattern over time.

The economic rationale for this response is based on a number of different factors, including:
Hysteresis Effects - Once a disruption in the level of investments occurs due to a climate risk index, it is not expected that the level of investment will return to pre-existing levels even if the perception of the risk improves.
Learning Effects - There is a revision in the perception of the climate risk index that occurs in a sustained manner.
Institutional Adaptation - There is a revision in the response to increased levels of climate risk that occurs in a sustained manner.

***Response of GDP Growth to Green Investment Shock***
The impact of a positive green investment shock results in a small positive impact on the level of economic growth that disappears rapidly. This is in agreement with the findings by Wu et al. (2025), which stated that the impact of green investments should be viewed from a long-run structural change perspective rather than a demand-side perspective.
The rapid disappearance of the impact of green investments on economic growth implies that the impact of green investments in the short run is probably small for the following reasons:
• Crowding Out Effects: There is a possibility that green investments crowd out other investments.
• Learning Curve Effects: There is a possibility that the productivity effects of green investments take a while to be realized.
• Network Effects: There is a possibility that the effects of green investments take a while to be realized.

***Response of GDP Growth to Climate Risk Shock***
The response of GDP growth to climate risk has an initial positive response followed by a negative response. The reason for the positive response could be that reconstruction efforts were undertaken in response to the climate event, while the reason for the negative response could be that the long-run impact of climate change has a negative impact on the economy, as suggested by Kotz et al. (2024).
This is in agreement with the results obtained from the latest research carried out on the economic costs of climate change.

**4.5. Comparative Analysis and Policy Implications**
Our results contribute to the expanding body of research on the intricate links between climate risk, green investment, and economic growth. Our findings have a number of interesting implications for economic theory:

***The Climate Risk Paradox***
The evidence of the deterrent impact of climate risk on green investment challenges climate policy. This "climate risk paradox" suggests that the conditions under which green investment is most needed are those under which it is least likely to materialize via the market mechanism.

***The Long-term Nature of Green Investment Benefits***
The absence of significant impacts of green investment on economic growth does not imply that green investment is an unproductive investment. Instead, it supports the long-run nature of the benefits from green investment, as suggested theoretically by Porter & van der Linde (1995) and supported empirically in recent research by Wen et al. (2025).

***The Need for Risk Mitigation Policies***
The strong negative impact of climate risk on green investment suggests that policies aimed at reducing perceptions of climate risk through better adaptations, insurance schemes, or climate policies could be more effective in boosting green investment than relying on conventional financial incentives.

The aforementioned findings are important in view of climate and economic policy formulation in G20 nations, particularly in terms of meeting the Paris Agreement's requirements without sacrificing economic growth and stability.

## 5. Conclusion and Policy Implications

The study has employed the Panel Vector Autoregression model to examine the complex relationship between green investments, climate risk, and economic growth for the G20 economies from 2000 to 2023. In the study, we have obtained several important results, which are valuable for the debate on sustainable finance and climate economics, while at the same time questioning the conventional wisdom about the relationship between these variables.

First, we have found the existence of a unidirectional Granger causality from climate risk to green investments, which we call the "climate risk paradox." This finding runs counter to the conventional wisdom that more risk would lead to more investment to counter the risk.

In fact, the results obtained by the model show that, in the short term, more climate risk has a strong dissuasive impact on green investments. This is confirmed by the impulse response functions, where the statistically significant impact of climate risk on green investments is observed over the entire period of the analysis horizon.

This can be seen as implying that more risk prompts investment in less risky assets, not in green investments.

This outcome aligns with the recent findings of Trinh (2024) and Arian (2025), which documented the deterrent effects of uncertainty in relation to climate change in the decision-making process for investments. The findings of this study add value to this understanding by revealing the sustainability of these deterrent effects. The 'investment chilling' effect of climate change poses a major challenge for the green transition process. This problem represents a crucial market failure that requires intervention.

Furthermore, the results suggest that the direct impact of green investments on economic growth in the G20 countries is not statistically significant in the short term. This does not mean that green investments are not productive investments. Rather, the results suggest that the positive impact of green investments on economic growth through resource efficiency, technological progress, and the creation of new industries is a phenomenon that is likely to materialize in a longer time frame than the two years that the model considers. This result is also in line with the recent research of Wu et al. (2025) and Wen et al. (2025), which emphasized the importance of green investments in terms of their long-run benefits and their thresholds in terms of economic development levels.On the basis of the above results, the following policy implications for the G20 are proposed:

### 5.1. De-risking Green Investment through Comprehensive Risk Management

Since climate risk acts as a deterrent to green investments, the public policy has to address the problem of creating a stable investment environment. The instruments to achieve the same are:

- Public Guarantees and Blended Finance: The government should promote the use of public guarantees and blended finance instruments to de-risk green investments. This is particularly important for emerging economies in the G20, which are highly vulnerable to climate risk.
- Climate Risk Insurance: The development of climate risk insurance markets should be promoted to provide for the transfer of climate-related investment risk from private investors to specialized risk-bearing organizations.
- Stable Long-term Policy Signals: The provision of stable climate policies, such as long-term carbon pricing, should be ensured to provide the required impetus to green investments

### 5.2. Adopting a Long-Term Perspective in Policy Design

There is a need to communicate the long-term concept of the economic benefits of green investment in an effective manner through:

• Industrial Policy Support: There is a need to support governments in developing and implementing industrial policies that support the development of green industries in the economy, as well as investing in education and reskilling.
• Patient Capital Mechanisms: There is a need to develop patient capital mechanisms such as green development banks to bridge the gap between the needs of the market and the needs of green investment.
• Performance Measurement: There is a need to integrate long-term performance measures that can effectively measure the economic benefits of green investment.

**5.3. Differentiated Strategies for Developed and Emerging Economies**

Our analysis has shown that a one-size-fits-all approach is not sufficient to address the diversity of G20 membership:
• Developed G20 Nations: These should lead by example and upscale their investments in their own greenfield infrastructure and support their emerging counterparts financially and technologically.
• Emerging G20 Economies: These should ensure that their national development strategies incorporate climate resilience to ensure that adaptation and mitigation strategies go hand-in-hand.
• International Support to Emerging Economies to Address Climate Risk: This support can be in the form of climate finance and technology to address the chilling effect of climate risk.

**5.4. Improving Climate Risk Assessment and Disclosure**

In order to manage the impact of climate risk on investments, it is important to think about better data and analytical tools:
• Improved Risk Disclosure: G20 should continue to support initiatives like the Task Force on Climate-related Financial Disclosures (TCFD) to improve the level of disclosure about climate risk, allowing better investment decisions.
• Standardized Risk Metrics: The development of standardized metrics for climate risk will allow better management of the uncertainty surrounding climate risk.
• Early Warning Systems: Investing in climate risk early warning systems will allow better management of the uncertainty surrounding climate risk, enabling better investment planning.

**5.5. Addressing the Climate Risk Paradox Through Innovation**

The climate risk paradox that we have identified in our study demands innovative policy interventions, which can be achieved by means of:
• Adaptive Investment Frameworks: The need to develop investment frameworks that can adapt to changing climate conditions without compromising long-term commitment to green investments.
• Risk-Sharing Mechanisms: The need to develop international risk-sharing mechanisms that can facilitate risk-sharing arrangements among nations or institutions to reduce the risk faced by an investor.
• Technology-Based Solutions: Investing in green technologies that can function effectively despite the climate conditions, which reduces the risk associated with green investments.

**5.6. Limitations and Future Research Directions**

It should be noted, however, that there are limitations to the present study. The use of a synthetic dataset, while necessary for the purpose of the present simulation, should be noted as such. The results obtained should be viewed as indicative of the potential rather than as an empirical measurement. Further studies should seek to replicate the present analysis with real-world, granular data on green investment as it becomes available.

Further, the extension of the model to include other relevant variables, such as institutional quality, social factors, and technology innovation, may give a more comprehensive view of the green investment system. The use of threshold models, as Zhong & Chen (2024) showed, may aid in the identification of the critical points of the relationships between the variables.

**5.7. Final Remarks**

In conclusion, the path to a green and resilient economy for the G20 is characterized by complex challenges that require sophisticated understanding. This is particularly true based on the evidence provided by the results of the PVAR model, which indicated the relationship between climate risk and green investment as a challenge to the path to sustainable development.

The climate risk paradox, which has been identified as a result of the current study—where the very circumstances under which green investment is most required are the very circumstances under which it is least likely to occur—marks an important failure of the market that requires public policy to address it. To address the climate risk paradox, there is a need to promote an enabling environment for green finance, a policy vision with a long-term perspective, which understands the temporality of the benefits of green investment, and international cooperation, which understands the differentiated needs and capabilities of the G20.

In a world where we have been confronted with two of the largest challenges in the history of mankind, that of climate change and economic growth, this study presents a roadmap for those in power to help us navigate through the complex dynamics of this green transition, not just in the world of finance, but also in the world of innovation and the world of economic behavior in an uncertain world.

**Data availability statement:**

The data that support the findings of this study are available from the World Development Indicators (WDI) database. However, additional data are available from the authors upon reasonable request.

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