Energy Economics 128 (2023) 107172

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco

The influence of income, economic policy uncertainty, geopolitical risk, and urbanization on renewable energy investments in G7 countries

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ARTICLE INFO

JEL codes:
C33
D80
Q42

Keywords:
Renewable energy investments
Economic policy uncertainty
Geopolitical risk
G7 countries
AMG

ABSTRACT

Renewable energy infrastructure development is seen as critical to solving environmental issues. Nevertheless, researchers have not adequately paid attention to how the socioeconomic and geopolitical environment affects renewable energy investments (REINV), which are important for promoting clean energy. In line with this gap, this research aims to analyze the role of economic policy uncertainty (EPU) and geopolitical risk (GPR), as well as controlling economic growth (GDP) and urbanization (URB) in G7 countries by considering their leading role in both economic and political areas. To this end, the study applies the augmented mean group (AMG) approach by constructing three different models for the period 2004–2018. The panel data results reveal that (i) GDP has a significantly increasing effect on REINV; (ii) EPU, GPR, and URB have a decreasing effect on REINV; (iii) the effect of EPU is much stronger than that of GPR; (iv) institutional structure, represented by government efficiency and regulatory quality, has no effect on REINV. Based on the results, the study points out that G7 countries need to promote transmission mechanisms that encourage REINV and take steps to minimize the negative effect of EPU and GPR on clean energy investments.

1. Introduction

The increasing determination to decarbonize all human-related activities and avert the threats associated with climate change is leading to the adoption of energy conversion technologies and measures, which remain one of the most effective ways to achieve carbon neutrality (Kartal et al., 2023; Pata et al., 2023a; Sharif et al., 2023). With the volume of energy production from solar power projected to exceed that from fossil fuels in 2023, total investment in clean energy is expected to exceed USD 1.7 trillion in the same year, far more than expected investment in fossil fuels (IEA, 2023). Given the expected 24% increase in all clean energy investments, which include renewables, low-emission fuels, electric vehicles, nuclear energy, efficiency improvements, and heat pumps, compared to an expected 15% increase in fossil fuel investments, clean energy investments would exceed fossil fuel investments by ~USD 0.6 trillion by 2023 (IEA, 2023). Clean energy investment has shown an upward trend over the past decade, except during the COVID-19 pandemic period, when utility investment, including renewable and clean energy investment, declined sharply (IEA, 2023; Statista, 2023).

On a more granular approach, risk-related aspects, such as EPU, and GPR, can be considered alongside economic (e.g., economic growth) and socioeconomic aspects (e.g., urbanization and demographics). For example, as shown in the COVID-19 pandemic scenario, policy uncertainties due to frequent interest rate adjustments or high cost of capital (monetary policy) and spending cuts (fiscal policy), as well as financially strained utilities, are potential factors inhibiting investment in clean technologies (IEA, 2023). In particular, rising market risks, policy, and regulatory uncertainties, especially in relevant markets,

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https://doi.org/10.1016/j.eneco.2023.107172
Received 30 June 2023; Received in revised form 24 October 2023; Accepted 30 October 2023
Available online 8 November 2023

Acronyms

Abbreviations

AMG	Augmented Mean Group
BRIC	Brazil, Russia, India, China
COVID-19	Coronavirus 2019
CSD	Cross-Sectional Dependence
ETFs	Exchange Traded Funds
EU	European Union
FD	Financial Development
IMF	International Monetary Fund
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
OECD	Organization for Economic Cooperation and Development
REC	Renewable Energy Consumption
SDGs	Sustainable Development Goals
UK	United Kingdom
USA	United States of America
USD	United States Dollar
WB	World Bank
WGI	Worldwide Governance Indicators

Dependent variable

REINV	Renewable Energy Investments

Explanatory variables

EPU	Economic Policy Uncertainty Index
GPR	Geopolitical Risk Index

Control variables

GDP	Gross Domestic Product
URB	Urbanization
GOVEF	Government Efficiency
REGQ	Regulatory Quality

Analysis scope

G7	Group of Seven Countries

would need to be mitigated to prevent a decline in future investment in clean energy technologies. A similar effect is expected from the risk associated with geopolitical situations arising from instability and conflict in certain regions. A vivid example is the ongoing Russia-Ukraine conflict with differing opinions suggesting that the situation can either slow down or incentivize the EU's energy transition plan, given the EU's reliance on Russian natural gas and oil. In addition to political uncertainty and geopolitical risk, economic and population indicators also play a role, which are intuitively associated with renewable energy investments. This is because developed economies account for a significant share of global clean energy investment due to their economic and relative population size (e.g., the USA, EU, and the G7).

The G7 countries account for 15% of the world's land area, 40% of global GDP, 10% of population, and about a quarter of carbon emissions (Sun et al., 2022). Fig. 1 shows the GDP per capita of the G7 countries in 2018.

In Fig. 1, the USA has the highest GDP per capita at USD 60,000 followed by the UK at USD 47,000 and Canada at USD 45,000. Italy and Japan are the countries with the lowest GDP among the G7 countries. The G7 countries are among the largest consumers of energy and emitters of carbon to sustain their socioeconomic development (Chu, 2023). Reducing the carbon intensity of G7 countries is an important agenda for achieving the SDGs. To achieve net zero greenhouse gas emissions by 2050, G7 countries are leading the energy transition by significantly increasing the share of renewable energy in their energy supply structure (Khan and Su, 2022; Usman, 2023). Especially after the global energy crisis triggered by the Russia-Ukraine conflict, G7 countries have placed more importance on the transition to renewable energy, France and Germany have accelerated their solar projects, and the USA has discussed expanding long-term tax incentives for renewable energy (Chu, 2023). However, G7 countries have not yet made significant progress on SDG-7 and SDG-13 (Xu et al., 2022).

To achieve SDG-7 and 13, as well as the goals of the 2015 Paris Agreement, G7 countries should make more efforts to increase their share and investments in renewable energy (Borozan, 2022). However, G7 countries are still highly dependent on fossil resources, which are either domestically produced or imported from other countries (Murshed et al., 2022). The recent energy crisis, triggered by tensions between Russia and Ukraine, has shown that dependence on fossil fuel imports will have serious political and economic consequences for countries. In this context, G7 countries need to increase their investments in renewable energy and reduce their dependence on foreign countries, as well as determine the right policies to promote energy investments by analyzing the determinants of REINV.

Fig. 2 shows the per capita amount of REINV in the G7 countries. Japan has the highest per capita investment in renewable energy at USD 153, followed by the USA and the UK. Italy and Canada have very low per capita investments in renewable energy compared to the other G7 countries. What should be done to promote REINV in the G7 countries? Do strategies such as transferring more resources from economic growth

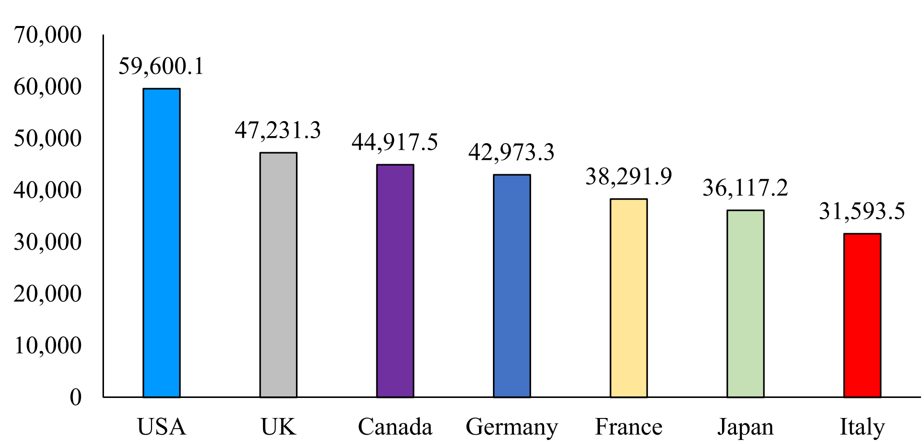

Fig. 1. Per capita GDP of G7 countries in 2018 (constant USD, 2015 prices).
Source: WB (2023).

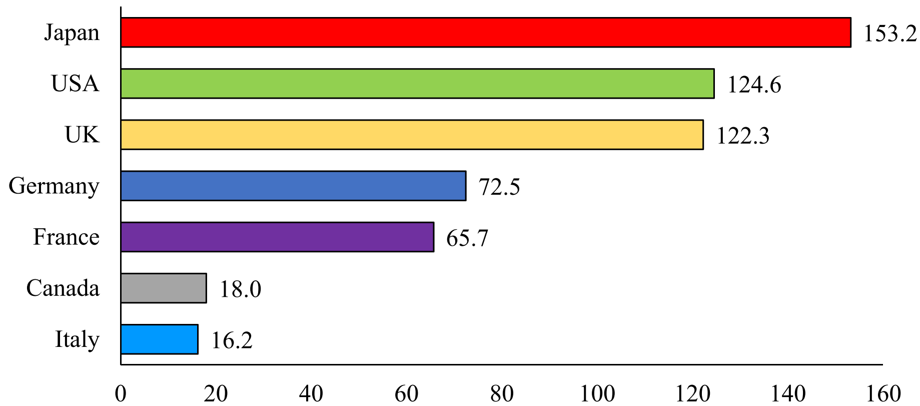

Fig. 2. Per capita REINV of the G7 countries in 2018 (constant USD, 2015 prices).
Source: Bloomberg (2023).

to REINV and reducing political and economic uncertainties enable REINV development? This study seeks answers to related research questions.

Based on this motivation, this study uncovers the drivers of renewable energy investments in G7 countries. Although some studies (e.g., Dutta and Dutta, 2022; Khan and Su, 2022) postulate the relevance of political uncertainty and geopolitical risk to renewable energy indicators, there is no evidence in the literature to support the specificity of renewable energy investment as the main dependent variable, nor to examine the G7 countries. In addition, the study examines the role of socioeconomic (including urbanization, government efficiency, and regulatory quality) and economic (GDP per capita) indicators. Importantly, the results of the study further enrich the literature demonstrating the vulnerability of clean energy systems. As a result, policymakers and stakeholders in the energy sector will be better able to hedge clean investments and associated market risks. This study therefore focuses on G7 countries, uses annual data for the period 2004–2018, and applies the AMG approach. By applying such an approach, the study mainly reveals that GDP has a stimulative effect on REINV, while EPU, GPR, and URB have a regressive effect, and GOVEF and REGQ have no effect. Based on the results obtained from a novel dataset, the study also discusses various policy caveats.

This study proceeds with a review of the literature in Section 2. The data set and methodology are outlined in Section 3, while the results of the study and associated policy caveats are addressed in Section 4. Finally, Section 5 concludes the study with an outlook for future research.

2. Literature review

The literature has been sparse on the drivers of renewable energy indicators. Some studies have focused on renewable energy stocks. For instance, Alola (2022) and Dutta and Dutta (2022) examine renewable energy aspects from the perspective of agricultural commodities and geopolitical risk, in that order. For the study of Alola (2022), by considering the case of the USA over the daily period from January 20, 2012 to August 2, 2018, renewable energy equity is employed as a proxy for clean energy assets and commodity prices (e.g., corn, soybeans, and wheat). The research shows that renewable energy stocks respond positively to price increases in some commodities (e.g., soybeans and wheat). Dutta and Dutta (2022) consider three categories of renewable energy ETFs (i.e., WilderHill Clean Energy ETF, Solar Energy ETF, and Global Clean Energy ETF) from April 15, 2008, to March 10, 2020. The result shows that high geopolitical risk increases the likelihood that ETFs fall into the low volatility regime. Conversely, high geopolitical risk lowers the probability that the ETFs fall into the high volatility regime. Overall, the result suggests that high geopolitical risk leads to a reduction in the risk of green assets, as fossil fuels are potentially exposed to stronger shocks during periods of high geopolitical risk, leading to a shift in consumer preference toward renewable energy sources.

Liu et al. (2020) and Feng and Zheng (2022) look at renewable energy enterprises and renewable energy innovation, respectively, to examine the role of EPU. Through a comparative analysis, various Chinese energy enterprises are considered over the quarterly period from 2007/Q1 to 2017/Q4. Considering all energy enterprises, the result shows that EPU hinders the innovation activity of conventional energy enterprises. In contrast, the innovation activity of renewable energy enterprises is not significantly unperturbed by changes in the EPU. Innovations in geothermal, solar, and other renewables are encouraged by an increase in the EPU. Meanwhile, ownership concentration plays only a moderating role between EPU and innovation in renewable energy enterprises. Moreover, Du et al. (2023) conclude that green finance promotes the transition to renewable energy in 30 Chinese provinces.

Bourcet (2020) presents extensive literature on the determinants of renewable energy deployment. Some studies have analyzed the determinants of renewable energy consumption and production. In these analyzes, FD and EPU have been considered as important determinants. For example, Kim and Park (2016) report that external financing is beneficial for renewable technologies in 30 countries. Kim and Park (2018) report that the Clean Development Mechanism is an effective tool to improve renewable energy deployment in countries with poor financial conditions. Ji and Zhang (2019) conclude that capital market development and foreign investment promote renewable energy growth in China. Anton and Nucu (2020) determine that FD stimulates REC in 28 European countries. Zhao et al. (2020) report that FD expands REC in China. Wang et al. (2021) reach to opposite results for China than Zhao et al. (2020). Shahbaz et al. (2021) verify the facilitative role of FD on REC in 34 developing countries. Shafiullah et al. (2021) state that EPU lowers REC in the USA. Zhang et al. (2021) conclude that higher EPU leads to lower REC in BRIC countries. Lei et al. (2021) define that EPU increases REC in China, while FD has no effect. Pata et al. (2022) find that improving access to and depth of financial services is an important tool for REC in the USA. Trinh et al. (2022) conclude that financial market development and financial institutions have a positive effect on REC in 180 countries. Irfan et al. (2023) determine that FD hinders energy transition in G7 countries.

Despite the presence of many studies analyzing the determinants of REC and renewable energy equity in the literature, no study has examined REINV, at best due to a lack of data. As far as known, only a limited number of researchers have analyzed the determinants of renewable energy investment at the micro level for China. For example, Yang et al. (2019) analyze the effects of government incentives, bank credits, energy consumption intensity, and economic development on REINV using a panel threshold model for 92 enterprises in China during 2007–2016. The researchers use a panel data analysis without considering CSD. In another study, Wang and Fan (2023) examine the effects of green bonds and credits on REINV for 31 provinces in China using the generalized method of moments and do not consider CSD for the panel data.

Some researchers have claimed to have empirically analyzed the determinants of REINV. For example, Abban and Hasan (2021) study the effect of factors (e.g., government incentives, population, economic growth, and energy imports) on REINV in 60 countries by using installed renewable energy capacity as an indicator. Alsagr (2023) claims to analyze the determinants of REINV in 23 advanced and developing countries, but renewable energy production is used as an indicator in this research. In fact, renewable energy investment, installed capacity, and production are different things. Energy investment is money spent to produce, while production is energy output. Installed capacity is how much renewable energy investments have been completed. In this context, REINV is a symbol of countries' expenditure on renewable resources. To the best knowledge of the authors, no study has analyzed the determinants of REINV in a macroeconomic context. An in-depth examination of the determinants of REINV can provide valuable insights that can contribute to the achievement of SDG targets, particularly SDG-7 and SDG-13. Therefore, this study is the first to empirically analyze the determinants of REINV considering the existence of CSD for G7 countries.

3. Methods

3.1. Data and variables

The study includes annual data from 2004 to 2018 to examine the effects of EPU and GPR on REINV in G7 countries. The data period ends in 2018 due to data availability of REINV at that time. Details on the variables are presented in Table 1.

3.2. Models

The following three linear-logarithmic models, given in Eqs. (1) to (3), are used in the empirical analyzes:

$$\ln REINV_{it} = \beta_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln URB + \beta_3 \ln EPU + \beta_4 \ln GPR_{it} + u_{1t} \quad (1)$$

$$\ln REINV_{it} = \beta_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln URB + \beta_3 \ln EPU + \beta_4 \ln GPR_{it} + \beta_5 \ln GOVEF_{it} + u_{2t} \quad (2)$$

Table 1
Details of the variables.

Symbol	Variable	Definition	Source
REINV	Renewable Energy Investments	Per capita, constant 2015 USD	Bloomberg (2023)
EPU	Economic Policy Uncertainty Index	A high level of index indicates a high level of economic policy uncertainty	EPU (2023)
GPR	Geopolitical Risk Index	A high level of index indicates a high level of geopolitical risk	Caldara and Iacoviello (2022)
GDP	Gross Domestic Product	Per capita, constant 2015 USD	WB (2023)
URB	Urbanization	Urban population (% of the total population)	WB (2023)
GOVEF	Government Efficiency	An index with values between 0 (poor governance performance) and 5 (strong governance performance)	WGI (2023)
REGQ	Regulatory Quality		

Notes: WGI normally varies between −2.5 and +2.5. The indicators are rescaled between 0 and 5 to employ linear-logarithmic models.

$$\ln REINV_{it} = \beta_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln URB + \beta_3 \ln EPU + \beta_4 \ln GPR_{it} + \beta_5 \ln REGQ_{it} + u_{3t} \quad (3)$$

The institutional variables (i.e., GOVEF and REGQ) are included in models 2 and 3 to check the robustness of the findings from Eq. (1).

3.3. Empirical methodology

This study follows a four-stage empirical strategy, as visually represented in Fig. 3. In the first stage, descriptive statistics are examined. The second stage analyzes the presence of CSD in the panel dataset. In the third stage, the effects of EPU, GPR, GDP, and URB on REINV are estimated using the AMG approach. The final stage examines whether the results of the baseline model vary according to alternative indicators of institutional quality.

Panel data methods are vulnerable to CSD, which is common in empirical estimates. CSD implies that an economic, social, or political shock in one cross-section affects the other cross-section. Analyzes of first-generation panel data that do not account for CSD and the effects of shocks that propagate across countries, such as the economic crisis, can lead to biased results. Therefore, the presence of CSD in the model should be investigated to avoid biased estimates. For this purpose, this study employs the LM test of Breusch and Pagan (1980), the CD-LM test of Pesaran (2004), and the bias-adjusted LM (LM_{Adj}) test of Pesaran et al. (2008). The theoretical background of the LMAdj test can be unveiled in Eq. (4):

$$LM_{Adj} = \sqrt{2/N(N-1)} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} (T-k)\hat{\rho}_{ij}^2 - \mu_{Tij} \Big/ v_{Tij} \quad (4)$$

The LM_{Adj} test adopts the null hypothesis of "no CSD" against the alternative "CSD." Considering that the presence of CSD in the models allows the use of second-generation panel data methods, the AMG estimator proposed by Eberhardt and Bond (2009) and Eberhardt and Teal (2010) is used to estimate the coefficients of the regressors. The AMG method applies a two-step strategy to obtain coefficients. First, the AMG method adds time dummies to the standard general equation, as shown in Eq. (5):

$$\Delta REINV_{it} = \beta \Delta X_{it} + \sum_{t=2}^{T} \gamma_t \Delta D_t + u_{it} \quad (5)$$

where Δ denotes the first difference, $REINV_{it}$ shows renewable energy investments per capita, X_{it} represents an explanatory variable, D_t indicates time dummies used to determine the dynamic effect, and γ_t represents time dummies' coefficients. Afterward, the new augmented model is estimated with dummies as in Eq. (6):

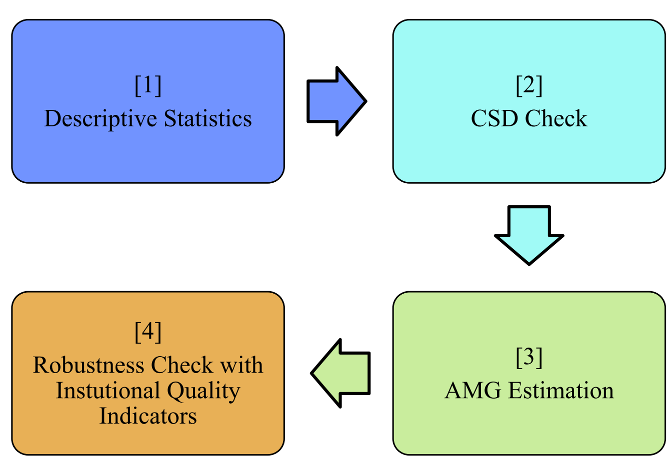

Fig. 3. Empirical flowchart.

$$REINV_{it} = \alpha_i + \beta_i \Delta X_{it} + d_i(\delta_i) + u_{it} \quad (6)$$

where $REINV_{it}$ shows renewable energy investments per capita, and X_{it} represents an explanatory variable. After the first step of the AMG method, γ_t is transformed into a regressor represented by δ_i shared across individual panel units, and δ_i represents the unobserved common factor. The AMG method provides researchers with a flexible modeling strategy with the following advantages (Eberhardt and Teal, 2013):

(i) The AMG approach can provide consistent estimates under homogeneity and heterogeneity assumptions; (ii) it gives robust estimates even in the presence of structural breaks or endogeneity; (iii) it can be implemented with the mixed integration level of the regressors (e.g., I(0) and I(1)), regardless of whether the variables are cointegrated or not. Therefore, no preliminary analysis is required to determine the level of integration and the presence of cointegration among the variables.

4. Results and discussion

4.1. Descriptive statistics

The first phase of the study examines the main statistics for the variables. The descriptive statistics for the variables are reported in Table 2.

GPR has the highest variations, while URB has the lowest variations. Thus, the GPR fluctuates more than the other variables. Considering that the GPR is closely related to day-to-day politics and economic activities, one can expect fluctuations like those of the variables. However, institutional changes take a much longer period. The small fluctuations and relatively stable behavior of the regulatory quality variables are therefore consistent with theoretical expectations.

4.2. CSD results

In the second phase, the study analyzes whether the shock in one country affects the other countries. The results of the CSD test for a total of three estimation models are reported in Table 3.

Table 3 indicates that the null of CSD is strongly rejected with three tests. Thus, CSD is present in the panel. Accordingly, the second-generation panel data methods are used.

4.3. AMG results

In the third step, considering the existence of CSD, the study performs the AMG approach for the coefficient estimation of Model 1 and the results for the model are shown in Table 4.

GDP has a positive effect on REINV, while EPU, GPR, and URB have a negative effect on REINV in G7 countries. Thus, an upsurge in economic prosperity encourages renewable energy investments, while such investments are vulnerable to an increase in economic policy uncertainties and geopolitical risks. In addition, increasing urbanization a negative impact on REINV in the G7 countries.

For robustness, the study extends the main estimation (i.e., Model 1) by adding institutional quality indicators to see whether empirical results change. GOVEF is included as a control variable in Model 2, and the results of the model are presented in Table 5.

Table 2
Descriptive statistics.

Variable	Mean	Standard Deviation	Minimum	Maximum
REINV	4.480	0.871	2.786	6.347
GDP	10.588	0.175	10.308	10.995
URB	4.374	0.076	4.214	4.518
EPU	4.903	0.477	4.097	6.297
GPR	−1.090	1.099	−2.977	1.329
GOVEF	0.278	0.476	−1.653	0.642
REGQ	1.354	0.086	1.144	1.478

Table 3
CSD results.

	Model 1	Model 2	Model 3
LM	74.290 (0.000)	54.540 (0.001)	94.620 (0.000)
CD-LM	5.259 (0.000)	3.178 (0.001)	4.517 (0000)
LM_{Adj}	11.380 (0.000)	5.906 (0.000)	14.980 (0.000)

Notes: () denotes probability values.

Table 4
Empirical results for Model 1.

Variables	Statistics	t-Stat.	Prob.
GDP	15.981	3.60	0.000
URB	−40.965	−2.18	0.029
EPU	−0.538	−1.79	0.074
GPR	−0.274	−2.02	0.043
Constant	15.272	0.19	0.850

Table 5
Empirical results for Model 2.

Variables	Statistics	t-Stat.	Prob.
GDP	14.186	2.88	0.000
URB	−40.412	−1.78	0.029
EPU	−0.508	−1.70	0.088
GPR	−0.354	−2.67	0.008
GOVEF	0.517	0.41	0.680
Constant	31.279	0.32	0.748

GDP has a positive effect on REINV, while EPU, GPR, and URB have a negative effect on REINV in G7 countries. In addition, GOVEF has no statistically significant effect on REINV. Therefore, Model 2 provides consistent estimations with Model 1.

Finally, REGQ is included as a control variable in Model 3, and the results of the model are shown in Table 6.

GDP has a positive effect on REINV, while EPU, GPR, and URB have a negative effect on REINV in G7 countries. Similar to Model 2, the control variable (i.e., REGQ) has no significant effect on REINV in Model 3. The overall findings of the AMG estimator are summarized in Fig. 4.

In summary, the three models provide consistent estimation results for the effects of EPU, GPR, GDP, and URB on REINV. Given these results, it can be argued that an increase in economic welfare promotes REINV, while an upsurge in EPU, GPR, and URB hinders REINV in G7 countries, and institutional quality does not play a significant role in REINV.

4.4. Discussion and policy caveats

The use of renewable energy has been considered since the second half of the 20th century as one of the possible solutions to meet the increasing energy demand, to change the global energy mix to prevent climate change, and to reverse environmental degradation. Renewable energy is considered as one of the possible solutions for the twenty-first century. Thus, investments in renewable energy are critical to promote the transition from unsustainable energy technologies to cleaner energy generation technologies and the provision of stable eco-friendly energy

Table 6
Empirical results for Model 3.

Variables	Statistics	t-Stat.	Prob.
GDP	15.089	3.40	0.000
URB	−40.965	−2.01	0.029
EPU	−0.528	−2.16	0.031
GPR	−0.264	−2.47	0.014
REGQ	2.646	1.01	0.312
Constant	37.329	0.39	0.695

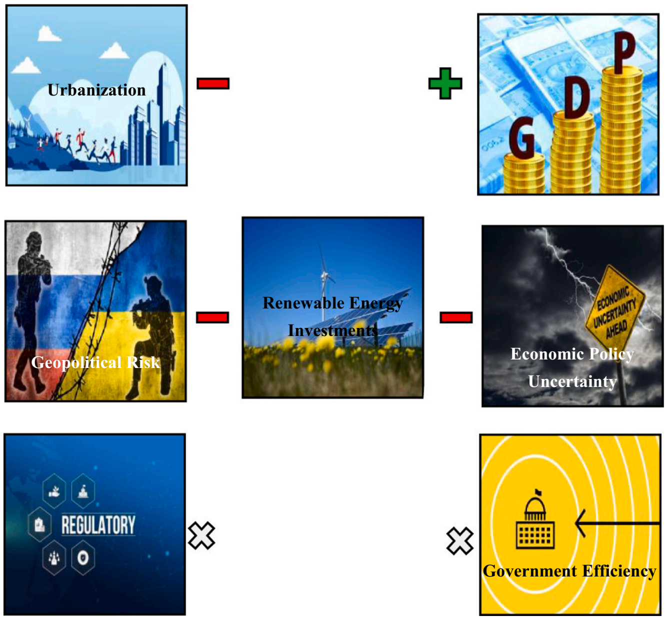

Fig. 4. Summary of the empirical outcomes.

for economic activities (Pata et al., 2023b). However, researchers have not paid adequate attention to understanding the dynamics of such investments. In particular, the role of EPU and GPR, which are important determinants, have been ignored. Therefore, this study examines the role of EPU and GPR as well as GDP and URB on renewable energy investments.

Economic growth has a positive effect on REINV. It is well known that economic growth and wealth are the main determinants of investments and savings. Therefore, a positive effect of increasing wealth levels may increase allocated resources for renewable energy investments. Lucas et al. (2016) unveil that overall economic well-being can promote the decisions for renewable energy investments. Bamati and Raoofi (2020) find that an increase in GDP level tots up renewable energy production levels and renewable energy investment increases to meet rising demand. Kılınç-Ata and Dolmatov (2023) find that economic growth is one of the most important determinants of renewable energy deployment and that increasing economic growth encourages the installation of new clean energy capacity. Therefore, the empirical results of the study in terms of the effect of economic growth on renewable energy investments are consistent with theoretical expectations. Accordingly, it can be concluded that policymakers of G7 countries should benefit from increasing economic growth by allocating more financial resources to REINV, which is made possible by increasing economic growth. In this context, policymakers may consider allocating land areas, long-term credits with low-interest rates, tax exemptions, and investment subsidies to promote REINV much more.

The estimation results indicate that an increase in EPU hinders the increase in REINV. It can be said that investment intuition decreases when uncertainties are high because the success, payoff time, and profitability of investments are uncertain. Therefore, economic agents can prefer to invest in more stable instruments (e.g., government bonds) rather than instruments, which are closely linked to economic activities and business cycles (e.g., renewable energy generation). According to Bloom et al. (2007), policy incentives to increase investment levels may not have an anticipated effect on investment levels during periods of high EPU due to the low responsiveness of economic agents. IMF (2019) highlights that an increase in uncertainty poses downside risks to global investment levels. For example, the level of investment in renewable energy may decline due to the existing high level of policy uncertainty in the economic environment. The empirical results on the effect of EPU on REINV indicate similar results to the previous literature. Policymakers should therefore try to limit the EPU resulting from various conflicts between countries. It can also be suggested that G7 countries should consider the effect of EPU on almost all areas, including REINV when making a decision or taking action in the economic sphere.

The estimates also show that an increase in GPR hinders REINV. The economic literature emphasizes that the investment climate is closely linked to the socioeconomic and political environment. In this regard, an increase in political tension, social unrest, and economic turmoil may discourage investors from allocating new resources to build new renewable energy facilities. Wang et al. (2019) note that an increase in geopolitical tensions (e.g., internal and external conflicts, terrorism, and political strife) heightens concerns among businesses, financial markets, individuals, and policymakers. Therefore, a rise in GPR can hinder investment in renewable energy by disrupting the investment climate. IMF (2019) unveils that an increase in GPR can slow economic activity. According to Flouros et al. (2022), the increase in the share of renewable energy is affected not only by the role of stakeholders and decision-making mechanisms, but also by the GPR. Therefore, decisions for new renewable energy investments may be postponed during periods of high geopolitical tensions. As in the case of the EPU, G7 countries can be advised to consider the effect of the GPR on many areas, including REINV, when they can be part of geopolitical tensions. Rather than trying to stimulate such geopolitical tensions, it would be good for G7 countries, as well as others, to try to reduce geopolitical tensions by continuing to rely on negotiations.

An increase in URB reduces REINV. This can be related to economies of scale and the structure of the energy market. It is well known that energy markets are closer to the structure of a market with imperfect competition than a market with perfect competition. (Dismukes and Upton Jr, 2015). There are sunk costs in energy investments and the share of fixed costs in total costs is relatively high. Generation and delivery of energy to densely or sparsely populated cities require roughly the same infrastructure investment, and the return on REINV can increase as long as renewable energy development is concentrated in certain areas (Farrel, 2016; IRENA, 2020). Thus, the benefits of economies of scale increase as the number of households and businesses concentrates in an urban area and the share of fixed costs in total costs decreases. Therefore, an increase in population in urban areas allows more households and businesses to be served with relatively low fixed infrastructure costs. Therefore, companies that invest in renewable energy can benefit from economies of scale as the level of urbanization increases. Overall, an increase in the level of urbanization can reduce the need for REINV.

Although the results show that institutional structure does not affect REINV, this does not mean that it can be completely ignored by policymakers. Rather, it means that policymakers should try to re-design the institutional structure so that it can help stimulate REINV.

5. Conclusion and future research

5.1. Conclusion

Increasing environmental problems have negatively affected all countries and societies. Therefore, a general interest in environment-related problems (e.g., global warming and climate change) has developed in recent years. Naturally, possible solutions to these kinds of problems have also been sought. The transition from fossil fuels to clean energy has been intensively highlighted to avoid or reduce environmental problems, and previous studies often focused on renewable energy consumption. However, a major shortcoming of such studies is that renewable energy production is also important, similar to REC. The REINV affects both the production and consumption of renewable energy. It is not possible to meet the supply and demand of renewable energy without providing the necessary investments. Therefore, from an environmental point of view, it is more important to focus on REINV than on renewable energy production and consumption.

Considering the above-mentioned concept, this study investigates the determinants of REINV in G7 countries, which is consistent with the leading role of G7 countries in combating climate-related environmental problems. This study employs the AMG approach and considers a wide range of factors by focusing on the effects of EPU and GPR and accounting for different control variables (i.e., GDP, URB, GOVEF, REGQ). The study finds that REINV increases as economies grow, but decreases over time as EPU, GPR, and URB increase. Moreover, EPU affects REINV more than GPR, but REINV is not affected by institutional structure (proxied by GOVEF and REGQ). It is also shown that the results are robust based on alternative estimation models. Consistent with the results, several policy caveats have been expressed, such as trying to use economic growth to support the REINV by tapping many more sources of financing; considering the EPU in economic-related decisions; and focusing on lowering the GPR through negotiations.

5.2. Limitations and future research

Although this study intends to investigate REINV in G7 in a much more comprehensive way, nevertheless, there are various constraints that researchers have faced while applying investigations. Firstly, because the study includes only some of the developed countries (i.e., G7 countries), new studies may include some more developed countries for empirical analyses either as a new scope or as an addition to G7 countries. Hence, REINV can be examined for more developed countries. Moreover, new studies can focus on emerging countries, which are out of the scope of this research.

Second, the study examines the determinants of REINV with a panel data analysis, but neglecting structural breaks is a limitation. In this context, future studies can use current time series methods that allow modeling of structural breaks with Fourier functions. In this way, the determinants of REINV can be discussed more comprehensively by accounting for external shocks such as war, economic crisis, and pandemic.

The third limitation is that the study focuses on the effects of uncertainty factors such as EPU and GPR on REINV. There are many measures of uncertainty, and these indicators are only two of them. Future studies can enrich the literature by examining the effects of climate policy uncertainty and various similar uncertainty indices on REINV.

The fourth limitation is that the study examines REINV at an aggregate level due to data limitations. The determinants and impacts of investments in solar, wind, biomass, and similar renewable energy sources may vary. Therefore, if data become available in the future, researchers can analyze the determinants of REINV at a disaggregated level and provide detailed insights into the transition to clean energy.

Finally, the study examines RENIV from the perspective of risk and uncertainty. Although this is an important point, the financing of RENIV has not yet been empirically studied. Future studies could shed light on the benefits of financialization in the clean energy transition on a country-by-country basis by examining the impact of financial development, financial inclusion, and financial depth on RENIV.

Disclosure statement

The authors certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethics approval and consent to participate

Not applicable.

Consent for publication

The authors are willing to permit the Journal to publish the article.

CRediT authorship contribution statement

Ugur Korkut Pata: Conceptualization, Supervision, Software, Data curation, Writing – original draft. **Andrew Adewale Alola:** Conceptualization, Writing – original draft, Writing – review & editing. **Sinan Erdogan:** Methodology, Software, Formal analysis, Visualization, Writing – original draft. **Mustafa Tevfik Kartal:** Conceptualization, Supervision, Methodology, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no competing interests.

Data availability

Data will be made available on request.

Acknowledgments

Not applicable.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2023.107172.

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