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Nexus between Renewable Energy, Credit Gap Risk, Financial Development and R&D Expenditure: Panel ARDL Approach

Ulaş Ünlü [1], Furkan Yıldırım [1,*], Ayhan Kuloğlu [2], Ersan Ersoy [3] and Emin Hüseyin Çetenak [4]

[1] The Department of Finance and Banking, The Faculty of Applied Sciences, Akdeniz University, Antalya 07058, Turkey
[2] The Department of Accounting and Tax, Vocational School, Nevsehir Haci Bektas Veli University, Nevsehir 50300, Turkey
[3] The Department of Accounting and Finance Management, The Faculty of Applied Sciences, Uşak University, Uşak 64300, Turkey
[4] The Department of Finance and Banking, Faculty of Economics and Administrative Sciences, Nigde Omer Halisdemir University, Nigde 51000, Turkey
* Correspondence: furkanyildirim@akdeniz.edu.tr

Abstract: In the study, we investigate the relationships between renewable energy consumption sub-indicators of G-8 countries and financial development, credit gap risk, and R&D expenditure from 1996 to 2018. The relationships among the variables in the study are analyzed by employing the Panel ARDL method and the Dumitrescu–Hurlin panel causality test. The cointegration relationships between the variables have been analyzed using the bounds test approach, and an unrestricted error correction model has been established. Contrary to previous studies in the renewable energy literature, this study employed the variable of credit gap risk. Therefore, we believe that this study will fill the gap in the literature and attract the attention of researchers and policymakers. The results indicate that increases in total demand for renewable energy positively affect the financial development of countries. Moreover, R&D expenditures increase as the demand for hydro energy and solar energy increases. This result indicates that wind power consumption has a short-term impact on R&D expenditure, and such an impact ceases to exist in the long run. According to the empirical research findings, the rise in demand for renewable energy may be a factor mitigating the credit gap risk of countries. In other words, the credit gap risk, which is considered a leading indicator of systemic banking crises, can be mitigated by the rise in the demand for renewable energy.

Keywords: renewable energy; credit gap risk; financial development index; R&D expenditure

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Citation: Ünlü, U.; Yıldırım, F.; Kuloğlu, A.; Ersoy, E.; Çetenak, E.H. Nexus between Renewable Energy, Credit Gap Risk, Financial Development and R&D Expenditure: Panel ARDL Approach. *Sustainability* **2022**, *14*, 16232. https://doi.org/10.3390/su142316232

Academic Editors: Miltiadis D. Lytras and Andreea Claudia Serban

Received: 27 August 2022
Accepted: 29 November 2022
Published: 5 December 2022

1. Introduction

Energy is of vital importance to ensure the welfare and development of countries, as mitigating climate change is one of the most vital tools in the determination of international policies today. The energy crisis, which has already emerged as a result of the Russia-Ukraine war, is one of the most important indicators of this. Considering that fossil fuels will be depleted in a short time in terms of reserve life, alternative energy sources that will replace these sources have become very important. It is estimated by some researchers that energy consumption in the world will increase by 48% up to 2040 [1].

In the future, renewable energy (RE) resources will no longer be a choice and will become a necessity. Considering global warming, making energy investments in the field of RE is extremely important for the growth of economies and the welfare of humanity. RE is obtained from natural processes that are constantly replenished. Renewable resources are often called green energy or clean energy. These major sources of energy include wind, solar, hydropower, geothermal, ocean power, and bio-energy.

RE has a crucial role in sustainable economic growth (EG) by subsidizing the environmental cost that can negatively trigger industrial output [2]. The use of RE contributes to a cleaner environment while also contributing to independence from the fossil fuel market and energy security. Increasing demand for energy consumption, together with technology development and policy support to reduce climate pollution, will increase the importance of RE in the global energy mix in the long run [3].

Promoting and expanding clean, green energy and RE resources known to be environmentally friendly can contribute to significantly reducing CO_2 emissions and other pollutants [4,5]. Zhang [6] asserted that financial development (FD) enhances CO_2 emissions by reducing financing costs, improving funding channels and attracting foreign direct investment (FDI). Some researchers have found that technological innovations assisted in mitigating pollution and enhancing environmental performance [7–10]. Further, increased R&D in energy may result in the efficient production and consumption of RE [11,12].

The role of FD in CO_2 emissions is a subject of considerable attention among policymakers and researchers, and there are studies claiming that FD can effectively reduce CO_2 emissions [13]. Nonetheless, some researchers oppose the arguments; they believe that FD may accelerate EG and, thus, stimulate a rise in CO_2 emissions [10,14,15].

Shahbaz et al. [10] argued that R&D activities were the only global solutions to the energy crises. Accordingly, R&D activities were crucial to EG since they helped explore alternative energy sources to become independent of the fossil fuel market. Consistent with this view, some researchers have found that a large investment in R&D expenditure is crucial to achieving long-term EG, and investment in R&D expenditure will accelerate EG through innovation and total factor productivity [16,17].

In the G8 countries, the rapid increase in urbanization brought about by rapid EG has resulted in a large rise in energy consumption, which accounted for environmental pollution. G8 countries have a major role in causing global warming and extreme weather conditions [18]. In addition, since the rapid increase in EG is closely related to the increase in CO_2 emissions and technological progress, FDI has increased in these countries, and energy demand has also increased [19].

According to the Basel committee, CG (Credit Gap) risk can contribute as an early warning system for countries to evaluate their systematic risks. The fact that the gap is positive and increasing assert that the credits are moving away from their trend, and the risks are accumulating. The BIS recommends close monitoring of credits when the gap is positive. As the demand for RE consumption in countries increases, the credit gap decreases. In other words, increases in RE demand have a reducing effect on systematic risks in countries. The main reason for this situation is that RE production costs are lower than the energy costs obtained from many fossil fuels. This situation reduces the need for energy-related credits in the real sector and prevents the growth of the credit gap of the countries.

This study is motivated by the G8 countries having a population of 922 million in 2022 [20]. We focused on these countries as they have large economic potential and a higher population. In this study, we analyze the relationship between RE, CG risk, FD and R&D expenditure for G8 economies by applying a panel ARDL approach. It is crucial to consider the roles of FD, R&D expenditure, and credit gap (CG) risk on RE demand. Most previous studies have focused on the relationship between RE and FD, CO_2 emissions, EG, and technological innovation (TI) while avoiding the variable of CG risk. Unlike previous studies in the renewable energy literature, this study employed the variable of credit gap risk. Therefore, we believe that this study will fill the gap in the literature. The second contribution involves the use of a panel ARDL approach which helps to avoid the existence of endogeneity bias and autocorrelation.

The remaining parts of this paper are planned as follows: The second part examines the literature. The third presents the data and the methodology used. The empirical results are presented and discussed in the fourth part. Finally, the fifth consists of conclusion and policy implications.

2. Literature Review

The rapid rise in CO_2 emissions after the 2000s has increased the importance of RE resources in the energy-environment-growth literature. Diversification of RE resources increases energy security and contributes to reducing fossil fuel dependence and CO_2 emissions [21]. There are many empirical studies showing that increasing the use of RE resources reduces greenhouse gas emissions significantly [22–25]. The main handicap of RE investments is the need for high investment costs [26]. Renewable investments require high levels of financing due to long-term payback periods [27]. Therefore, interest in studies examining the relationship between FD and RE has increased.

There is in-depth literature on RE and FD [28–30]. Studies at the global level prove that FD increases the usage of renewable resources and has a long-term positive influence on environmental sustainability [31]. Countries with well-developed financial markets appear to acquire growth in the RE sector courtesy of easier access to external financing [32]. There is empirical evidence showing that FD has a positive influence on the use of RE resources in different country-country groups and time periods; OECD (38) countries and the period 1995–2019 [33]; China and the period 1992–2013 [30]; EU (28) and the period 1990–2015 [3]; India and the period 1971–2015 [29]; United Arab Emirates and the period 1989–2019 [34]; BRI countries and 2000–2014 period [35]. Eren et al. [28], in their research on India covering the period 1971–2015, stated that there is a unilateral causality from FD to RE. Anton & Nucu [3] explicated the impact of FD on RE consumption in EU-28 countries in the period 1990–2015 using the panel data method. Their findings show that three distinct dimensions of FD have a positive impact on the share of RE consumption. Kim & Park [32] examined whether FD at the global level encourages the use of RE for 30 countries in the period of 2000–2013. As a result, they stated that countries with well-developed financial markets experienced growth in the renewable sector courtesy of easy access to finance. Ji & Zhang [29] stated that the contribution of FD to China's RE growth is 42.2%. Wang et al. [36] stated in their study that, contrary to the previous study on China, FD negatively affected the use of RE in the long run and detected a unilateral causality from RE consumption to FD.

In the energy FD literature, there are many empirical studies showing that FD increases the use of RE resources and thus contributes to the reduction of greenhouse gas emissions [37,38]. Empirical studies showing that FD reduces the use of CO_2 emissions have been confirmed over different time and country-country groups; India and the period 1971–2008 [39]; APEC countries and the period 1990–2016 [40]; Gulf Cooperation Council (GCC) countries and the period 1980–2011 [41]; Turkey and the period 1960–2011 [42]; G-20 and the period 1986–2008 [43]; MINT Countries and the period 1969–2019 [44]. Conversely, there are empirical studies showing that FD increases CO_2 emissions [6]. There are also studies that have determined that FD has no impact on CO_2 emissions [45]. Unlike the studies above, Shahbaz et al.'s [46] study on G-7 countries between 1870 and 2014 stated that the influence of FD on emissions is in the form of the letter M. Shahbaz et al. [47] detected a U-shaped link between FD and emissions over the UK in the period 1870–2017. Ehigiamusoe & Lean [48] conducted a study on 122 countries by dividing countries into income groups in the 1990–2014 period, stating that FD decreased emissions in high-income groups. On the contrary, FD increased emissions in middle-and low-income groups. Acheampong et al. [13] found similar results. Gök [49] conducted a meta-analysis study showing that the effect of FD on emissions will vary in size and direction according to the indicators used (FD indicators, analysis technique, country or region groups and time period). Xiong et al. [50] found in their study that FD increased greenhouse gas emissions in underdeveloped regions of China and decreased them in developed regions during the 1997–2011 period.

In studies conducted in the field of energy with general R&D expenditures, there are empirical studies stating that R&D studies reduce greenhouse gas emissions through the techniques developed in RE production; USA and the period 1974–2009 [51]; APEC (16) and the period 1990–2015 [52]; EU (15), China and the USA, and the period 1990–2013 [53,54] examined the effect of R&D expenditures on greenhouse gas emissions in 19 high-income OECD countries between 2003 and 2015. As a result, they could not detect a significant relationship between CO_2 emissions and renewable R&D expenditures. In addition, they found that power and storage R&D expenditures reduce emissions. [55]. They also conducted a study of developed and developing countries between 1995 and 2018 and found a unilateral causality relationship between R&D expenditures and RE for developed countries. Adedoyin et al.'s [56] study on the EU (16) in the 1997–2015 period determined a bilateral relationship between R&D studies and RE.

One of the effective ways to fulfil the targets set in the Paris Climate Agreement by reducing greenhouse gas emissions is to reduce emissions through loans [57]. There are many studies proving that emissions can be reduced by giving loans to environmentally friendly investments [3]. In their study conducted on 23 EU member countries over the period of 1990–2013, Al-Mulali et al. [37] stated that loans given to the private sector increase emissions in the long run and financial resources are allocated to non-environmentally friendly resources. Umar et al. [58] and Lahiani et al. [59] show that CO2-zero financings have a reducing effect on emissions. However, there are not enough studies investigating the direct or indirect relationship between credit risk and RE. Umar et al. [58] conducted research on 344 financial institutions in 19 European countries during the 2011–2020 period and stated that green financing reduces credit risk. Ji & Zhang [29] stated that the growth of the loan market contributes to the development of RE shares and that the development of RE requires high self-financing needs due to the high risk-cost element. Sweerts et al. [60] stated in their study that reducing financial risks has a key role in unlocking the RE potential for Africa. Guo [61], in his study on China, stated that an increase in financial risk increases emissions.

3. Materials and Methods

3.1. Data Sources

The relationships between RE consumption sub-indicators of G-8 countries and FD, CG risk, and R&D expenditures are investigated. The natural logarithms of the variables are used, and their annual data are obtained over the period 1996–2018. A total of seven variables, comprised of four independent and three dependent, are utilized. The dependent variables of the study consist of the FD index, CG risk, and R&D expenditures. Independent variables are hydropower, solar power, wind power, and CO_2 emission. The data of the FD index variable are obtained from the IMF database; the data of the CG risk variable are obtained from the BIS database; the data for the R&D expenditures variable are obtained from the World Bank (WDI) database; the data of hydropower, solar power, wind power variables are obtained from the BP Statistical Review of World Energy database; and the data of CO_2 emission variable are obtained from the World Bank's database. The abbreviations and explanations of the variables are presented in Table 1.

Table 1. Descriptions of Selected Variables.

Variables	Abbr.	Explanation	Source
FD Index	FDI	FD index generated by taking into account the access, efficiency, and depth of financial markets (%)	IMF
CG Risk	CGAP	[Credit/GDP—Trend (Credit/GDP)] (%)	BIS
R&D Expenditures	RND	Innovation is measured by certain activities such as several patents and R&D in 1 year (%)	WDI
Hydro Power	HYDRO	Hydroelectric energy consumption (Terawatt hour)	BP
Solar Power	SOLAR	Solar energy consumption (Terawatt hour)	BP
Wind Power	WIND	Wind energy consumption (Terawatt hour)	BP
CO_2 Emission	CO_2	Energy-related CO_2 emissions (Metric tons per capita)	WDI

Svirydzenka [62] revealed the IMF FD index with 20 different indicators representing the development of financial markets and institutions. Researchers classified those financial indicators in terms of depth, access and efficiency and established three different indexes for each financial market and institution. The IMF FD index is derived from the combination of those indexes and is fit to represent the multidimensional nature of financial markets and institutions.

The ratio of bank credit extended to the private sector to GDP was developed by the BIS. Drehmann et al. [63] concluded that the credit/GDP gap risk might better measure the accumulation of risks in the banking system than various alternative variables. A positive and increasing gap displays that the credits are likely to move away from their own trends and the risks tend to accumulate.

As one of the major drivers of innovation, R&D involves activities that lead to potential advancements in technology. Paramati et al. [64] stated that R&D activities increased the competitiveness of RE technologies by reducing the need for energy and raw materials, mitigating capital costs, and enhancing the efficiency of RE production.

Hydraulic energy is described as a type of energy resource obtained by water flow and the rate of the waterfall. It is based on the principle of converting the potential energy of flowing water into electrical energy. Solar energy involves the systems that store the sun's rays and heat and convert them into electrical energy. Solar energy is also crucial in terms of lowering future CO_2 emissions and generating a RE resource. Wind energy is a natural, renewable, clean, and solar-based energy type. Non-carbon emitting, non-natural resource consuming, non-global warming/acid rain causing features of wind energy to render itself an environmentally friendly energy resource [65]. CO_2 emission is expressed as the emitting of CO_2, which is formed due to burning fossil fuels containing CO_2, into the atmosphere. As energy consumption increases, CO_2 emissions also gradually increase [5].

3.2. Methodology and Model Specification

The relationships are examined by employing the Panel ARDL method. The inconvenience of employing the cointegration method for analyzing series with different degrees of cointegration is overcome by the Panel ARDL method. The advantage of such an approach involves the fact that it investigates whether a cointegration relationship exists between the variables, regardless of the degree to which the variables are cointegrated [66,67]. Nevertheless, the employment of such a method seems suitable due to three reasons. Firstly, the bounds test procedure is simple, and unlike multivariate cointegration methods such as Johansen & Juselius [68], the presence of a cointegration relationship is determined after the lag length of the model is estimated with the OLS. Secondly, the bounds test procedure does not require preliminary testing of the variables included in the unit root test model, unlike Johansen & Juselius's [68] cointegration techniques [69]. The bounds test can be performed regardless of whether they are all I (0) and I (1) or whether they are all cointegrated I (1), except that the series in the model is I (2). Thirdly, the bounds test is highly effective for small or limited sample sets. The PMG estimator is utilized for estimating the panel ARDL. This estimator is preferred for estimating dynamic panels with a large number of cross-sections and time. The PMG estimator allows for estimating different constant terms, different error variances, and short-term impacts for each cross-section unit. Besides, the value of the concordance coefficient can be estimated by employing the PMG method. The concordance coefficient is the estimated value of the coefficient of error correction term in the model exhibiting short-term impacts. By courtesy of this coefficient, the degree of concordance realized in each period can be determined. In other words, the time required to reach a new equilibrium due to an inequilibrium can be determined with the help of this coefficient. The ARDL model for a certain period and a certain number of units is shown in Equation (1).

$$X_{it} = \alpha_{it} + \sum_{i=1}^{m} \gamma_{it}\, Y_{i,t-j} + \sum_{i=1}^{n} \beta_{it}\, Z_{i,t-j} + \mu_{it} \tag{1}$$

In this equation, $X_{i,t}$ denotes dependent variables, γ_{it}, α_{it}, and β_{it} represent parametric coefficients, $Y_{i,t}$ denotes internal variables, $Z_{i,t}$ denotes the control variables, μ_{it} denotes the error term, i denotes a certain number of units, and t represents a certain period.

Models are established to investigate the relationships between RE sub-indicators and FD, the credit gap, and R&D expenditures in compliance with other studies [70–73]. Indicators of the RE sector occupy crucial places in the literature. In this framework, the models based on the study are not only the models that include the variables associated with RE, but they also utilize the CO_2 emission variable as an explanatory variable. In these models, an attempt has been made to figure out which RE variables are associated with the FD of countries, credit gap, and R&D expenditures. The ARDL model and its phases established for regression and bounds testing for models with three dependent variables and four independent variables are presented below. Equation (2) has been established on the basis of the theoretical model applied in [3] in order to establish the relationship between financial development and renewable energy sources. Equation (3) was developed based on the theoretical model applied in [37] to examine the relationship between renewable energy sources and credit risk. Equation (4) has been constructed on the basis of the theoretical model applied in [54,55] studies in order to examine the causality relationship between renewable energy sources and R&D studies.

$$FDI_{i,t} = \beta_0 + \beta_1 HYDRO_{i,t} + \beta_2 SOLAR_{i,t} + \beta_3 WIND_{i,t} + \beta_4 CO2_{i,t} + \epsilon_{i,t} \tag{2}$$

$$CGAP_{i,t} = \beta_0 + \beta_1 HYDRO_{i,t} + \beta_2 SOLAR_{i,t} + \beta_3 WIND_{i,t} + \beta_4 CO2_{i,t} + \epsilon_{i,t} \tag{3}$$

$$RND_{i,t} = \beta_0 + \beta_1 HYDRO_{i,t} + \beta_2 SOLAR_{i,t} + \beta_3 WIND_{i,t} + \beta_4 CO2_{i,t} + \epsilon_{i,t} \tag{4}$$

The cointegration relationships among the variables have been analyzed by performing the bounds test. To this end, an unrestricted ECM has been established. The adapted version of the model for this study is given below.

$$\begin{aligned} \Delta FDI_{i,t} = \alpha 0 + & \sum_{i=1}^{m} \beta_{1it} \Delta FDI_{i,t-i} + \sum_{i=0}^{n} \beta_{2it} \Delta HYDRO_{i,t-i} + \sum_{i=0}^{p} \beta_{3it} \Delta SOLAR_{i,t-i} + \sum_{i=0}^{r} \beta_{4it} \Delta WIND_{i,t-i} \\ & + \sum_{i=0}^{h} \beta_{5it} \Delta CO2_{i,t-i} + S_1 FDI_{i,t-1} + S_2 HYDRO_{i,t-1} + S_3 SOLAR_{i,t-1} + S_4 WIND_{i,t-1} + S_5 CO2_{i,t-1} \\ & + \mu_t \end{aligned} \tag{5}$$

$$\begin{aligned} \Delta CGAP_{i,t} = \alpha 0 + & \sum_{i=1}^{m} \beta_{1it} \Delta CGAP_{i,t-i} + \sum_{i=0}^{n} \beta_{2it} \Delta HYDRO_{i,t-i} + \sum_{i=0}^{p} \beta_{3it} \Delta SOLAR_{i,t-i} + \sum_{i=0}^{r} \beta_{4it} \Delta WIND_{i,t-i} \\ & + \sum_{i=0}^{h} \beta_{5it} \Delta CO2_{i,t-i} + S_1 CGAP_{i,t-1} + S_2 HYDRO_{i,t-1} + S_3 SOLAR_{i,t-1} + S_4 WIND_{i,t-1} + S_5 CO2_{i,t-1} \\ & + \mu_t \end{aligned} \tag{6}$$

$$\begin{aligned} \Delta RND_{i,t} = \alpha 0 + & \sum_{i=1}^{m} \beta_{1it} \Delta RND_{i,t-i} + \sum_{i=0}^{n} \beta_{2it} \Delta HYDRO_{i,t-i} + \sum_{i=0}^{p} \beta_{3it} \Delta SOLAR_{i,t-i} + \sum_{i=0}^{r} \beta_{4it} \Delta WIND_{i,t-i} \\ & + \sum_{i=0}^{h} \beta_{5it} \Delta CO2_{i,t-i} + S_1 ARGE_{i,t-1} + S_2 HYDRO_{i,t-1} + S_3 SOLAR_{i,t-1} + S_4 WIND_{i,t-1} + S_5 CO2_{i,t-1} \\ & + \mu_t \end{aligned} \tag{7}$$

The models that contain the error term (ECT):

$$\begin{aligned} \Delta FDI_{i,t} = \alpha 0 + & \sum_{i=1}^{m} \beta_{1it} \Delta FDI_{i,t-i} + \sum_{i=0}^{n} \beta_{2it} \Delta HYDRO_{i,t-i} + \sum_{i=0}^{p} \beta_{3it} \Delta SOLAR_{i,t-i} + \sum_{i=0}^{r} \beta_{4it} \Delta WIND_{i,t-i} \\ & + \sum_{i=0}^{h} \beta_{5it} \Delta CO2_{i,t-i} + \sum_{i=0}^{w} \gamma ECT_{i,t-1} + \mu_t \end{aligned} \tag{8}$$

$$\begin{aligned} ECT_{i,t} = FDI_{it} - \sum_{i=1}^{m} F_{1i}\Delta FDI_{i,t-1} - \sum_{i=0}^{n} F_{2i}\Delta HYDRO_{i,t-1} - \sum_{i=0}^{p} F_{3i}\Delta SOLAR_{i,t-1} - \sum_{i=0}^{r} F_{4i}\Delta WIND_{i,t-1} \\ - \sum_{i=0}^{h} F_{5i}\Delta CO2_{i,t-1} \end{aligned} \tag{9}$$

$$\begin{aligned} \Delta CGAP_{i,t} = \alpha 0 + \sum_{i=1}^{m} \beta_{1it}\Delta CGAP_{i,t-i} + \sum_{i=0}^{n} \beta_{2it}\Delta HYDRO_{i,t-i} + \sum_{i=0}^{p} \beta_{3it}\Delta SOLAR_{i,t-i} + \sum_{i=0}^{r} \beta_{4it}\Delta WIND_{i,t-i} \\ + \sum_{i=0}^{h} \beta_{5it}\Delta CO2_{i,t-i} + \sum_{i=0}^{w} \gamma ECT_{i,t-1} + \mu_t \end{aligned} \tag{10}$$

$$\begin{aligned} ECT_{i,t} = CGAP_{it} - \sum_{i=1}^{m} F_{1i}\Delta CGAP_{i,t-1} - \sum_{i=0}^{n} F_{2i}\Delta HYDRO_{i,t-1} - \sum_{i=0}^{p} F_{3i}\Delta SOLAR_{i,t-1} - \sum_{i=0}^{r} F_{4i}\Delta WIND_{i,t-1} \\ - \sum_{i=0}^{h} F_{5i}\Delta CO2_{i,t-1} \end{aligned} \tag{11}$$

$$\begin{aligned} \Delta RND_{i,t} = \alpha 0 + \sum_{i=1}^{m} \beta_{1it}\Delta RND_{i,t-i} + \sum_{i=0}^{n} \beta_{2it}\Delta HYDRO_{i,t-i} + \sum_{i=0}^{p} \beta_{3it}\Delta SOLAR_{i,t-i} + \sum_{i=0}^{r} \beta_{4it}\Delta WIND_{i,t-i} \\ + \sum_{i=0}^{h} \beta_{5it}\Delta CO2_{i,t-i} + \sum_{i=0}^{w} \gamma ECT_{i,t-1} + \mu_t \end{aligned} \tag{12}$$

$$\begin{aligned} ECT_{i,t} = RND_{it} - \sum_{i=1}^{m} F_{1i}\Delta RND_{i,t-1} - \sum_{i=0}^{n} F_{2i}\Delta HYDRO_{i,t-1} - \sum_{i=0}^{p} F_{3i}\Delta SOLAR_{i,t-1} - \sum_{i=0}^{r} F_{4i}\Delta WIND_{i,t-1} \\ - \sum_{i=0}^{h} F_{5i}\Delta CO2_{i,t-1} \end{aligned} \tag{13}$$

In these equations, α is the constant term; Δ denotes the difference of the variable; S1, S2, S3, S4, and S5 denote the long-term coefficients; and μ_t stands for the error term. m, n, p, r, h, w coefficients indicate the lag length of the relevant variables, and the suitable lag length is chosen according to the critical values of Akaike, Schwarz, and Hannan–Quinn criteria. $ECT_{i,t-1}$ is the error correction term and the parameter γ indicates the adjustment rate of the equilibrium level. The ones given with other alphabetical abbreviations express the meanings in the variable definition.

In performing the panel cointegration tests, the existence of relationships between dependent and independent variables is investigated. Nevertheless, causality analysis is required to determine the direction of the existing causality. The test developed by D-H [74] is a bootstrap panel causality test and is more powerful than others. In this test, test statistics and probability values are calculated using the Monte Carlo simulation. In the panel causality test, the null hypothesis (H_0) is defined as "No causality exists running from Y to X for all units", and the alternative hypothesis (H_1) implies that "There is causality running from Y to X for all units" [75]. The test statistic used to test the underlying hypothesis is the sum of individual Wald statistics. The basic equation of the panel causality test is presented in Equation (14).

$$Y_t = \alpha_i + \sum_{k=1}^{K} Y_i^k Y_{i,t-k} + \sum_{k=1}^{K} \beta_i^k X_{i,t-k} + \epsilon_{i,t} \tag{14}$$

The hypotheses are formulated as follows.

H_1. *A causal and positive relationship exists between the FD index and RE consumption.*

H_2. *A causal and negative relationship exists between CG risk and RE consumption.*

H_3. *A causal and positive relationship exists between R&D expenditures and RE consumption.*

In order to establish a more financially sound economic infrastructure, financial development, which is expressed by the development of money and capital markets, is of great importance in increasing investments and achieving economic growth. Although the literature investigating the relationship between financial development and renewable energy consumption is quite limited, there are studies advocating the existence of a positive relationship between financial development and renewable energy consumption [73,76]. Wu and Broadstock [73] investigated the impact of financial development and institutional quality on renewable energy consumption and found that financial development and institutional quality had a positive impact on renewable energy consumption. Kutan et al. [77] found that the development of the stock market, which is an indicator of financial development, in some developing country economies (Brazil, China, India, and South Africa) had a vital role in renewable energy consumption. Anton and Nucu [3] revealed that a positive relationship existed between the three main dimensions of financial development and renewable energy consumption in 28 European Union countries.

Policymakers in various countries and researchers working in this field emphasize that R&D expenditures should be made in order to increase the usage of clean energy and reduce greenhouse gases [78–80]. R&D expenditure is a variable frequently used in many studies conducted in the literature and contributes to the provision of economic welfare by encouraging technological progress [81,82]. In this study, it was suggested that R&D expenditures were the driving force of sustainable development, not economic growth. Progress in innovations not only enhances the efficiency of technology but also contributes to the creation of a clean environment so that economic prosperity and a clean environment are made possible with the encouragement of R&D expenditures [56,83]. In this context, we expect a positive relationship between RD expenditures and Renewable Energy consumption.

A positive and increasing credit deficit indicates that the risks are growing. The Basel committee emphasizes that credits should be closely monitored in cases of positive deficits. Since renewable energy production costs are lower than the energy costs incurred through the use of many fossil fuels, an increase in demand for renewable energy reduces the effect of systematic risks. This situation reduces the need for energy-related credits in the real sector and prevents the credit deficit of countries from growing. In this context, we expect a negative relationship between credit gap risk and renewable energy consumption.

4. Results

Within the scope of the analysis, first of all, the descriptive statistics of the series are examined. Descriptive statistics of the series are presented in Table 2.

Table 2. Descriptive Statistics of the Variables.

Variables	Mean	Median	Std. Dev.	Skewness	Kurtosis
FDI	−0.242063	−0.234796	0.120098	−1.273039	5.470695
CGAP	−1.479051	1.400000	10.73830	−0.713834	2.692857
RND	0.724617	0.777731	0.328963	−0.556146	2.484204
HYDRO	5.075890	5.089834	1.351284	−0.344469	2.313853
SOLAR	0.192583	0.505000	3.067212	−0.114606	1.737697
WIND	2.468628	2.798075	2.379560	−0.991059	4.078198
CO_2	13.58044	13.21299	0.888022	1.265065	3.420311

The mean and median values of the variables are, in general, close to each other. The highest standard deviation value belongs to the SOLAR variable. The kurtosis of the distribution ranges between 1.73–5.47, indicating the asymmetrical feature of distribution. As to the skewness values, it is observed that the distribution is skewed to the right.

Nonetheless, the existence of multicollinearity between the variables is found. The correlation coefficients calculated for this purpose are included in the correlation matrix shown in Table 3. Işık & Belke [84] stated that if the correlation coefficients exceeded 0.80, a multicollinearity problem could have been mentioned. Another method employed to detect multicollinearity is the variance inflation factor (VIF). VIF is estimated to determine the degree to which an argument is associated with other arguments. Curto & Pinto [85] stated that a multicollinearity problem existed among the variables since the VIF value was higher than or equal to 10. The correlation matrix and VIF values are shown in Table 3.

Table 3. Correlation Matrix and VIF Values.

	FDI	**CGAP**	**RND**	**HYDRO**	**SOLAR**	**WIND**	**CO_2**
FDI	1.000						
CGAP	−0.127 *	1.000					
RND	0.131 *	−0.305 *	1.000				
HYDRO	0.107 *	0.081 *	0.240 *	1.000			
SOLAR	−0.317 *	−0.339 *	0.422 *	0.100 *	1.00		
WIND	−0.607 *	0.020 *	0.174 *	−0.090 *	0.701 *	1.000	
CO_2	−0.377 *	−0.105 *	0.570 *	0.448 *	0.306 *	0.281 *	1.00
VIF				1.116	4.323	4.353	2.80

Note: * indicates significance at 1% significance level.

The highest correlation coefficient value observed in the correlation matrix in Table 3 is found as 0.57, which is between the RND and CO_2 variables. The absence of high correlation coefficients allows the exclusion of the multicollinearity possibility among the variables. Besides, the low VIF values support this view. In this context, all selected variables are included in the analysis. Upon performing the panel data analysis, first of all, the stationarity of the series included in the model should be ensured because spurious regression problems may arise in estimations made with non-stationary series [86]. Various panel unit root tests are performed to test the stationarity of the data. The unit root tests to be performed in the study are the 1st-generation panel unit root tests, such as Levin, Lin, and Chu (LLC), Im Pesaran Shin (IPS), and Fisher ADF Chi-square unit root tests. They allow the coefficients to be heterogeneous by removing the condition that the autoregressive coefficient of cross-section units should be homogeneous. They also argued that, unlike individual unit root tests, it has limited power compared to alternative hypotheses that have extremely persistent deviations from equilibrium. In this respect, these unit root tests are recommended for analyses with small samples in which the extreme deviation is felt even more [87]. Unit root test results are tabulated in terms of statistics and probability values and the results are presented in Table 4.

Table 4. Panel Unit Root Test Results.

Variables	**LLC**		**IPS W-Stat.**		**ADF-Fisher Chi-Square**	
	Test Sta.	***p*-Value**	**Test Sta.**	***p*-Value**	**Test Sta.**	***p*-Value**
FDI	−3.21627	0.0006 *	−4.39482	0.0000 *	47.5223	0.0000 *
ΔFDI	−5.22739	0.0000 *	−6.84404	0.0000 *	70.1263	0.0000 *
CGAP	−2.20810	0.0136 **	−1.58871	0.0561 ***	28.5544	0.0120 **
ΔCGAP	−2.01422	0.0220 **	−1.02859	0.1518	31.9750	0.0040 *
RND	−0.11717	0.4534	0.87558	0.8094	8.39211	0.8679
ΔRND	−5.42623	0.0000 *	−4.88997	0.0000 *	50.4563	0.0000 *
HYDRO	−3.53830	0.0000 *	−3.09781	0.0010 *	33.2458	0.0027 *

Table 4. *Cont.*

Variables	LLC		IPS W-Stat.		ADF-Fisher Chi-Square	
	Test Sta.	*p*-Value	Test Sta.	*p*-Value	Test Sta.	*p*-Value
ΔHYDRO	−7.76036	0.0000 *	−8.44565	0.0000 *	87.2736	0.0000 *
SOLAR	−1.26747	0.1025	1.59231	0.9443	5.77952	0.9717
ΔSOLAR	−5.41612	0.0000 *	−4.63997	0.0000 *	51.4464	0.0000 *
WIND	−14.1065	0.0000 *	−9.84331	0.0000 *	289.792	0.0000 *
ΔWIND	−3.63205	0.0000 *	−4.22729	0.0000 *	45.3998	0.0000 *
CO_2	2.04740	0.9797	2.51722	0.9941	8.63910	0.8535
ΔCO_2	−3.43594	0.0003 *	−5.74045	0.0000 *	59.1278	0.0000 *

Note: *, **, and *** indicate significance at 1%, 5%, and 10% significance levels, respectively.

Since t statistical values of the FDI, CGAP, HYDRO, and WIND variables at the level exceed the critical value level, it is seen that H_0 is rejected. That is, the series is stationary at the level. Since the t statistical values of RND, SOLAR, and CO2 variables are below the critical value level, it is seen that H_0 is not rejected: that is, the series contains a unit root. Upon taking the 1st difference of the series, they are stationary, and H_0 is rejected.

After testing the stationarity, Pedroni [88] and Kao [89] panel cointegration tests are performed to detect long-term relationships. The test results are presented in Tables 5 and 6.

Table 5. Pedroni (1999) [88] Cointegration Test Results.

Model 1	**FDI**		**Model 2**	**CGAP**	**Model 3 RND**	
Statistics	**Statistic Value**	**Prob.**	**Statistic Value**	**Prob.**	**Statistic Value**	**Prob.**
Panel v-Statistic	0.030254	0.4879	−1.210165	0.8869	−0.907519	0.8179
Panel rho-Statistic	−0.876227	0.1905	0.683297	0.7528	−0.528645	0.2985
Panel PP-Statistic	−4.087206	0.0000 *	−2.473964	0.0067 *	−5.749244	0.0000 *
Panel ADF-Statistic	−2.192170	0.0142 **	−3.645199	0.0001 *	−4.027110	0.0000 *
Group rho-Statistic	−0.293303	0.3846	1.850110	0.9679	−0.064739	0.4742
Group PP-Statistic	−5.529959	0.0000 *	−3.778075	0.0001 *	−8.973033	0.0000 *
Group ADF-Statistic	−2.470955	0.0067 *	−3.576916	0.0002 *	−4.220821	0.0000 *

Note: * and ** indicate significance at 1% and 5% significance levels, respectively.

Table 6. Kao (1999) [89] Cointegration Test Results.

Model 1	**FDI**		**Model 2**	**CGAP**	**Model 3 RND**	
Statistics	***t*-Statistic**	**Prob.**	***t*-Statistic**	**Prob.**	***t*-Statistic**	**Prob.**
ADF	−5.558876	0.0000 *	−3.431680	0.0003 *	−3.719359	0.0001 *

Note: * indicates significance at a 1% significance level.

Upon considering Pedroni's cointegration test results, the panel PP-statistics and panel ADF-statistics from within-group statistics, and group PP-statistics and panel ADF-statistics from inter-group statistics, it is seen that H_0 implying "no cointegration relationship exists between the variables" is rejected. In other words, according to the Pedroni cointegration test, there is a long-term relationship between the variables. The Kao cointegration test results support the Pedroni cointegration test results, which determined cointegration relationships among the related variables. In other words, according to the Kao cointegration test results, H_0 implying "no cointegration relationship exists between the variables", is rejected.

According to the Hausman test results, it is understood that the coefficients are homogeneous. According to the obtained results, it is decided to use the PMG estimator. The short- and long-term estimation results of the PMG ARDL model are shown in Table 7.

Table 7. Results for PMG Estimator.

Model 1	FDI		Model 2	CGAP	Model 3	RND
Variable	**Coef.**	***p* Value**	**Coef.**	***p* Value**	**Coef.**	***p* Value**
Long-run Coef.						
HYDRO	0.151542	0.002 *	−7.322607	0.0014 *	0.628512	0.0080 *
SOLAR	0.005246	0.0917 ***	−0.536194	0.0350 **	0.067471	0.0015 *
WIND	0.020914	0.0000 *	−0.779205	0.0600 ***	0.002997	0.7846
CO_2	0.269693	0.0000 *	−3.437412	0.4564	0.912376	0.1174
Short-run Coef.						
ECT (−1)	−0.725370	0.0000 *	−0.985654	0.0000 *	−0.439412	0.0013 *
ΔHYDRO	−0.071165	0.0005 *	5.086047	0.1550	−0.155822	0.0076 *
ΔSOLAR	0.018183	0.3697	−1.497751	0.3902	−0.004750	0.7230
ΔWIND	0.004637	0.7988	−7.304792	0.0026 *	0.043337	0.0114 **
ΔCO_2	−0.191496	0.2116	−29.51912	0.1757	−0.498837	0.0000
Constant	−3.352958	0.0000 *	87.98992	0.0000 *	−1.873676	0.0433 **
Hausman Test	5.954502	0.1672	4.473034	0.3458	8.652423	0.1704

Note: Lag length is determined in accordance with the Akaike Information Criterion (AIC). *, **, and *** indicate significance at 1%, 5%, and 10% significance levels, respectively.

Upon considering the long-term analysis presented in Table 7, it is concluded that hydropower consumption (HPC), wind power consumption (WPC), and CO_2 emission variables in Model 1 have a positive association with the FD index at the 1% significance level; whereas solar power consumption (SPC) is at the 5% level. The increase in the RE consumption of countries increases their FD. In other words, increases in total demand for RE positively affect the FD of countries. In Model 2, a negative and long-term relationship exists between the CG risk variable and the HPC, the SPC, and the WPC variables at the 1%, 5%, and 10% levels, whereas no such relationship exists regarding the CO_2 emission variable. According to the findings of the analysis, this can be interpreted as the rise in demand for energy may be a factor mitigating the CG risk of countries. In other words, the CG risk, which is considered a leading indicator of systemic banking crises, can be reduced by the increase in the demand for RE. In Model 3, a positive and long-term relationship exists between R&N expenditures and the HPC and SPC variables at a 1% significance level, whereas no such relationship exists regarding the WPC and CO_2 emission variables. In other words, R&D expenditures increase as the demand for hydro energy and solar energy increases. The ECT (error correction term) coefficient is negative and statistically significant. Accordingly, the obtained error correction coefficients are calculated as −0.72 in Model 1, −0.98 in Model 2, and −0.43 in Model 3. That is, 72% of the deviation at time t-1 in Model 1, 98% in Model 2, and 43% in Model 3 are corrected at time t. The remarkable point in short-term predictions is that WPC, which is statistically insignificant in the long run in Model 3, is significant in the short run. This result indicates that WPC has a short-term impact on R&D expenditures, and such an impact ceases to exist in the long run. Upon examining the short-term coefficient results of the variables, it can be claimed that they are less effective than the long-term and that the impacts heighten as the duration gets longer. Dumitrescu-Hurlin (D-H) Panel Causality Test Results are presented in Table 8.

Table 8. Dumitrescu-Hurlin (D-H) Panel Causality Test Results.

Causality Direction Model 1	**Null Hypothesis (H_0)**	**Prob.**	**W-Stat.**	**Zbar-Stat.**	**Decision**
HYDRO→FDI	HYDRO=/=>FDI	0.0009 *	3.29598	3.32861	**Reject H_0**
FDI→HYDRO	FDI=/=>HYDRO	0.3444	0.49889	0.94550	Accept H_0
SOLAR→FDI	SOLAR=/=>FDI	0.0015 *	3.20709	3.16716	**Reject H_0**
FDI→SOLAR	FDI=/=>SOLAR	0.0004 *	3.83893	4.12656	**Reject H_0**
WIND→FDI	WIND=/=>FDI	0.0004 *	4.43522	5.06944	**Reject H_0**
FDI→WIND	FDI=/=>WIND	0.0004 *	4.44855	5.06944	**Reject H_0**
CO_2→FDI	CO_2=/=>FDI	0.0025 *	3.09667	3.02406	**Reject H_0**
FDI→CO_2	FDI=/=>CO_2	0.6166	0.79000	0.50066	Accept H_0
Causality Direction Model 2	**Null Hypothesis (H_0)**	**Prob.**	**W-Stat.**	**Zbar-Stat.**	**Decision**
HYDRO→CGAP	HYDRO=/=>CGAP	0.0388 **	4.34680	2.06611	**Reject H_0**
CGAP→HYDRO	CGAP=/=>HYDRO	0.1195	3.83872	1.55680	Accept H_0
SOLAR→CGAP	SOLAR=/=>CGAP	0.0318 **	4.52029	2.14748	**Reject H_0**
CGAP→SOLAR	CGAP=/=>SOLAR	0.2922	3.39700	1.05329	Accept H_0
WIND→CGAP	WIND=/=>CGAP	0.6589	2.75736	0.44149	Accept H_0
CGAP→WIND	CGAP=/=>WIND	0.7175	2.67617	0.36177	Accept H_0
CO_2→CGAP	CO_2=/=>CGAP	0.4648	3.05221	0.73096	Accept H_0
CGAP→CO_2	CGAP=/=>CO_2	0.9905	2.29559	0.01188	Accept H_0
Causality Direction Model 3	**Null Hypothesis (H_0)**	**Prob.**	**W-Stat.**	**Zbar-Stat.**	**Decision**
HYDRO→RND	HYDRO=/=>RND	0.0102 **	4.60259	2.32252	**Reject H_0**
RND→HYDRO	RND=/=>HYDRO	0.4860	2.99961	0.69664	Accept H_0
SOLAR→RND	SOLAR=/=>RND	0.0018 *	5.44638	3.12208	**Reject H_0**
RND→SOLAR	RND=/=>SOLAR	0.4860	2.99961	0.69664	Accept H_0
WIND→RND	WIND=/=>RND	0.0005 *	7.71448	5.44201	**Reject H_0**
RND→WIND	RND=/=>WIND	0.6440	2.74675	0.46216	Accept H_0
CO_2→RND	CO_2=/=>RND	0.0587 ***	4.17172	1.89061	**Reject H_0**
RND→CO_2	RND=/=>CO_2	0.9349	2.20429	0.08163	Accept H_0

Note: → and =/=> indicates the direction and existence of causality respectively. *, **, and *** indicate significance at 1%, 5%, and 10% significance levels, respectively.

Twelve of the 24 causal relationships, which are investigated for Models 1, 2, and 3, support the causal relationship. In Model 1, a unilateral causality exists running from HPC to the FD index at the 1% significance level. That is, although HPC affects FD, the FD index has no impact on HPC. The second causal relationship is a bilateral causality between SPC and the FD index at a 1% significance level. While solar energy demand affects FD, the FD index also has an impact on solar energy demand. The third causal relationship in Model 1 is found between WPC and the FD index. The causality relationship is a bilateral causality relationship between wind energy consumption and the FD index at the 1% significance level. While wind energy demand affects FD, the FD index also has an impact on wind energy demand. The final causal relationship for Model 1 exists between CO_2 emissions and the FD index. There is a unilateral causality from CO_2 emissions to the FD index at the 1% significance level. Although CO_2 emissions affect FD, the FD index has no influence on CO_2 emissions. Findings obtained from Model 1 indicate that the financial development of countries affects renewable energy consumption, whereas renewable energy consumption affects financial development. Developments in the financial intermediation activities of countries reduce the costs of renewable energy investment projects and encourage the usage of environmentally friendly energy resources. The increase in energy investments in countries would positively affect the financial development level of countries. Besides, developments in the securities market within the financial system would enhance financial efficiency by shifting the capital allocation to environmentally- friendly energy projects, and this would increase the demand for renewable energy resources. The findings of Model 1 are supported by the results of the [36] study. The increase in the renewable energy demand of developed countries due to environmental factors creates the need to provide resources for these large-budget investments. The need to obtain financial resources for large-budget investments contributes to deepening the financial resources of countries. On the other hand, causality findings from financial development to renewable energy sources reveal that increases in the level of financial development are one of the important triggers that increase the demand for environmentally friendly energy sources in the long run. Developments in financial intermediation activities will reduce the investment costs of renewable energy investment projects and encourage the use of environmentally friendly energy resources [32–35].

In Model 2, the first causality exists between HPC and CG risk. There is a unilateral causality from HPC to CG risk at a 5% significance level. Although the demand for hydropower affects the CG risk, the CG risk has no impact on the demand for hydropower. In Model 2, the second causal relationship exists between SPC and CG risk. There is a unilateral causality running from SPC to a CG risk at a 5% significance level. Although the demand for solar power affects the CG risk of the countries, the CG risk has no impact on the demand for solar power. Findings obtained from Model 2 reveal that the countries' demands for renewable energy affect the credit deficit risk, which is one of the systematic risks of countries. Renewable energy investment projects cost lower than the energy costs incurred through the use of various fossil fuels. With the increase in the efficiency of banks' intermediation, their tendency to lend increases, and this situation enhances the accessibility of funds in renewable energy investment projects of the real sector and the efficiency of energy investments. Enhancing the efficiency of energy investments increases not only the countries' demands for renewable energy but also reduces the risk of credit deficit. The findings obtained in Model 2 are consistent with the study of [60]. In developed countries, there is a one-way causality relationship from renewable energy sources to credit risk. [59] stated in their study that emission-free loans reduce credit risk. In addition, [37] stated in their study that loans given to the private sector are not used in an environmentally friendly manner. The increase in the demand for renewable energy sources in developed countries causes an increase in the environmentally friendly financing provided by financial institutions. Environmentally friendly financing reduces credit risk [59].

The first causal relationship in Model 3 exists between hydropower consumption and R&D expenditures. There is a unilateral causal relationship from HPC to R&D expenditures at a 5% significance level. Although the demand for hydropower affects R&D expenditures, R&D expenditures have no impact on the demand for hydropower. The second causal relationship in Model 3 exists between solar power consumption and R&D expenditures. A unilateral causal relationship exists from SPC to R&D expenditures at a 1% significance level. Although the demand for solar power affects R&D expenditures, R&D expenditures do not have any impact on the demand for solar power. The third causal relationship in Model 3 is found between WPC and R&D expenditures. A unilateral causal relationship exists from WPC to R&D expenditures at the 1% significance level. Although demand for wind power affects R&D expenditures, R&D expenditures have no impact on demand for wind power. The final causal relationship in Model 3 exists between CO_2 emissions and R&D expenditures. A unilateral causality exists from CO_2 emissions to R&D expenditures at a 10% significance level. Although CO_2 emissions affect R&D expenditures, R&D expenditures do not have any impact on CO_2 emissions. The findings obtained from Model 3 indicate that the countries' demand for renewable energy affects the R&D expenditures of the countries. R&D activities both reduce the need for energy and raw materials, reduce capital costs, and increase the competitiveness of renewable energy technologies by enhancing the efficiency of renewable energy production. The rise in the countries' demands for renewable energy encourages the development and dissemination of technological knowledge to fulfil such demand, encourage energy production, and enable the discovery of alternative energy resources. Our findings in Model 3 are compatible with another study [56]. R&D and innovation activities to be carried out in the field of renewable energy increase renewable energy efficiency and reduce costs. Technological innovations in renewable energy play an important role in reducing total energy intensity and in transitioning to efficient, low-carbon energy systems at the lowest cost. R&D activities increase the competitiveness of renewable energy technologies, both by reducing the need for energy and raw materials and reducing capital costs and by increasing the efficiency of renewable energy production [51–54].

5. Conclusions and Policy Implications

Rapid population growth in the world and developments in technology have led to an increase in both production and consumption. The rise in production and consumption inevitably revealed the energy demand. The increasing energy demand is largely met by fossil-based energy sources. While problems such as inflation, low growth rates and current account deficit arise in energy-importing countries, RE resources emerge as an important alternative to fossil fuels, since fossil-based energy reserves are limited and cause global warming and environmental problems.

This study aims to evaluate the relationships between RE, CG risk, FD and R&D expenditure for G8 economies over the period 1996–2018. This study focuses on the G8 countries. The relationships between the variables in the study are analyzed by employing the Panel ARDL method and the D–H panel causality test.

HPC, WPC, and CO_2 emission variables in Model 1 have a positive association with the FD index at the 1% level, whereas SPC is at the 5% level. These empirical findings show that the rise in the RE consumption of countries increases their FD. In other words, increases in total demand for RE positively affect the FD of countries. According to the results from Model 2, the rise in demand for energy may be a factor mitigating the CG risk of countries. In Model 3, it is concluded that R&D expenditures increase as the demand for hydro energy and solar energy increases. This result asserts that WPC has a short-term impact on R&D expenditures, and such an impact ceases to exist in the long run. The panel causality test results reveal that twelve of the twenty-four causality relationships support the causality relationship.

Upon comparing the model results with the literature, we can see that the results of our studies are mostly consistent with each other. There is in-depth literature on financial development in the use of renewable energy resources [3,29–32]. Similarly, a causal relationship running from financial development to wind and solar energy is observed in our study. The increase in the financial depth of the countries allows the funding of renewable energy investments that require large budgets. On the contrary, there is a causality running from renewable energy sources to financial development, which is consistent with the results of the study [36]. Another result of our study is that there is a unilateral causality running from renewable sources to R&D expenditures, consistent with the study of [56]. This situation causes high-income country groups with financial depth to shift to renewable energy investments in order to maintain sustainable and green growth. R&D studies need to be enhanced for the development of renewable technologies [90]. Finally, a unilateral causality running from renewable energy resources to credit risk, which is consistent with the study [60], was found. [37] stated in their study that when the loans extended to the private sector were not used in an environmentally-friendly manner, they increased the credit risk, and the study [59] stated that the loans extended in the form of zero-emission reduced the credit risk. Therefore, the rise in the usage of renewable energy resources in developed countries indicates that the correct use of loans reduces credit risk.

The nexus of RE, FD, CO_2 emissions, EG, TI, and R&D expenditure has been extensively investigated by scholars in the literature. However, this is the first study to use CG risk in the RE literature. We fill the gap in the literature by concentrating on the association between RE consumption and CG risk. According to the Basel committee, CG risk can contribute as an early warning system for countries to evaluate their systematic risks. The fact that the gap is positive and increases assert that the credits are moving away from their trend and the risks are accumulating. The BIS recommends close monitoring of credits when the gap is positive. As the demand for RE consumption in countries increases, the credit gap decreases. In other words, increases in RE demand have a reducing effect on systematic risks in countries. The main reason for this situation is that RE production costs are lower than the energy costs obtained from many fossil fuels. This situation reduces the need for energy-related credits in the real sector and prevents the growth of the credit gap of the countries. In this context, financial policies are needed to address the increase in RE demand on a global scale. This study suggests that policymakers should limit the exemptions and exceptions that encourage fossil fuel consumption and that these exemptions and exceptions can use for economically and environmentally efficient sustainable energy projects. However, since increasing the use of RE is related to environmental awareness and education, it can be suggested as a policy option to protect the environment by expanding social education programs.

Supporting renewable energy investments depends not only on energy policies implemented by countries and legal regulations but also on technical and infrastructure factors, resources to finance energy investments, and market conditions. Although conventional funding methods can be used to finance these energy investments, funding methods designed by taking into account the characteristics of renewable energy resources can also be chosen. Private sector bonds or green bonds can also be issued in the realization of renewable energy projects. Green bonds differ from conventional bonds mainly in that the proceeds of the green bond are utilized in green projects. In order to ensure the efficient usage of renewable energy projects, the state should provide support on issues such as lower credit costs and tax reductions, and the importance of a clean environment and renewable energy should be emphasized in educational curricula.

Understanding the extent to which financial development drives countries' R&D expenditures, credit risk variables and usage of renewable energy sources enable G8 countries to contribute to the development of the energy sector by implementing policies based on sustainable, green growth and reducing dependency on energy imports.

Our study includes various limitations in terms of country groups, time periods and variables used. Firstly, our findings are limited by the size of the data that we could obtain. Secondly, we had to concentrate on three different models using the subcomponents of renewable energy. Moreover, we confirmed that the usage of renewable energy resources reduced credit risk and increased R&D expenditures in G8 country groups. It is recommended that future studies should try to confirm this situation by including other country groups and using the credit risk variable in their models.

Author Contributions: Conceptualization, U.Ü.; Data curation, F.Y.; Formal analysis, F.Y. and U.Ü.; Project administration, E.E.; Visualization, E.H.Ç.; Writing—original draft, U.Ü., F.Y. and A.K; Review & editing, U.Ü, F.Y., A.K., E.E. and E.H.Ç. All authors have read and agreed to the published version of the manuscript.

Funding: This article has not been supported by any fund.

Data Availability Statement: Publicly available datasets were analyzed in this study. This data can be found here: the International Monetary Fund (IMF) database, the Bank for International Settlements (BIS) database, the World Bank (WDI) database, and the British Petroleum (BP) Statistical Review of World Energy database.

Conflicts of Interest: The authors declare no conflict of interest.

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