



Is there any recovery power for economic growth from green finance? Evidence from OECD member countries

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Abstract

This paper investigates the dynamic interactions between green finance, economic growth, and green energy consumption for the Organization of Economic Cooperation and Development (OECD) members. The econometric analysis is conducted on annual data gathered throughout 2010–2020 using different estimation techniques of the Vector Autoregressive model, causality, and co-integration approaches. The main results confirmed a positive bi-directional relationship between GDP and green energy consumption. In addition, there is a two-way relationship between the volume of green bond issuance and the use of green energy in OECD countries. The recommended practical policy recommendations are establishing a unified green bonds market among OECD member states, prioritizing green projects to support the issued green bonds, improving the financial system, and financing rural electrification and electric vehicle transition by green bonds.

Keywords Green recovery · Decarbonization economic policy · COVID-19 · Causality approach · Green finance

JEL Classification Q41 · K31 · C32

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1 Introduction

The emergence of the coronavirus disease at the end of 2019 and its transformation into a pandemic in the world in 2020 severely disrupted economic growth globally. Meyer et al. (2022) declare that the COVID-19 pandemic has caused severe exogenous supply and demand shocks for firms and businesses. It has changed the expectations of businesses for future situations of economic markets. Teng et al. (2022) argue that COVID-19 has altered the traditional global supply chain causing unprecedented shock to economic sectors. In order to control the rapid spread of COVID-19 and reduce the deaths caused by this pandemic, governments were forced to order the closure of cities, economic enterprises, hotels, and domestic and international travel (Nicolar et al., 2020). These measures lead to the reduction of economic activities, stagnation, the spread of poverty and unemployment, the reduction of people purchasing power, and the bankruptcy of many economic enterprises. In such a way, the years 2020 and 2021 can be called dark and stagnant years for the world economy.

With the discovery of the COVID-19 vaccine, the threat caused by this pandemic is fading gradually, and the economy of many countries can return to their regular activity. However, to compensate for the economic stagnation of the previous years, the governments have announced an economic growth program with all the power and capacities under the concept of economic growth recovery in the world economic literature (Wang and Zhang 2021). The recovery of economic growth can neutralize COVID-19's adverse effects and increase government budget income. Improve job creation and put the welfare level of society in a more favorable situation.

Achieving economic growth as a priority for the world's countries is a logical and correct matter (Economic growth is the basis of development, job creation, poverty alleviation, and reduction of investment risk in the world.). Because in the shadow of such economic growth, the post-COVID-19 era can be accompanied by a decrease in unemployment and flourishing of human development. Another issue that should be considered is achieving eco-friendly economic growth that can put countries on the path of sustainable development indicators. The fact that countries should think about protecting their environment has been a concern of the United Nations for the last few decades, and countries have always been invited to cooperate comprehensively to eliminate the threats of global warming and environmental pollution. Many experts (e.g., Elavarasan et al. 2021) have considered the post-COVID era a global opportunity to advance sustainable development indicators. While another group of experts (e.g., see Ray et al. (2022), who confirmed the temporary impact of COVID-19 on the reduction of CO₂ emissions, has called countries' lack of attention to environmental issues and focusing only on revitalizing economic engines a severe threat to the path of sustainable development in the post-COVID-19 era.

One of the issues in achieving green economic recovery is the lack of sufficient capital to promote green projects in countries. It is crucial to open a special field for finance called green finance (Taghizadeh-Hesary and Yoshino, 2019; Zhang

et al., 2022a; Taghizadeh-Hesary et al., 2022; Zhao et al. 2022). On the other hand, assessing the rule of green finance instruments in filling the finance gap of green projects is essential.

Developing green financing tools are a globally accepted solution for developing green projects in different countries (Sun et al., 2022). It can help increase investment in clean energy development projects, reduce energy intensity and increase energy effectiveness. Green financing tools can help attract capital from the private sector and abroad for developing and implementing green energy projects, with favorable guarantees from the issuer and a reasonable investment return rate. One of the newest and most effective green financing tools is green bonds. In recent decades, many countries have been developing their green bond markets and using this financing tool to develop green energy consumption and reduce dependence on fossil energy. Historically, the World Bank issued the first green bond in November 2008 following the intentions of Swedish Pension Funds to invest in clean environment projects in 2007. Figure 1 shows the development trend of the green bond market in different regions of the world. According to the data, the volume of green bonds issued worldwide has increased from 37 billion US dollars in 2014 to more than 500 billion US dollars in 2021, which shows a 13-fold increase in this market globally. Among the different regions of the world, Europe and Asia–Pacific are the two leaders in developing the global green bond market. In such a way, the number of green bonds issued in Europe in 2021 was about 265 billion US dollars, and Asia–Pacific has more than 130 billion US dollars. This degree of green bond market development shows the importance of this green financing tool for the countries of the world, especially Europe and Asia–Pacific. Countries that can issue green bonds with proper legislation and transparency of the market will surely enjoy its positive effects during the path of energy transition and environmental protection.

Studying how GDP changes, issued green bonds, and clean energy demand can provide essential and effective strategic policies. Especially in the post-COVID-19

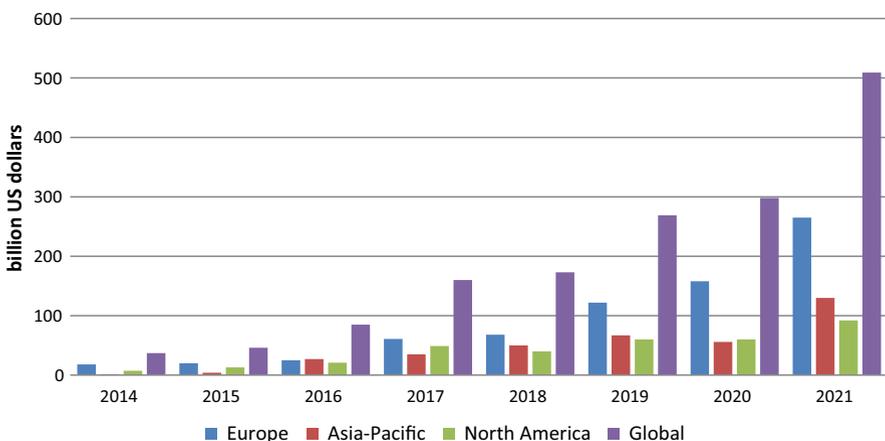


Fig. 1 Issued green bonds in different regions, 2014–2021, billion US dollars. *Source:* Authors from Climate bonds (<https://www.climatebonds.net/market/data/>)

era, policymakers are doing their best to use different programs and tools to increase the consumption of renewable energy compared to the consumption of fossil energy and increase their economic growth to a greater share of the consumption of green energy. However, the issue of the existence/absence of nexus between economic growth and the issuance of green bonds, between economic growth and clean energy consumption, and the issuance of green bonds—clean energy consumption, requires more comprehensive and detailed research.

The main objective of this paper is to explore the causal relationship between issued green bonds, economic growth, and green energy consumption for 38 OECD member countries throughout 2010–2020. The main reasons for choosing OECD as the case study are: OECD member countries have strong economies and suitable infrastructures for developing green energy. Therefore, it is essential to investigate the issue of issuing green bonds and its effect on economic variables. According to the OECD Economic Outlook (2022), member countries have experienced an unprecedented economic recession due to the spread of COVID-19. The predictions are that their economic power will be restored to the level before the spread of COVID-19. Another reason is the developing of the green financing market in OECD member countries. The issuing of green bonds started in 2007–8 and reached over 3 billion US dollars in 2011, 95 billion US dollars in 2016, and around 3 trillion US dollars in 2021.

The contributions of this paper to the previous literature are from the following aspects: The triple causal relationship between green bond issuance, economic growth, and clean energy consumption has been considered in this research. Moreover, a panel of OECD countries is analyzed through the panel-VAR technique, which considers all variables as exogenous, providing practical results. In addition, this article discusses the main obstacles to developing the green bond market in OECD countries in the post-COVID-19 era.

To fill in the literature gap and contribute to existing literature, the research structure is determined as below: Sect. 2 provides a brief discussion about the previous studies to recognize the literature gap to fill in. The following Section clarifies the data information and the econometric modeling strategy. Section 4 argues the empirical findings and estimations. Section 5 expresses a discussion with the aim of clarification developing barriers to the green bonds market in the OECD member countries. Section 6 provides the robustness check results. The final section concludes the paper and provides policy implications and recommendations for future research.

2 Literature review

To discuss the literature review, two separate approaches can be considered. The first approach to the subject literature is to review studies that have addressed the importance of green financing, especially green bonds. In a study, Uddin et al. (2022) expressed that green bonds have spillover impacts different aspects of local and global economies. It can provide a better investment climate for green projects and help countries achieve sustainable development. Flammer (2021) addressed green

bonds as an efficient instrument to promote climate-friendly investments in countries. In another study, Tang and Zhang (2020) argued that green bonds could provide significant advantages for shareholders leading to a better green capital market. Several studies have focused on the fact that to achieve sustainable development. It is necessary to establish and develop green bonds market. Bhutta et al. (2022) studied the impacts of green bonds and concluded that promoting green bonds is helpful in combating environmental degradation. In another study, Wang et al. (2022) analyzed monthly data from 2011 to 2021 of different economies and found that issued green bonds significantly contribute to sustainable development. Tolliver et al. (2020) expressed that in line with the Paris Agreement, all countries try differently to promote green financing tools, and green bonds are among the most appropriate instruments. Voica et al. (2015) declared that promoting green investments is essential for countries to increase the share of consumption of green energy in the total energy consumption basket. The other fresh studies about the importance of green financing instruments are summarized in Table 1 as follows:

In the second literature review approach, there are studies focusing on the relationship between green bonds, green energy consumption, and economic growth. Ntsama et al. (2021) expressed that issued green bonds have different economic and social advantages improving good governance indicators and social responsibilities, which are two success wings for sustainable development. Lie t al. (2021) studied the interactions between green energy and green finance in the case of China from 1990 to 2020. The Wavelet Power Spectrum technique findings revealed that green finance positively impacts green energy development. Similarly, Zhou and Li (2022) explored the relationship between green finance, green energy, and sustainable development in China. They found out the crucial role of clean energy consumption and green finance tools on environmental sustainability. Zhang et al. (2022b) argued that as green finance tools can enhance private participation in green projects, it also causes GDP growth and environmental protection. In another study, Yang et al. (2022) concentrated on G7 economies and denoted green financing tools' significant roles in green economic growth and sustainable development. Rasoulinezhad and Taghizadeh-Hesary (2022) applied the STIRPAT (the stochastic impact by regression on the population, affluence, and technology) to analyze the impacts of green finance in 10 economies. The major findings confirmed green bonds' positive and statistically significant role on CO₂ emissions reduction and green project promotion. Huang et al. (2022) emphasized green finance's role in promoting green innovation, which can solve the problem of high energy intensity and low energy efficiency in non-developed economies. Focusing on the linkage between green fiancé and green economic performance, Feng et al. (2022a) analyzed a group of countries in the Belt and Road Initiative (BRI) throughout 2008–2018. They concluded that government policies are crucial to reach efficient green financing tools to go toward green economic recovery in the post-COVID era. In another fresh study, Kung et al. (2022) investigated the impacts of issued green bonds on bioenergy development in China. The results of conducting a recourse model confirmed the positive role of issued green bonds on biopower and biofuels in Taiwan. Cui et al. (2022) studied the green bonds market under COVID-19. They concluded that the market of green bonds was affected harshly by the consequences of COVID-19. However, the market

Table 1 Summarization of fresh studies on green bonds' role in sustainable development. *Source:* Authors

Author/s	Year of research	Main findings
Teti et al.	(2022)	Issued green bonds are efficient instruments for investors in green projects
Ning et al.	(2022)	Green bonds are practical tools for promoting sustainable green financing
Baldacci and Possamai	(2022)	Providing incentives by governments may lead to a more efficient green bonds market, causing better green projects' promotion
Lin and Hong	(2022)	Green bonds market helps China to promote green projects and energy transformation
Chai et al.	(2022)	Green bonds are appropriate tools in the COVID-19 era in order to increase clean energy consumption
Khan et al.	(2022)	In Asia, green finance reduces environmental pollution
Mamun et al.	(2022)	Green bonds accelerate the speed of the decarbonization process around the world
Nguyen et al.	(2022)	Developing economies can use green bonds to access sufficient capital to invest in green projects
Loffler et al.	(2021)	Green bonds help countries to conduct greenium concept, which means environment-friendly economic activities
Chen and Zhao	(2021)	Environment-related projects in China are positively affected by green bonds

has the potential to recover and positively helps countries promote green economic activities.

Reviewing the collection of the latest literature on green bonds, economic growth, and clean energy consumption shows that, so far, no comprehensive and in-depth research has been done on the causal relationship of these three variables for OECD countries. Therefore, this article tries to solve this literature gap and can have diverse and new strategic and practical results for experts and policymakers. The causal relationship between these three variables is more important for the post-COVID-19 era, when the countries of the world seek to achieve the recovery of economic growth and prioritize sustainable development indicators.

3 Strategy and method of research

3.1 Data sources and characteristics

This paper tries to find out the causal interactions between issued green bonds, economic growth, and renewable energy consumption for the case of 38 OECD member countries. The countries are experiencing the situation of economic growth recovery in the post-COVID era with consideration of sustainable development indicators

achievements. To do the empirical analysis, the annual data of variables are gathered from different global databases (the World Bank, the initiative Climate Bonds; BP Statistical Review of World Energy 2021; OECD Main Economic Indicators (MEI)) throughout 2010–2020 (observation numbers for panel data are 418).

Regarding three selected variables in the OECD member countries, Table 2 reports the correlation among these series:

The results of pairwise correlation among three variables depicted the positive relationship between economic growths, issued green bonds, and green energy consumption in the 38 OECD member countries, meaning that all these variables may have significant impacts on each other.

3.2 Estimation process strategy

Choosing an appropriate estimator is a crucial step in doing research. In this paper, to explore how three variables of economic growth, issued green bonds and green energy consumption, are related, the Vector Autoregressive model (VAR) in the panel data framework for 38 OECD member states is employed. The estimation technique of VAR has various advantages (Grossmann et al. 2014), including exogenous observations, and can be written as Eq. 1:

$$y_{i,t} = \beta_0 + \sum_{j=1}^p \beta_j y_{i,t-j} + \mu_i + e_{i,t} \quad (1)$$

$$i = [1, \dots, 37], t = [2010 - 2020]$$

In the above Equation, y denotes dependent variables. β and μ are the coefficient vector and heterogeneity, respectively. e represents a random error.

A possibility that can be done in the framework of the panel-VAR approach model is to implement variance decomposition, which shows a percentage change in the variable's value from which variable and how much.

According to the three variables of issued green bonds, economic growth, and green energy consumption, the paper will examine the three following Eqs. (2–4):

$$\Delta \text{EGRO}_{i,t} = f(\Delta \text{EGRO}_{i,t-1}, \Delta \text{GBON}_{i,t-1}, \Delta \text{GEC}_{i,t-1}) \quad (2)$$

Table 2 Correlations between three variables of the model. *Source:* Author's compilation from SPSS 20

Variables	Economic growth	Issued green bonds	Green energy consumption
Economic growth	1	–	–
Issued green bonds	0.014	1	–
Green energy consumption	0.081	0.321	1

$$\Delta \text{GBON}_{i,t} = f(\Delta \text{EGRO}_{i,t-1}, \Delta \text{GBON}_{i,t-1}, \Delta \text{GEC}_{i,t-1}) \quad (3)$$

$$\Delta \text{GEC}_{i,t} = f(\Delta \text{EGRO}_{i,t-1}, \Delta \text{GBON}_{i,t-1}, \Delta \text{GEC}_{i,t-1}) \quad (4)$$

where Δ shows the first variable difference in the model.

In order to ensure the correctness of using the Vector Autoregression method, it is necessary to perform unit root tests. In this paper, the cross-sectional dependency of variables is checked by the Pesaran Cross-Sectional test. Then the second-generation panel unit root test (Pesaran CIPS Pesaran 2007) is conducted. In the next step, the Westerlund co-integration test is used to find out the existence of a long-term relationship among series. The Granger Wald causality test is employed to ascertain the existence and direction of causality relationship. The conceptual framework of the empirical modelling strategy is shown in Fig. 2 as follows:

4 Estimation results and discussions

In the first step, the existence of the unit root in the series is checked. Pesaran's cross-sectional test is employed to clarify whether the variables are interdependent. The results of this test are represented in Table 3:

The findings, reported in Table 3, confirmed the dependency between variables. Therefore, the second generation of panel data unit root tests can be employed to find out whether exists a unit root in series. To this end, the CIPS (Table 4) is conducted and depicts the non-stationarity of series at level.

Since the three variables of our model are not stationary, the existence of co-integration nexus between series is checked employing the Westerlund's panel co-integration test. The test's results, reported in Table 5, confirmed the absence of co-integration linkage between three variables.

According to the above carried preliminary tests, it is not possible to do an estimation with error correction. As a popular solution, we can transform all variables into the logarithmic form which may lower the challenge of heterogeneity of variables. Of course, it should be pointed out that because the growth rate cannot be

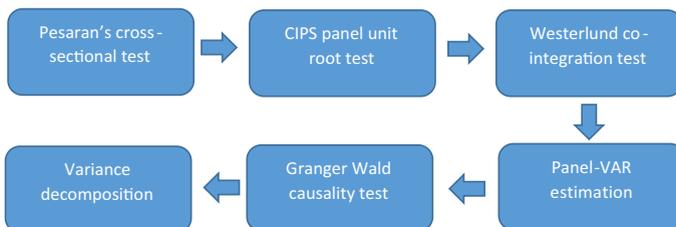


Fig. 2 Conceptual framework of empirical modeling. *Source:* Authors' depiction

converted into a logarithm, we are forced to change the economic growth variable. The best alternative for this variable is the amount of GDP.

The findings of re-conducting the Pesaran panel unit root test, listed in Table 6, confirmed data non-stationarity for issued green bonds and GDP. In contrast, the CIPS statistics for green energy consumption are close to the critical value causing the need to test stationarity for the variables in the form of logarithm and first different approach.

The results of CIPS for the first difference of the logarithmic series, represented in Table 7, depicted the stationarity of all three series.

After determination of stationarity of variables, the VAR estimation can be conducted. However, prior to estimation, it is necessary to recognize an appropriate number of lags. To this end, the Hansen and Singleton (1982) and Andrews and Lu (2001) criteria are employed (Table 8):

By determining the appropriate lags number, the panel single-lag VAR technique is conducted to evaluate the impacts of variables. The results of the estimation are reported in Table 9:

The major empirical estimation results confirmed that the lagged GDP and green energy consumption positively impact the GDP variable. The green energy demand affects the growth rate of issued green bonds has statistically significant value. Therefore green energy consumption level of OECD in the previous period impacts the development of green bonds in the present period. Green energy demand in the examined OECD member countries is influenced by the previous values of GDP and issued green bonds. Both growth rates have the impact of increasing the level of consumption of green energy in these economies.

Table 3 Pesaran’s cross-sectional test. *Source:* Authors’ calculations Pesaran’s cross-sectional

–	CD-test	Prob	Mean ρ	Mean abs (ρ)
Economic growth	44.394	0.00	0.70	0.80
Issued green bonds	39.402	0.00	0.69	0.71
Green energy consumption	38.711	0.00	0.54	0.68

Table 4 CIPS unit root test. *Source:* Authors’ calculations

Variable	CIPS	Critical value		
		10%	5%	1%
Economic growth	– 1.510	– 2.06	– 2.18	– 2.35
Issued green bonds	– 2.023	– 2.06	– 2.18	– 2.35
Green energy consumption	– 2.429	– 2.06	– 2.18	– 2.35

Table 5 Westerlund’s co-integration test. *Source:* Authors’ calculations

	Stat	Prob
H0: No co-integration	0.7983	0.2193

Table 6 CIPS unit root test (logarithmic variable). *Source:* Authors' calculations

Variable	CIPS	Critical value		
		10%	5%	1%
GDP	-1.942	-2.06	-2.18	-2.35
Issued green bonds	-2.288	-2.06	-2.18	-2.35
Green energy consumption	-2.351	-2.06	-2.18	-2.35

Table 7 CIPS unit root test (first difference). *Source:* Authors' calculations

Variable	CIPS	Critical value		
		10%	5%	1%
GDP	-2.863	-2.1	-2.21	-2.45
Issued green bonds	-2.895	-2.1	-2.21	-2.45
Green energy consumption	-3.562	-2.1	-2.21	-2.45

Table 8 Lags selection. *Source:* Authors' calculation

Lag	CD	J	J prob	MBIC	MAIC	MQIC
1	0.983	34.53	0.100	-95.014	-18.54	-50.032
2	0.984	18.119	0.443	-70.021	-18.65	-39.992
3	0.821	12.493	0.179	-31.481	-5.390	-16.011

The causal relationship among the three variables is checked in the next step using the Granger-Wald test. The results are reported in Table 10:

According to Table 10, it can be expressed that:

- i. There is a bi-directional linkage between green energy demands toward GDP.
- ii. A bi-directional causality relationship exists between issued green bonds and the volume of consumption of green energy sources.
- iii. There is not any significant causal relationship between issued green bonds and GDP.

The above findings from the results of the causality test of the relationships between the three variables of GDP, published green bonds, and clean energy consumption can be shown in Fig. 3:

The remarks from conducting the causality test are as follows: (i) a bi-directional causality relationship presents between green bonds and green energy consumption, which corresponds to the findings of other studies about green energy (the main role of issued green bonds is the improvement of lowering carbon-projects causing a larger contribution of renewable energy sources in a country), (ii) There is also bi-directional connectivity between GDP and green energy consumption, (iii) A causal linkage was not confirmed between green bonds and GDP, (iv) the concept of "neutrality hypothesis" in the relationship between GDP

Table 9 Panel VAR results.
Source: Authors' calculations

	Coefficient	Standard error	z	P > z
dln (GDP)				
dln (GDP) L1	0.132	0.062	3.442	0.000
dln (GBON) L1	0.031	0.042	1.142	0.319
dln (GEC) L1	0.042	0.011	2.103	0.032
dln (GBON)				
dln (GDP) L1	0.142	0.173	1.243	0.219
dln (GBON) L1	0.041	0.063	1.381	0.201
dln (GEC) L1	0.162	0.031	-3.618	0.000
dln (GEC)				
dln (GDP) L1	0.391	0.131	2.449	0.000
dln (GBON) L1	0.182	0.072	2.229	0.019
dln (GEC) L1	0.184	0.058	1.504	0.283

dln shows the first difference of the logarithm of variables

Table 10 Granger causality
 Wald test. *Source:* Authors' calculations

	Chi2	Df	Prob > Chi2
dln (GDP)			
dln (GBON)	1.513	1	0.281
dln (GEC)	4.421	1	0.028
All	6.318	2	0.024
dln (GBON)			
dln (GDP)	1.295	1	0.313
dln (GEC)	13.193	1	0.010
All	14.048	2	0.000
dln (GEC)			
dln (GDP)	7.221	1	0.000
dln (GBON)	5.459	1	0.025
All	10.582	2	0.009

dln indicates the first difference of the logarithm of variables

and issued green bonds exists in OECD member countries. It is a crucial finding, highlighting that policies related to green bonds market development may not retard GDP size in OECD countries. It can be expressed that any development in the green bonds market may increase the volume of green energy consumption in these economies, which can be defined as a major element for long-run economic growth recovery beyond the shadow of threats of COVID-19.

To ascertain the reliability of estimation results, the stability test, as reported in Table 11, is conducted:

The variance decomposition can be implied to clarify the contributions of variables to change of each other. As reported in Table 12, nearly 0.40% of the variation in GDP is explained by changes in the volume of consumption of renewable energy sources, whereas the volume of issued green bonds has a contribution

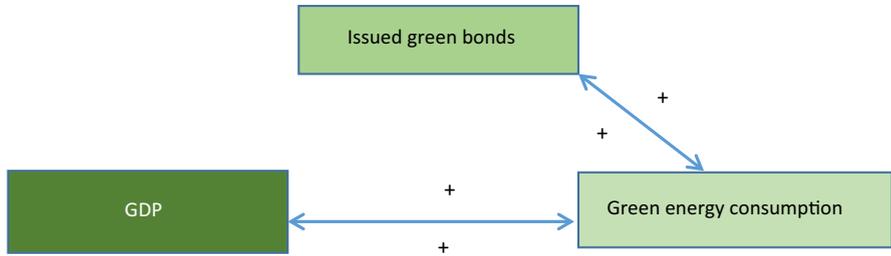


Fig. 3 GDP -Green bonds green energy consumption relationship in OECD. *Source:* Authors’ depiction

of nearly 1.05% to the variation of GDP in OECD member countries. Analyzing variance decomposition of issued green bonds, it can be highlighted that renewable energy consumption and GDP have contributions of nearly 0.40% and 3.43%, respectively to the variation in issued green bonds. In addition, 17.5% and 1.32% of variation in renewable energy consumption are explained by issued green bonds and GDP, respectively.

5 Discussion

As it is clear from the research findings, developing the green bond market as one of the most important green financing tools can play an important role in developing economic growth and clean energy consumption in OECD countries. In addition, developing green financing tools can help these economies to pave the path to sustainable development more easily and quickly. Considering the economic challenges caused by COVID-19 and the war between Russia and Ukraine, this issue is vital for the OECD countries seeking economic recovery based on protecting the environment (OECD, 2020). Historically, the OECD member countries are pioneers in issuing green bonds worldwide. For example, Japan represented its first issued green bonds in October 2014, South Korea sold its first green bonds through the Korea Export–Import Bank (KEXIM) in 2013, and Canada and Italy announced its first issuing green bonds in 2020 and 2021, respectively. Generally, OECD countries have announced various programs to go toward sustainable development. The most famous programs are the 2050 Zero Carbon Emissions in Japan, Clean Power Roadmap for Atlantic Canada, Offshore Wind Energy Roadmap by 2030 in the Netherlands, Turkey’s Decarbonization

Table 11 Stability test. *Source:* Authors’ calculations

Eigenvalue		Modulus
Real	Imaginary	
- 0.274291	0	0.274291
0.182939	0	0.182939
0.089313	0	0.089313

Table 12 Variance decomposition. *Source:* Authors' calculations

Response of	Impulse from		
	dln (GDP)	dln (GBON)	dln (GEC)
dln (GDP)			
1	1.00	0.000	0.000
10	0.981	0.0040	0.0105
15	0.981	0.0040	0.0105
dln (GBON)			
1	0.000	0.999	0.000
10	0.0041	0.985	0.0343
15	0.0041	0.985	0.0343
dln (GEC)			
1	0.1517	0.000	0.8751
10	0.1754	0.0134	0.8549
15	0.1754	0.0134	0.8549

Roadmap by 2050, National Energy Strategy in Italy, and the US Sustainable Finance Roadmap. In all these programs, the issue of green financing or strategies to solve the insufficiency of capital to promote green projects has been drawn big attention. However, barriers to develop green financing tools such as green bonds exist in OECD. For instance, the green bonds market's transparency remains a crucial challenge. In the absence of transparency in the green bond market, investors will be afraid to participate and bring their capital. Therefore there will be little trust in the green bond market without transparency. Russia's military tension with Ukraine has increased the risk of investment in many OECD countries. Therefore green projects in these countries are not the priority of investment by private sector capitalists. Despite the fading of the threat of COVID-19, many life and business patterns have changed, and it seems that there is a need to develop information technology infrastructure in the markets of green financing tools. The result of such action will be the emergence of digital green financing tools such as digital green bonds. Feng et al. (2022b) argued that the global green energy markets need IT-based financing tools to attract global capital for low-carbon transition plans beyond geographical borders.

6 Robustness check

To investigate the robustness of the results of estimations, additional analysis is conducted. To this end, we expand the econometric model by adding two control variables of inflation rate and FDI collected from the World Bank database. The new estimation is done through a panel co-integration estimator, Fully Modified Ordinary Least Squares (FMOLS). The estimation results are provided in Table 13:

According to Table 13, it can be expressed that the primary estimation results are robust to the use of control variables.

In addition, another robustness check is done for a sample group of OECD countries. To this end, the interconnections among issued green bonds, green energy consumption, and GDP in the EU members in OECD is analyzed through the Granger-Wald causality test. The results of the second robustness check are reported in Table 14, revealing the same results in Table 10.

7 Conclusions and policy recommendations

This paper studied the issue of green economic recovery in the post-COVID-19 era in OECD member countries. To this end, the relationship between economic growths, issued green bonds, and green energy consumption was explored through econometric techniques. Regarding the aforementioned empirical estimation findings, the following concluding remarks can be expressed:

- a. There is a positive bi-directional causal linkage between GDP and renewable energy consumption. Therefore, it can be pointed out that the further expansion of the use of clean energy has a positive and meaningful contribution to the economic growth of the OECD countries. Economic growth in these countries leads to more investment in green projects and, as a result increase the share of renewable energy sources in the aggregate energy consumption portfolio of OECD countries.
- b. A bi-directional linkage between the growth rate of issued green bonds and the consumption volume of renewable energy sources exists. In another sense, there is a two-way relationship between the volume of green bond issuance and the use of green energy in OECD countries.

Table 13 Robustness check (FMOLS estimation)

Dependent variable	Explanatory variable	Coefficient	Standard error	<i>P</i> value
GDP	Issued green bonds	0.021	0.024	–
	Green energy consumption	0.173	0.059	***
	Inflation rate	0.19–3	0.031	**
	FDI	0.118	0.026	–
Issued green bonds	GDP	0.231	0.006	–
	Green energy consumption	0.127	0.023	***
	Inflation rate	–0.052	0.045	–
	FDI	0.106	0.039	***
Green energy consumption	Issued green bonds	0.231	0.142	***
	GDP	0.021	0.041	***
	Inflation rate	–0.036	0.041	***
	FDI	0.100	0.031	–

*** and ** denote statistically significant at 1% and %, respectively

Table 14 Second robustness check (sub-sampling). *Source:* Authors' calculations

	Chi2	Df	Prob > Chi2
dln (GDP)			
dln (GBON)	1.817	1	0.301
dln (GEC)	4.153	1	0.054
dln (GBON)			
dln (GDP)	1.401	1	0.282
dln (GEC)	13.006	1	0.021
dln (GEC)			
dln (GDP)	7.632	1	0.049
dln (GBON)	5.028	1	0.020

dln indicates the first difference of the logarithm of variables

- c. No causal relationship exists between GDP and issued green bonds in OCED member countries, expressing the lack of efficiency in issued green bonds.
- d. Analyzing variance decomposition of issued green bonds, it can be highlighted that renewable energy consumption and GDP have contributions of nearly 0.40% and 3.43%, respectively to the variation in issued green bonds. In addition, 17.5% and 1.32% of variation in renewable energy consumption are explained by issued green bonds and GDP, respectively.
- e. OECD countries need to implement policies to have more effect on their economic growth. The higher the share of green bonds issued in the growth of the GDP of these countries, it indicates the further development of the use of clean energy in agriculture and various industries.

As practical policy recommendations, financial system improvement (to increase the credibility and reputation of the green bond issuers), financing rural electrification (to increase the life quality of the rural population), and electric vehicle transition by green bonds are highly recommended. Moreover, OECD countries need to conduct different policies like tax incentives and an increase in the rate of return of green bonds to attract the private sector to green bond markets. The countries should also collect carbon tax from the polluting industries and inject it into green bonds as seed money to increase the rate of return of green projects (Yoshino et al. 2021). In addition, market integrity and enhancing risk-return profile may be addressed as two practical policy implications for these nations to make the green bond market an accelerator for GDP growth. Attention to these policies should be paid more in the COVID-era and the post-COVID era since this pandemic has reduced the volume of investments in green energy projects that would endanger climate-related goals. These applied policies may increase the effectiveness of issued green bonds so that their impact on the growth of the OECD countries' GDP is more significant. Another essential practical policy is the development of infrastructure for the application of digital green

financing tools. The digital issuance and use of green financing tools will lead to more manageable development of the market of these types of tools around the world, greater transparency, and better adaptation to the business climate in the post-COVID-19 era.

Although this paper has significant contributions to the earlier literature, further exploration of the green finance-income-renewable energy relationship at the country level gives more detailed policies to OECD economies. Comparing practical experiments of countries to develop green bonds market under the condition of COVID-19 would represent a further finding for the relationship between these variables. Another suggestion for future research is quantifying the COVID-19's effects and its inclusion as an important variable in the econometric model. This will calculate the direct and indirect effect of COVID-19 on the relationship between the model variables, which will provide policymakers and experts with more accurate strategic and practical policies.

Declarations

Conflict of interest We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all the authors. We declare that there is no conflict of interest.

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