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NEXUS BETWEEN RENEWABLE ENERGY CONSUMPTION, FINANCIAL DEVELOPMENT, AND ECONOMIC GROWTH: EVIDENCE FROM IEA COUNTRIES

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Abstract

The need for energy sources is increasing day by day. However, limited energy resources lead economies to use renewable energy resources. This paper explores the relations between renewable energy consumption, financial development, and economic growth. The study employs ARDL approach to investigate the long-term and short-term cointegration correlations between variables. The current paper focuses on the period 1996-2017 to investigate whether financial development indicators can play a role on renewable energy consumption for twelve IEA countries. According to panel cointegration test results, long-term variables are statistically significant. Also economic growth is observed affecting renewable energy consumption positively in the short term. According to panel causality test results in the short-term there is relation between financial development and renewable energy consumption, and economic growth and renewable energy consumption. Finally, the use of subcomponents of financial development indicator have efficiently captured the different aspects of financial system affecting renewable energy consumption.
Keywords: Renewable energy consumption, Economic growth, Financial development.

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YENİLENEBİLİR ENERJİ TÜKETİMİ, FİNANSAL GELİŞMİŞLİK VE EKONOMİK BÜYÜME ARASINDAKİ İLİŞKİ: IEA ÜLKELERİ ÜZERİNE UYGULAMA

Özet

Enerji kaynaklarına olan ihtiyaç her geçen gün artmaktadır. Ancak sınırlı enerji kaynakları, ekonomileri yenilenebilir enerji kaynaklarını kullanmaya yöneltmektedir. Bu çalışma yenilenebilir enerji tüketimi, finansal gelişmişlik ve ekonomik büyüme arasındaki ilişkiyi incelemektedir. Çalışma, değişkenler arasındaki uzun vadeli ve kısa vadeli eşbütünleşme korelasyonlarını araştırmak için ARDL yaklaşımını kullanmaktadır. Mevcut çalışma, finansal gelişme göstergelerinin on iki IEA ülkesi için yenilenebilir enerji tüketimi üzerinde bir rol oynayıp oynayamayacağını araştırmak için 1996-2017 dönemine odaklanmaktadır. Panel eşbütünleşme testi sonuçlarına göre uzun dönemli değişkenler istatistiksel olarak anlamlıdır. Ayrıca ekonomik büyümenin kısa vadede yenilenebilir enerji tüketimini olumlu yönde etkilediği görülmektedir. Panel nedensellik testi

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sonuçlarına göre kısa dönemde finansal gelişmişlik ve yenilenebilir enerji tüketimi ile ekonomik büyüme ve yenilenebilir enerji tüketimi arasında ilişki bulunmaktadır. Son olarak, finansal gelişmişlik göstergesinin alt bileşenlerinin kullanımı, finansal sistemin yenilenebilir enerji tüketimini etkileyen farklı yönlerini etkin bir şekilde ortaya çıkarmıştır.
Anahtar Kelimeler: Yenilenebilir enerji, Ekonomik büyüme, Finansal gelişmişlik.

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Introduction

Today, most economic activities in a country strictly depend on energy. The apparent explanation is that energy consumption (EC) is the main component in producing most consumer goods. Therefore, an increase in production, R&D, and other related business lines, raises the need for energy resources. However, not all countries were energy self-sufficient before; some are still not today (Roser, 2020).

There were significant energy crises throughout history. Especially in the first half of the 20th century, World War I, World War II, and "The Great Depression" instantly eroded world economies (Temin, 1991). The latter event was the Arab oil embargo in October 1973, the temporary cessation of oil shipments from the Arabian region to several countries, including the United States (Zeidan, 2020). It had a global seismic effect on the world economy (Vernon, 1976). The global financial crisis in 2008 and the oil war between Russia and Saudi Arabia also significantly affected energy resources. The limited energy resources are the other side of the coin. According to IEA World Energy Outlook 2020, the share of primary energy from renewable resources was 11% in 2019. The global total energy consumption mainly relies on non-renewable resources such as coal, oil/petroleum, natural gas, and nuclear. The accessibility to energy resources, whether renewable or non-renewable and being finite of non-renewable energy resources force countries to emphasize renewable energy resources for a sustainable economy.

The information about energy needs or EC of countries has a historical background of more than a hundred years. The first EC data of nations has been statistically archived since the early 1900s. The early records have begun with physical storage then transferred into online data (The Shift Data Portal, 2020). The online EC data starts from 1960 on World Bank Database and 1965 on Our World in Data. The empirical researches on EC are highly dependent on this availability of data.

One of the first studies investigating the relationship between EC and economic growth (EG) is conducted by Kraft & Kraft (1978). Despite its availability, they did not utilize the data from 1900-1947 due to the global depression and two world wars. Then, significant number of studies investigating this relationship have emerged (Eden & Hwang, 1984; Abosedra & Baghestani, 1989; Maish & Masih, 1996; Asafu-Adjaye, 2000; Soytas & Sari, 2003; Halicioglu, 2009; Ozturk, 2010; Rahman & Velayutham, 2020). Yet, studies researching the relationship between EC and financial development (FD) has first begun in 2009 conducted by Karanfil (2009). The most well-known later author in this area was Sadorsky (2010). The idea was that EG and FD might directly or indirectly affect EC. As proxies of FD, the stock market and banking system (Sadorsky, 2010), as well as foreign direct investment (FDI) (Alam et al., 2015), have a vital role in the economy. The efficiently working financial system will support all participants in all sectors, providing increasing activities in those areas and higher energy demand. This perspective may be narrowed to the private sector because, as FD, the most frequently used indicator is 'domestic credit to private sector'. (Alam et al., 2015; Mahalik et al., 2017; Alsaleh & Abdul-Rahim, 2019; Fernandes & Reddy, 2021; Tsaurai, 2020; Durusu-Ciftci, et.al.,2020; Pan et al., 2019). This stems from the hypothesis that the financial contribution to the private sector will increase their productivity and affect EG and EC.

There is a gap in the literature that the relationship between financial development and renewable energy consumption (REC) was investigated through the financial system in a general manner. The financial development at a country level was first divided into three components by Sadorsky (2010) foreign direct investment (FDI) , stock market, and banking system. Later, the FDI was separated unintentionally by the following authors that a new research area emerged named the FDI & energy consumption (Pao & Tsai, 2011; Omri & Kahouli, 2014). The remaining two financial development components were separated into three sub-groups: the stock market, bond market, and banking system, first conducted by Topcu & Payne (2017) and Destek (2018). So, this study is assumed to fill this gap which is the augmented FD relation with REC and EG.

In the following parts, the theoretical background, literature review, data, methodological approaches used in empirical application and conclusion are stated, respectively.

A. THEORETICAL BACKGROUND

EC and the factors affecting its value on a country level have become a significant research area in recent years. From a macroeconomic perspective, economic growth (Asongu et al., 2020; Eluwole et al., 2020; Salahuddin et al., 2015), financial development (Ali et al., 2015; Destek, 2018; Nkalu et al., 2020; Qamruzzaman & Jianguo, 2020; Sadorsky, 2010; Topcu & Payne, 2017), foreign direct investment (Eluwole et al., 2020; Tamazian et al., 2009), policies (Bulut & Muratoglu, 2018; Sadorsky, 2010; Topcu & Payne, 2017), and other relevant components of economics have significant effects on REC. There are also environmental issues about REC, whether it stimulates environmental pollution (Hafeez et al., 2019) or CO_2 emissions (Al-Mulali & Binti Che Sab, 2012). The environmental-related EC studies address the disastrous results on the environment and how to prevent them.

This study will investigate the relations between REC, FD, and EG. There is a lack of studies in the literature that FD may also affect REC through different dimensions of the financial system. The first studies are conducted by Topcu & Altay (2017), and Topcu & Payne (2017) defined the dimensions of the financial system of banking, stock-market, and bond-market. The following researcher is Destek (2018), and he described these dimensions as similar but with different indicators. Although Sadorsky (2010) is the pioneer in analyzing FD and EC, he did not mention any dimensions of the financial system; instead, he emphasized the effect of the stock market on countries' energy demand.

The theoretical approaches behind these relations are represented in the following sections in detail.

1. Economic growth and renewable energy consumption

Four hypotheses have been proposed in the EG and REC literature: feedback, growth, conversation, and neutrality (Shahbaz & Lean, 2012). According to the feedback hypothesis, the relation between EG and REC is bi-directional, which means that the dynamics of REC and EG are interrelated. If the EG is proxied as the increasing economic activities will result in higher energy demand, EG will increase REC (Akhtar et al., 2016). In the opposite relation, REC is related to energy prices. An increase in energy demand of both public and private sector industries will end up in higher production costs. If the production costs increase, the whole sector and economy will be affected. Thus, the effect of REC on EG is evident. (Magazzino, 2018) The growth hypothesis suggests that unidirectional relation exists from REC to EG, revealing that REC plays a crucial role in EG both directly and indirectly in the production process as input costs (Shahbaz & Lean, 2012). In the opposite relation, a country's EG stems from mostly non (or low)-energy-related economic activities. The conversation hypothesis proposes that a unidirectional connection exists from EG to REC, which means that energy-related policies do not negatively affect total EG (Akhtar et al., 2016). In the opposite relation, the highly energy-dependent industries do not contribute to EG. Lastly, the neutrality hypothesis implies no relationship between EG and REC, which implies that both energy conversation policies, high and low energy-related industries are not related to EG, and increasing economic activities do not interfere with total REC (Shahbaz & Lean, 2012).

In this regard, it is assumed that:

H1: Economic growth increases renewable energy consumption.

2. Financial development and renewable energy consumption

Like REC and EG, there are also proposed hypotheses on the relation between REC and FD. These hypotheses are growth, conservation, feedback, and neutrality (Topcu & Altay, 2017). In the growth hypothesis, unidirectional relation from REC to FD exists, which means that energy conservation policies are expected to impact the financial sector in an economy. In the conservation hypothesis, there exists a relation between FD and REC which implies that monetary policies influence REC. Also, in these economies, energy-saving projects are heavily related to the financial sector. In the feedback hypothesis, two-way relation exists between FD and REC, which means that energy-saving projects affect REC, and REC has a reverse impact on FD. In the neutrality hypothesis, neither REC nor FD has a significant effect on each other.

2.1. Financial development stimulates the use of goods and causes higher renewable energy consumption.

The primary assumption about the effect of FD on REC relies on the idea that improved FD promotes savings, borrowing, and investment. With low borrowing cost, consumers tend to purchase goods which add to energy demand (Abbasi & Riaz, 2016; Mukhtarov et al., 2019; Shahbaz, Khan, & Tahir, 2013; Zeren & Koc, 2014). A developed financial market enhances participation by consumers and businesses, promotes economic activity, and boosts energy use (Hafeez et al., 2019; Islam et al., 2013;

Topcu & Payne, 2017). The effect of FD on REC through the savings of individuals is called a direct effect. The indirect effect of FD means first FD positively influences economic growth, then the total energy demand enhances with this growth (Alam et al., 2015; Magazzino, 2018). Also, improved stock market activities are considered one indirect effect of FD on REC (Destek, 2018).

Whether FD has an effect on REC in an industry is highly related to this industry's energy dependency. Compared with a less energy-intensive industry, FD is expected to create more energy demand in an energy-intensive industry. (Topcu & Altay, 2017). Moreover, in higher energy-intensive industries, FD may increase REC due to increases in purchasing new industrial machines and equipment encouraged by lower financing costs and increased financing networks (Dogan & Seker, 2016).

2.2. Financial development increases energy efficiency, thus decreases renewable energy consumption.

FD can affect energy efficiency in two ways. It increases the consumers' savings, encouraging purchasing energy-efficient consumer goods and lowering REC (Durusu-Ciftci, Soytas, & Nazlioglu, 2020). Although consumers' preferences to buy consumer goods such as refrigerators, washing machines, or other home appliances directly add to energy use, it lowers energy use if the purchases are energy efficient (Islam et al., 2013).

The second way is that FD postulates firms to invest in energy-efficient innovations competitively to lower production costs (Burakov & Freidin, 2017; Pan et al., 2019), which results in a decrease in energy demand (Topcu & Payne, 2017). The improvement in energy efficiency, which leads to low REC, has been stated by several researchers (Abbasi & Riaz, 2016; Ali et al., 2015; Assi et al., 2020; Dogan & Seker, 2016; Pata, 2018).

The policies about environmental energy resources stimulate firms to invest in alternative energy resources instead of non-renewable ones (Alsaleh & Abdul-Rahim, 2019; Shahbaz & Balsalobre-Lorente, 2020). The improvement in the financial position leads to increase Research and Development activities towards the advancement of environmental quality (Vasanth et al., 2015). Thus, global competition and environmental issues reduce REC and the shift to safer renewable sources of energy (Burakov & Freidin, 2017).

2.3. Financial Institutions may have different effects on renewable energy consumption by efficiency levels.

Whether FD is affecting REC positively or negatively is simply relying on the efficiency level of financial institutions. Main assumptions and observations about the effect of FD on energy demand or consumption studies did not directly address but somewhat indirectly conclude this hypothesis.

In the aforementioned sections, briefly, FD is related to financialization which means FD either increases individuals' and firms' excess funds (which is called "financial liberalization" (Shahbaz & Lean, 2012)), results in higher economic activities (Mahalik, Babu, Loganathan, & Shahbaz, 2017) (purchasing consumable goods by individuals and higher production of consumable goods by firms) and energy demand; or increases financial support for energy efficiency related R&D expenditures by firms which results in a decrease in energy (Sadorsky, 2010; Tamazian et al., 2009). Whether financial institutions are capable of establishing such functions is not questioned.

The financial institutions are divided into three subsections in REC literature: banking system, stock market, and bond market. In the banking system, efficiency is related to the efficient use of financial resources and improved banking system for reallocating these resources for environmentally friendly R&D expenditures by firms rather than wasting them in consumer financing (Shahbaz et al., 2016). Moreover, not all firms are stated as "bona fide". Some may be using initially borrowed loans ineffectively; thus, they may end up with lousy depth. Here, the ineffectiveness shows the poorly management of environmentally friendly projects conducted by these firms. If the financial system continues to fund these firms, the financial resources reserved for these firms will be nothing but waste allocation (Chai et al., 2016). Second, the efficiency of a stock market is associated with the advancement of technology, reduction of information cost, and profitability of investment (Alam et al., 2015). A capable and enduring stock market increases capital accumulation and enhances acquisition (Mironiuc & Huian, 2017). Thus, it spreads financial risk and borrowing costs and excessive transparency between creditors and borrowers, insurance services, expands saving and portfolio options (Alam et al.,2015). Third, the bond market is stated as another dimension of FD (Destek, 2018). Improved debt instruments are increasing the efficiency in the usage of financial resources. Indeed, there is also one specific bond type called "Green Bond" mainly used by firms to maintain environmental projects (Miola et al., 2021).

The financial depth and foreign direct investment are also related to the stock market's efficiency (Hermes & Lensink, 2003; Jalil & Feridun, 2011; Qamruzzaman & Jianguo, 2020; Shahbaz et al., 2013). However, foreign capital and trade openness are not in the scope of this study.

Besides the debate on whether FD decreases or increases REC, in this study, it is assumed that:

H2: Financial development promotes renewable energy consumption through both three dimensions of the financial system.

B. DATA

Table 1 presents information on all variables used in this study, examining the relationship between REC, FD, and EG. FD indicators are analyzed under three groups. As the financial indicators in the first group (FIN1) consist of stock market variables, the second group (FIN2) indicators consist of banking variables. Indicators in the third group (FIN3) include bond market variables. In addition, the effect of GDP on REC is analyzed under the economic development model (EDM). Data for all variables used were taken from the world bank database. While data on real GDP were collected from the World Development Indicators (WDI), data on FD indicators were collected from the Global Financial Development (GFD) for twelve countries belonging to the IEA[1] , which includes (Austria, Australia, Korea, Rep., Turkey, United States, Greece, Hungary, Ireland, Japan, New Zealand, Poland, Spain) for

[1] The International Energy Agency was established on 15 November 1974 within the structure of the OECD. Its task is to run the comprehensive cooperation program in the energy field. For this purpose, IEA members have decided to establish an International Energy Program.

the period 1996-2017. IEA has thirty[2] member countries; however, the remaining 18 member countries were excluded from the analysis because the data for these countries for the indicators in Table 1 are either missing or not available.

Table 1: The description of variables

Variable	Abbreviated	Model	Countries	Period
Stock market total value traded to GDP (%)	SMTVTrade	FIN1	Austria Australia Korea, Rep. Turkey United States Greece Hungary Ireland Japan New Zealand Poland Spain	1996-2017
Bank return on equity (%, after-tax)	ROE			
Stock market capitalization to GDP (%)	SMC			
Stock market turnover ratio (%)	SMTR			
Liquid liabilities to GDP (%)	LL	FIN2		
Domestic credit to private sector (% of GDP)	DCPrvtS			
Deposit Money banks" assets to GDP (%)	DMB			
Outstanding international private debt securities to GDP (%)	OprvtDS	FIN3		
Outstanding international public debt securities to GDP (%)	OpblcDS			
GDP growth (annual %)	GDP	EDM		
Renewable energy share of TFEC (%)	REC			

Table 2: Descriptive Statistics

	Mean	Std. Dev.	Min.	Max.	Skewness	Kurtosis	Obs
SMTVTrade	54.2216	62.9435	1.7742	313.716	1.6872	5.5014	264
ROE	7.0441	15.9593	-101.476	33.227	-3.1746	17.9236	264
SMC	55.0932	35.9331	3.8775	153.211	0.7754	2.6592	264
SMTR	87.2009	66.6253	4.4864	361.639	1.2080	4.5961	264
LL	83.9245	45.5452	8.4662	231.313	1.5307	5.2394	264
DCPrvtS	101.5096	52.5347	12.8947	221.288	0.1420	2.0655	264
DMB	98.1778	46.0402	21.7854	241.549	0.5805	2.7686	264
OprvtDS	25.5918	33.6070	0.0761	217.586	2.8585	13.2584	264
OpblcDS	6.6653	7.3941	0.0140	29.2529	1.1906	3.4316	264
GDP	2.9777	3.3816	-9.1324	25.1625	0.5748	10.6233	264
REC	11.5232	9.0671	0.6086	35.3942	1.0995	3.1024	264

[2]Australia, Austria, Germany, United States, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Netherlands, England, Ireland, Spain, Sweden, Switzerland, Italy, Japan, Canada, Korea, Luxembourg, Hungary, Norway, Poland, Portugal, Slovak Republic, Turkey, New Zealand, Greece

Descriptive statistics of the variables are shown in Table 2. Stock market total value traded to GDP (%) (SMTVTrade), Bank return on equity (%, after-tax) (ROE), Stock market capitalization to GDP (%) (SMC) and Stock market turnover ratio (%) (SMTR) are the components of FIN1(bank related) and all variables have similar descriptive statistics, except ROE. Liquid liabilities to GDP (%) (LL), Domestic credit to private sector (% of GDP) (DCPrvtS) and Deposit Money banks" assets to GDP (%) (DMB) are the components of FIN2 (stock related) and Outstanding international private debt securities to GDP (%) (OprvtDS) and Outstanding international public debt securities to GDP (%) (OpblcDS) are the components of FIN3 (bond related). The GDP growth (annual %) (GDP) variable has the minimum standard deviation among all other variables.

C. METHODOLOGY

In the study, the dependency between the cross-sections forming the panel was investigated with the tests proposed by Breusch-Pagan (1980) and Pesaran (2004) and Baltagi, Feng, and Kao (2012). The stationarity of the series was investigated using the CADF (Cross-Sectional Dependence Lagrange Multiplier) method, which also takes into account the cross-sectional dependence and structural breaks. The homogeneity of the cointegration coefficients was determined by the Slope Homogeneity Test presented by Pesaran-Yamagata (2008). The existence of a cointegration relationship between series was examined with the Westerlund (2007) Panel Cointegration test, which takes into account the cross-sectional dependency. The long-term and short-term cointegration coefficients were investigated by way of the dynamic fixed effect (DFE) model as well as the mean group (MG) and pooled mean group (PMG) estimators. Finally, the causality relationship between the series was investigated through the Panel Fisher causality test.

1. Panel Unit Root Test

Before testing the relationship between series in panel data analysis, it is important to investigate the presence of cross-sectional dependency. Cross-section dependency should be taken into consideration in the selection of unit root and cointegration tests to be applied. In case of cross-sectional dependency between the units of the series, it is essential to use second-generation panel unit root tests for panel data. Pesaran (2007) proposed a unit root test based on the standard unit root statistics over the cross-section generalized Dickey-Fuller (CADF) regression. The CADF equation is estimated by adding the lagged values of the cross-section means, and the first differences of the cross-section mean to the standard ADF equation. Pesaran's (2007) approach is based on simple arithmetic averages of ADF statistics (CADFi) expanded with individual cross-section averages. Individual CADF statistics are used to obtain CIPS (cross-section expanded Im, Pesaran, and Shin) statistics. Simple CADF regression

$$\Delta Y_{it} = \alpha_i + \rho_i^* Y_{it-1} + d_0 \bar{Y}_{t-1} + d_1 \Delta \bar{Y}_t + \varepsilon_{it}$$

Here $\bar{Y}_t$ is the mean of all N observations over time t. The presence of lagged cross-sectional averages and first differences take into account the correlation between units through a factor structure. After the CADF regression is estimated, the t-statistics of the lagged variables are averaged to obtain the CIPS statistics. CIPS statistics are included in equation ().

$$CIPS = N^{-1}\sum_{i=1}^{N} CADF_i$$

The combined asymptotic limit of CIPS statistics is not standard and critical values are calculated for various T and N values (Pesaran, 2007).

2. Panel Cointegration Test

Since this study examines the relationship between REC, FD, and EG, first of all, we investigated whether there is a long-term relationship between the variables with Westerlund Panel Cointegration test. Westerlund (2007) proposed four-panel cointegration tests based on error correction model. The basis of these four tests is to test the existence of cointegration by deciding whether each unit has its error correction. The Westerlund (2007) panel cointegration is derived from the following equations:

$\boldsymbol{FIN1}$: $\Delta REC_{it} = \hat{\delta}_i' d_t + \hat{\alpha}_i REC_{it-1} + \hat{\lambda}_i' SMTVTRADE_{it-1} + \hat{\gamma}_i' ROE_{it-1} + \hat{\theta}_i' SMC_{it-1} + \hat{\zeta}_i' SMTR_{it-1} + \sum_{j=1}^{p_t} \hat{\alpha}_{ij} \Delta REC_{it-j} + \sum_{j=0}^{p_i} \hat{\varphi}_{ij} \Delta SMTVTRADE_{it-j} + \sum_{j=0}^{p_i} \hat{\omega}_{ij} \Delta ROE_{it-j} + \sum_{j=0}^{p_i} \hat{\psi}_{ij} \Delta SMC_{it-j} + \sum_{j=0}^{p_i} \hat{\upsilon}_{ij} \Delta SMTR_{it-j} + \hat{e}_{it}$

$\boldsymbol{FIN2}$: $\Delta REC_{it} = \hat{\delta}_i' d_t + \hat{\alpha}_i REC_{it-1} + \hat{\lambda}_i' LL_{it-1} + \hat{\gamma}_i' DCPRVTS_{it-1} + \hat{\theta}_i' DMB_{it-1} + \sum_{j=1}^{p_i} \hat{\alpha}_{ij} \Delta REC_{it-j} + \sum_{j=0}^{p_i} \hat{\varphi}_{ij} \Delta LL_{it-j} + \sum_{j=0}^{p_i} \hat{\omega}_{ij} \Delta DCPRVTS_{it-j} + \sum_{j=0}^{p_i} \hat{\psi}_{ij} \Delta DMB_{it-j} + \hat{e}_{it}$

$\boldsymbol{FIN3}$: $\Delta REC_{it} = \hat{\delta}_i' d_t + \hat{\alpha}_i REC_{it-1} + \hat{\lambda}_i' OPBLCDS_{it-1} + \hat{\gamma}_i' OPRVTDS_{it-1} + \sum_{j=1}^{p_i} \hat{\alpha}_{ij} \Delta REC_{it-j} + \sum_{j=0}^{p_i} \hat{\varphi}_{ij} \Delta OPBLCDS_{it-j} + \sum_{j=0}^{p_i} \hat{\omega}_{ij} \Delta OPRVTDS_{it-j} + \hat{e}_{it}$

$\boldsymbol{EDM}$: $\Delta REC_{it} = \hat{\delta}_i' d_t + \hat{\alpha}_i REC_{it-1} + \hat{\lambda}_i' GDP_{it-1} + \sum_{j=1}^{p_i} \hat{\alpha}_{ij} \Delta REC_{it-j} + \sum_{j=0}^{p_i} \hat{\varphi}_{ij} \Delta GDP_{it-j} + \hat{e}_{it}$

where $i = 1, \ldots, N$ and $t = 1, \ldots, T$ index cross-sectional and the time-series units, d_t contains the deterministic components (constant and trend), and it can be handled in three situations ($d_t = \{\emptyset\}$ or $d_t = 1$ or $d_t = (0,1)$). The lag order p_i is permitted to vary across individuals and can be determined preferably using a data-dependent rule (Westerlund, 2007:8).

Then the test statistics are computed as follows:

$G_t = \frac{1}{N}\sum_{i=1}^{N} \frac{\hat{\alpha}_i}{SE(\hat{\alpha}_i)}$ and $\quad G_a = \frac{1}{N}\sum_{i=1}^{N} \frac{T\hat{\alpha}_i}{\hat{\alpha}_i(1)}$

where $SE(\hat{\alpha}_i)$ is the conventional standard error of $\hat{\alpha}_i$. The second type of statistics, called panel statistics, also has some procedures. Likewise, group mean statistics after determined lag orders p_i, we regress ΔREC_{it} and REC_{it-1} onto d_t, the lags of ΔREC_{it} as well as the simultaneous and lagged values of independent variables. Specific to the EDM model

$\boldsymbol{FIN1}$: $\Delta\widetilde{REC}_{it} = \Delta REC_{it} - \hat{\delta}_i' d_t - \hat{\lambda}_i' GDP_{it-1} - \sum_{j=1}^{p_i} \hat{\alpha}_{ij} \Delta REC_{it-j} - \sum_{j=0}^{p_i} \hat{\varphi}_{ij} \Delta GDP_{it-j}$

and

$$\widetilde{REC}_{it-1} = REC_{it-1} - \tilde{\delta}_i' d_t - \tilde{\lambda}_i' GDP_{it-1} - \sum_{j=1}^{p_i} \tilde{\alpha}_{ij} \Delta REC_{it-j} - \sum_{j=0}^{p_i} \tilde{\varphi}_{ij} \Delta GDP_{it-j}$$

The second step of panel statistics involves the common error correction parameter α and estimating its standard error.

$$\hat{\alpha} = (\sum_{i=1}^{N}\sum_{t=2}^{T} \widetilde{REC}_{it-1}^2)^{-1} (\sum_{i=1}^{N}\sum_{t=2}^{T} \frac{1}{\widehat{\alpha}_i(1)} \widetilde{REC}_{it-1} \Delta\widetilde{REC}_{it})$$

and

$$SE(\hat{\alpha}) = ((\hat{S}_N^2)^{-1} \sum_{i=1}^{N}\sum_{t=2}^{T} \widetilde{REC}_{it-1}^2)^{-1/2}$$

where $\hat{S}_N^2 = \frac{1}{N}\sum_{i=1}^{N} \hat{S}_i^2$ and $\hat{\sigma}_i$ denote the estimated regression standard error in EDM model. The final step for the panel statistics is calculated as follows

$P_t = \frac{\hat{\alpha}}{SE(\hat{\alpha})}$ and $P_t = T\hat{\alpha}$

In Westerlund (2007), no cointegration null hypothesis is tested versus the alternative hypothesis that there is cointegration.

Panel ARDL technique was used to investigate the long-term and short-term cointegration correlations between variables and extract the error correction version of the panel features to define short-term dynamics. Unlike traditional cointegration approaches, the panel ARDL approach uses an individually summarized equation form. Also, the approach includes the dynamic fixed effect (DFE) model as well as the mean group (MG) and pooled mean group (PMG) estimators. All three models estimate both long- and short-term parameters by establishing an error correction model. The MG estimation method proposed by Pesaran and Smith (1995) uses the average of the long-term parameters of the ARDL model for each unit, thus allowing the evaluation of long-term parameters according to units. The PMG estimation method allows the slope and constant parameters to vary according to units, and allows the constant parameter to change, but the slope parameter to be constant, as in the fixed effects estimator (Pesaran, Shin, and Smith, 1999). The dynamic fixed effects estimator, which estimates the error correction model under the fixed effects assumption, keeps all parameters constant. Error correction model specific to EDM model as follows:

$$\Delta REC_{it} = \phi_i REC_{it-1} + \beta_i' GDP_{it} + \sum_{j=1}^{p-1} \lambda_{ij} \Delta REC_{it-j} + \sum_{j=0}^{q-1} \delta_{ij} \Delta GDP_{it-j} + \varepsilon_{it}$$

where ϕ_i is the error correction parameter, indicates a long-term relationship between REC and GDP if it is negative and statistically significant.

3. Panel Causality Test

Emirmahmutoglu and Kose (2011) simply expanded the Toda-Yamamoto approach to Granger causation in time series data for panel data sets. This approach to panel causation also takes into account cross-section dependency, as critical values for panel statistics are derived from boot distributions, regardless of whether the variables are stationary or cointegrated. In the case of Granger non-causality, the null hypothesis is be expressed as $H_0: R_i \alpha_i = \acute{0}$, for all i. Where R_i is $(q_i \times p^2 k_i)$ matrix with rank q_i for each cross-sectional units and $\acute{0}$ is a $(q_i \times 1)$ zeros vector. To test the null hypothesis, Emirmahmutoglu and Kose (2011) offer estimating a level VAR $(k_i + dmax_i)$ in heterogeneous mixed panels:

$$z_{i,t} = \mu_i + A_{i1} z_{i,t-1} + \ldots + A_{ik} z_{i,t-k} \sum_{l=k_i+1}^{k_i+dmax_i} A_{il} z_{i,t-l} + u_{i,t}$$

Where $A_{i1}, \ldots, A_{ik}$ are fixed (p×p) matrices of parameters that are allowed to vary across units. To test the Granger non-causality hypothesis Fisher test statistics (λ) are used as follows:

$$\lambda = -2 \sum_{i=1}^{N} ln(p_i)$$

where p_i is the $p - value$ corresponding to the Wald statistic of the i-th individual cross-section In this causality approach developed by Emirmahmutoglu and Kose (2011), the following bivariate VAR model is estimated for each cross-section:

$$y_{i,t} = \mu_i^y + \sum_{j=1}^{k_i+dmax_i} A_{21,ij} x_{i,t-j} + \sum_{j=1}^{k_i+dmax_i} A_{22,ij} y_{i,t-j} + u_{i,t}^y$$

where $dmax_i$ is defined for each unit as the maximum integration order suspected to occur in the system (Emirmahmutoglu and Kose, 2011:872).

D. EMPIRICAL FINDINGS

The current paper focuses on the period 1996-2017 to investigate whether FD indicators can play a role in REC for twelve IEA countries. To determine the appropriate unit root approach, firstly, the correlation between units was investigated in the panel data. Information on the test results applied to determine the existence of a relationship between the units is presented in Table 3.

Table 3: Cross-Section Dependency Test

Series / Method	LM	CD_{LM}	LM_{BC}	CD
OPrvtDS	409.8329***	29.92681***	29.64110***	10.16362***
OPblcDS	262.8994***	17.13789***	16.85218***	-2.141532**
LL	537.0100***	40.99616***	40.71044***	3.343265***
DCPrvtS	676.1990***	53.11100***	52.82529***	12.11029***
DMB	722.8059***	57.16761***	56.88190***	13.33023***
SMTVTrade	431.3679***	31.80119***	31.51548***	9.940698***
ROE	115.7163***	4.327251***	4.041537***	4.915839***
SMC	336.5543***	23.54873***	23.26302***	10.42817***
SMTR	264.4631***	17.27399***	16.98828***	4.736146***
GDP	277.4217***	18.40190***	18.11618***	14.70694***
REC	904.3698***	72.97073***	72.68501***	21.33809***

***** denotes significance at 0.01.**

It is followed from Table 3 that all series used in the study have inter-unit correlations within the framework of cross-sectional dependency approaches. In this context, the unit root analysis of the series containing cross-section dependency was investigated with the CADF approach of Pesaran (2007), one of the second-generation unit root tests, and the findings are presented in Table 4.

Table 4: Panel CIPS Values

	Levels				**First Difference**			
	Constant (C)	**Lags**	**Constant/ Trend (C/T)**	**Lags**	**Constant (C)**	**Lags**	**Constant/ Trend (C/T)**	**Lags**
OPrvtDS	0.617	3	2.652	3	-1.865**	2	-1.847 **	2
OPblcDS	-0.242	3	0.780	3	-3.157***	2	-2.555***	2
LL	-1.707**	3	2.538	3	-4.098***	1	-2.785***	1
DCPrvtS	2.711	3	4.450	3	-1.657**	2	-2.325**	2
DMB	3.970	3	-0.017	1	-4.461***	1	-3.914***	1
SMTVTrade	-1.417*	3	-3.574***	3	-4.755***	3	-3.208***	3
SMR	-2.424***	3	-0.158	3	-2.488***	3	-3.171***	2
ROE	-0.580	3	-1.280*	3	-2.513***	3	-1.745**	2
SMC	0.495	3	1.028	3	-5.032***	1	-4.414***	1
SMTR	-1.830**	3	1.774	3	-2.865***	2	-2.781***	2
GDP	-2.456***	3	-1.497*	3	-3.142***	3	-5.672***	1
REC	0.924	3	-1.710**	3	-3.651***	3	-2.721***	3
DMBACB	-0.745	3	2.035	3	-4.206***	1	-3.809***	1

Critical value for levels: %10: -2.140 %5: -2.250 %1: -2.450. *, **, and * denote significance at 0.01, 0.05 and 0.10, respectively.**

According to Pesaran's (2007) constant and constant-trend model findings in Table 3, all series except GDP and SMTVTrade series are found to be stationary at the first difference (I(1)). GDP and SMTVTrade series are stationary at levels (I(0)). In reference to the constant model, the LL, SMR, and SMTR series are also determined to be stationary at their levels.

Table 5: Slope Homogeneity Test

	FIN1		FIN2		FIN3	
	Statistic	P-Value	Statistic	P-Value	Statistic	P-Value
$\hat{\Delta}$ Test	-0.588	0.557	-0.832	0.406	-0.204	0.838
$\widehat{\Delta_{adj}}$ Test	-0.772	0.440	-1.064	0.287	-0.247	0.805

To account for autocorrelation in the residual, be used the HAC robust standard errors following Blomquist and Westerlund (2013), we used the Quadratic-Sphere kernel with, say, a bandwidth of 6.

The Delta test, which is used to determine whether the slope coefficient in the cointegration equation is homogeneous or not and which was put forward by Swamy in 1970, was developed by Pesaran and Yamagata (2008). Table 5 shows the results of the slope homogeneity for all three models. As can be seen, the null hypothesis of slope homogeneity is not rejected by both delta and delta-adjusted tests; thus, it supports country-specific homogeneity. Since there is a cross-sectional dependency problem in series, Westerlund (2007) cointegration test was used.

Table 6: Panel Cointegration Test

		G_t	G_a	P_t	P_a
FIN1	Statistic	-0.574	-0.098	-0.815	-0.041
	Z-Value	4.732	4.765	3.778	2.878
	Robust P-Value	0.730	0.720	0.380	0.570
FIN2	Statistic	-2.448	-2.276	-9.541	-6.026
	Z-Value	1.018	5.713	-1.070	2.793
	Robust P-Value	0.160	0.040**	0.000***	0.010**
FIN3	Statistic	-2.860	-3.585	-6.479	-4.627
	Z-Value	-1.364	4.748	1.602	3.003
	Robust P-Value	0.300	0.030**	0.010**	0.020**
EDM	Statistic	-1.963	-3.024	-8.608	-7.467
	Z-Value	-1.696	4.621	-1.501	0.862
	Robust P-Value	0.160	0.000***	0.000***	0.030**

*****, **, and * denote significance at 0.01, 0.05 and 0.10, respectively.**

The Westerlund (2007) panel cointegration analysis results based on the error correction model are presented in Table 6. According to G_a, P_t, and P_a test statistics, except for the G_t test statistics, the null hypothesis can be rejected for FIN2, FIN3, and EDM models, but it cannot be rejected for the FIN1 model. Therefore, it can be said that there is a long-term relationship between the relevant variables and renewable energy consumption for FIN2, FIN3, and EDM models within the scope of bootstrap critical values but not for the FIN1 model.

Table 7: Long-Term and Short-Term Estimations

Model		Variable	MG	PMG	DFE
FIN2	Long-Term	LL	0.2808*	-0.0731**	0.09217
		DCPrvtS	-0.1409	0.0889**	0.0817
		DMB	0.0618	0.1134***	0.0533
	Short-Term	EC_{-1}	-0.2046***	-0.1241***	-0.0637***
		DLL	0.0029	0.0035	-0.0032
		DDCPrvtS	-0.0285	-0.0369*	-0.0053
		DDMB	-0.0240	-0.0048	-0.0039
		C	-	0.2879	-
	Hausman Chi-Sq. Test		MG Vs. PMG	DFE Vs. PMG	MG Vs. DFE
			11.23 (0.0106)	6.63 (0.0845)	0.46 (0.9269)
FIN3	Long-Term	OPblcDS	22.8738	-0.4231***	0.6888**
		OPrvtDS	0.9329*	0.2276***	0.1479***
	Short-Term	EC_{-1}	-0.0526**	-0.1378**	-0.0721***
		DOPblcDS	-1.0105	-0.8976	-0.0315
		DOPrvtDS	-0.0404	-0.042	-0.0030
		C	-	2.7406	0.4004
	Hausman Chi-Sq. Test		MG Vs. PMG	DFE Vs. PMG	MG Vs. DFE
			3.53 (0.1712)	45.31 (0.000)	0.94 (0.6260)
EDM	Long-Term	GDP	-2.7348	0.1620**	-2.1756
	Short-Term	EC_{-1}	0.0437**	0.0322***	-0.0571***
		DGDP	0.0258	-0.0012	0.0670***
	Hausman Chi-Sq. Test		MG Vs. PMG	DFE Vs. PMG	MG Vs. DFE
			0.30 (0.5824)	15.02 (0.0001)	0.01 (0.9340)

*****, **, and * denote significance at 0.01, 0.05 and 0.10, respectively.**

The outputs of long and short-term relationship estimates of MG, PMG, and DFE methods of FIN2, FIN3, and EDM models are presented in Table 7. According to Hausman chi-square test results, it is accepted that the most suitable estimator for FIN3 and EDM models belongs to DFE method, and for FIN2 model belongs to PNG method. When FIN2 model results are examined, the error correction parameter (-0.1241) is negative and significant, and there is a long-term relationship between the variables. Accordingly, approximately 12% of the imbalances that occur in one period will be corrected in the next period, and it will be brought closer to the long-term balance. Long-term coefficients of liquid liabilities, domestic credit to private sector, and deposit money banks' assets variables are statistically significant as -0.0731, 0.0889, and 0.1134, respectively. In the long run, 1% increase in LL is expected to reduce renewable energy consumption by about 0.07%. The 1% increase in DCPrvtS and DMB is expected to increase renewable energy consumption by about 0.09% and 0.11%, respectively. While the short-term relationship between DCPrtS and REC is negative and statistically significant, the short-term parameters of LL and DMB variables are not statistically significant. These results show that while the hypothesis H2 is valid for LL, one of the banking indicators, the findings regarding DCPrvtS and DMB do not support the hypothesis.

When the DFE estimation results of the FIN3 model are examined, it is observed from Table 7 that the error correction parameter is negative and statistically significant, and the long-term coefficients of the OPblcDS and OPrvtDS variables are positively signed and statistically significant. Accordingly, the 1% increase in the variables of outstanding international private debt securities and outstanding international public debt securities is expected to increase renewable energy consumption by approximately 0.69 and 0.15, respectively. However, it was determined that the short-term coefficients of OPblcDS and OPrvtDS variables are not statistically significant. Findings on stock market indicators support the H2 hypothesis, suggesting that financial development increases renewable energy consumption.

Finally, according to the DFE estimation results of the economic development model, the error correction parameter is negative and statistically significant. While the long-term coefficient of GDP is negative but not statistically significant, the short-term coefficient is positively (0.0670) and statistically significant. Accordingly, a 1% increase in GDP in the short term will increase renewable energy consumption by approximately 0.07%. In this case, it can be said that the H1 hypothesis is valid for these countries in the short term.

Considering that there is a long-term relationship between variables, causality analysis was applied to examine short-term dynamics.

Table 8: Fisher Causality Test (For Panel)

	OPrvtDS→ REC	**OPblcDS→ REC**	**LL→REC**	**DCPrvtS→ REC**	**DMB→ REC**	**SMTVTrade→ REC**
Fisher Test	63.636***	56.803**	70.008***	41.499	43.239	40.306
	SMR→ REC	ROE→ REC	SMC→ REC	SMTR→ REC	GDP→ REC	DMBACB→ REC
Fisher Test	20.365	25.722	28.471	27.247	87.401***	36.250
*****, **, and * denote significance at 0.01, 0.05 and 0.10, respectively.**						

The causality relationship between the series was examined with the Panel-Fisher causality test. As can be seen in Table 8, a causality relationship towards renewable energy consumption (REC) from the outstanding international private debt securities (OPrvtDS), outstanding international public debt securities (OPblcDS), and gross domestic product (GDP) has been determined for the panel. A causality relationship to REC from all other variables has not been found.

Table 9: Fisher Causality Test (individual country results)

Country	Austria		Australia		Korea, Rep.		Turkey		United States		Greece	
	Wald	**P-value**	**Wald**	**P-value**	**Wald**	**P-value**	**Wald**	**P-value**	**Wald**	**P-value**	**Wald**	**P-value**
OPrvtDS→REC	2.831* (1)	0.092	0.339 (1)	0.561	1.168 (1)	0.280	0.005 (1)	0.945	1.598 (1)	0.206	4.539 (2)	0.103
OPblcDS→REC	0.021 (1)	0.886	1.752 (1)	0.186	2.599 (1)	0.107	0.015 (1)	0.902	10.772** (3)	0.013	0.401 (1)	0.526
LL→REC	0.250 (1)	0.617	0.052 (1)	0.819	23.28***5 (3)	0.000	0.747 (1)	0.387	0.099 (1)	0.753	0.666 (1)	0.415
DCPrvtS→REC	1.311 (1)	0.252	1.455 (1)	0.228	0.080 (1)	0.777	6.895** (2)	0.032	0.001 (1)	0.978	1.844 (1)	0.175
DMB→REC	0.350 (1)	0.554	1.262 (1)	0.261	9.820** (3)	0.020	0.014 (1)	0.904	0.120 (1)	0.729	0.308 (1)	0.579
SMTVTrade →REC	4.786*(2)	0.091	1.697 (2)	0.428	1.719 (1)	0.190	0.242 (1)	0.623	0.249 (2)	0.883	2.393 (2)	0.302
SMR→REC	0.137 (1)	0.711	1.157 (1)	0.282	0.080 (1)	0.778	0.525 (1)	0.469	0.020 (1)	0.888	1.623 (1)	0.203
ROE→REC	0.017 (1)	0.896	2.097 (1)	0.148	0.080 (1)	0.778	0.732 (1)	0.392	0.109 (1)	0.741	6.692** (1)	0.010
SMC→REC	0.007 (1)	0.932	0.880 (1)	0.348	0.006 (1)	0.938	1.528 (1)	0.216	0.616 (1)	0.432	8.731** (2)	0.013
SMTR→REC	8.712** (2)	0.013	0.462 (1)	0.497	1.944 (1)	0.163	0.998 (1)	0.318	0.066 (1)	0.798	0.022 (1)	0.883
GDP→REC	1.085 (1)	0.298	3.383* (1)	0.066	0.011 (1)	0.918	0.420 (1)	0.517	0.024 (1)	0.877	8.627*** (1)	0.003
DMBACB→REC	13.004*** (3)	0.005	0.009 (1)	0.923	0.765 (2)	0.682	0.342 (3)	0.952	1.829 (3)	0.609	2.220 (1)	0.136

*****, **, and * denote significance at 0.01, 0.05 and 0.10, respectively. Values in () indicate the lag lengths.**

Table 9: Fisher Causality Test (individual country results) (continue)

Country	Hungary		Ireland		Japan		New Zealand		Poland		Spain	
	Wald	P-value	Wald	P-value	Wald	P-value	Wald	P-value	Wald	P-value	Wald	P-value
OPrvtDS→REC	1.699 (1)	0.192	31.720*** (2)	0.000	0.191 (1)	0.662	0.262 (1)	0.609	0.484 (1)	0.487	6.523 (1)	0.11
OPblcDS→REC	4.098** (1)	0.0403	6.435** (2)	0.040	6.501* (3)	0.090	1.885 (1)	0.170	16.656*** (3)	0.001	1.675 (1)	0.196
LL→REC	7.494*** (1)	0.006	28.034*** (2)	0.000	0.232 (1)	0.630	0.325 (1)	0.569	1.989 (3)	0.575	1.168 (1)	0.280
DCPrvtS→REC	0.034 (1)	0.854	5.362 (3)	0.147	0.380 (1)	0.538	0.538 (1)	0.463	2.046 (1)	0.153	16.634*** (3)	0.001
DMB→REC	0.107 (1)	0.744	14.396*** (2)	0.001	0.061 (1)	0.805	9.869** (3)	0.020	1.283 (2)	0.527	3.088* (1)	0.079
SMTVTrade →REC	0.144 (2)	0.931	3.371 (2)	0.185	0.000 (1)	0.998	0.526 (1)	0.468	23.249*** (3)	0.000	1.400 (2)	0.497
SMR→REC	1.857 (2)	0.395	0.708 (1)	0.400	0.021 (1)	0.884	0.466 (1)	0.495	5.021 (3)	0.170	1.357 (1)	0.244
ROE→REC	0.205 (2)	0.903	1.111 (2)	0.574	0.537 (1)	0.464	1.351 (1)	0.245	0.256 (1)	0.613	4.118 (3)	0.249
SMC→REC	2.136 (2)	0.314	0.234 (2)	0.890	2.316 (2)	0.314	0.332 (1)	0.565	7.338*** (3)	0.062	1.230 (2)	0.541
SMTR→REC	4.714** (1)	0.030	0.097 (1)	0.755	0.012 (1)	0.912	0.441 (1)	0.507	0.407 (1)	0.523	0.100 (2)	0.951
GDP→REC	27.957*** (1)	0.000	12.257*** (1)	0.000	1.247 (1)	0.264	0.384 (1)	0.535	6.222* (3)	0.101	7.984*** (1)	0.005
DMBACB→REC	0.046 (2)	0.977	1.107 (2)	0.575	2.373 (1)	0.123	1.405 (1)	0.236	11.024*** (3)	0.012	2.355 (2)	0.308

The individual country results obtained from the Emirmahmutoğlu-Köse (2011) causality test are given in Table 9. When individual country results were evaluated, "OPrvtDS is not cause of REC" null hypothesis was rejected for Austria and Ireland and accepted for all other countries. The "OPblcDS is not the cause of REC" null hypothesis was rejected for United States, Hungary, Ireland, Japan, and Poland while it was accepted for all other countries. There is a causal relationship from LL to REC for Korea Rep., Hungary, and Ireland. A causality relationship from DCPrvtS to REC has been identified for Turkey and Spain only. When examining individual country results for BMG, it is seen that there is a causality relationship from DMB to REC for Korea, New Zealand, and Spain. There is a causal relationship from DMBACB to REC for Australia and Poland. A causality relationship from SMTVTrade to REC has been established for Austria and Poland. No causality relationship from SMR to REC has been found for any country level, and only for Greece, a causal relationship exists from ROE to REC. Again, there is a causal relationship from SMC to REC only for Greece and Poland. A causality relationship from SMTR to REC has been observed for Austria and Hungary. Finally, when examining individual country levels for the GDP variable, there is a causality relationship from GDP to REC for Australia, Greece, Hungary, Ireland, Poland, and Spain.

E. CONCLUSION

In this study, the relation between financial development (FD), economic growth (EG), and renewable energy consumption (REC) are investigated for twelve countries belonging to the IEA, which includes Austria, Australia, Korea, Rep., Turkey, United States, Greece, Hungary, Ireland, Japan, New Zealand, Poland, Spain for the period 1996-2017. FD is evaluated with three subdimensions as banking, stock market, and bond market. The effect of three financial development variables FIN1 (stock market), FIN2 (banking), and FIN3 (bond market) and economic growth on REC are investigated. In the empirical application, cointegration and causality tests are applied for each financial development indicator, EG, and REC data. Several prerequisite tests for cointegration and causality tests are also applied to our model.

According to panel cointegration test results, long-term coefficients of liquid liabilities (LL), domestic credit to private sector (DCPrvtS), deposit money banks' assets (DMB), outstanding international public debt securities (OPblcDS), and outstanding international private debt securities (OPrvtDS) variables are statistically significant. Yet, LL is observed negatively correlated with renewable energy consumption while DCPrvtS, DMB, OPblcDS, and OPrvtDS are positively in the long run. EG is observed affecting REC positively in the short term.

According to panel causality test results, a causality relationship towards REC from the outstanding international private debt securities (OPrvtDS), outstanding international public debt securities (OPblcDS), and gross domestic product (GDP) has been determined for the panel. At the country level, REC is causally related to several FD indicators and EG for different countries in our whole sample. These results also imply the existence of short-term relation between FD & REC, and EG & REC.

In conclusion, three different components of FD efficiently evaluate the effect of FD on REC. The general observation is that both stock market, banking, and bond market-related FD indicators positively affect REC except liquid liabilities. This result is assumed to be stemming from that higher liquid liabilities leads countries to turn to non-renewable energy sources. Thus, short-term debt obligations may decrease the efficiency of energy use (Shahbaz & Lean, 2012; Sadorsky, 2010; Tamazian et al., 2009). Furthermore, the well-developed bond market seems highly related to REC in the short term. This result is also consistent with the literature (Destek, 2018; Miola et al., 2021). As a general observation, the stock market and bond market variables seem to be more related to REC than banking indicators. Furthermore, the results support the main concern about FD measurement mentioned previously in our research: the effect of FD on REC changes drastically according to indicators. In the context of economic growth, the results also validate our hypothesis, assuming the positive effect of EG on REC (Akhtar et al., 2016; Magazzino, 2018; Shahbaz & Lean, 2012).

It is suggested that an increase in economic growth results in higher renewable energy consumption for policymakers. Similarly, enhancement in financial development causes advance in REC. Governors might support businesses through loanable funds and capital market instruments to promote renewable energy consumption. Financialization via the banking sector, capital, and bond markets seems to provide firms with higher operational activities and renewable energy consumption.

Our empirical findings rely on our sample and utilize methodological approaches. Although our main concern is covering all aspects of the relation between FD, economic growth, and REC, different methodologies and sample countries maybe result in various observations. Thus, it is suggested that our approach can be applied to other countries and varying periods. Another restriction is the utilized data. Some energy efficiency-related country data does not exist or is hard to gain; the statements about the effect of FD and economic growth on energy efficiency rather than REC relies on our assumptions. This effect can also be investigated via further studies.

Contribution Rate Declaration

The authors declare that they have contributed equally to the article.

Conflict of Interest Declaration

The authors of the article declare that there is no conflict of interest between them.

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