

# FINANCIAL DEVELOPMENT IMPACT ON RENEWABLE ENERGY FOR CARBON NEUTRALITY AND SUSTAINABILITY

**LAMIAA SAAD MOHAMED RAMADAN<sup>1</sup>, MEDHAT EL-AKKAD<sup>2</sup> and KHAIRIA  
ABDEL FATTAH<sup>3</sup>**

<sup>1</sup>Teaching Assistant, Economics Department, Faculty of Commerce, Zagazig University, Egypt.

Corresponding author E-mail: lamiaas0ramadanl@gmail.com

<sup>2</sup>Professor of Economics, Faculty of Commerce, Zagazig University, Egypt.

<sup>3</sup>Professor of Economics, Faculty of Commerce, Zagazig University, Egypt.

## Abstract

The present paper examines whether financial development (FD) promotes the deployment of RETs, using Panel data fixed effect model for 93 developed and developing countries from 1978 to 2014. Our empirical findings show the importance of the banking sector in the development of RE in comparison to other financial institution. In the opposite, each and overall component of stock market development haven't impact on RE expansion. Composite index includes six variables of financial development positively impact RE expansion.

## INTRODUCTION

The consumption of renewable energy (RE) contributes not only to a cleaner environment (through reduction of greenhouse gas emissions) but also to independence from fossil fuel markets and to energy security [1]. In order to strengthen the global response to the threats of climate change, in the context of sustainable development (SD), the Paris Agreement goal is to limit global warming to less than 2 preferably to 1.5 degrees Celsius, compared to pre-industrial levels. Therefore, the three main Green House Gas (GHG) emitters (EU), China, and (USA.) concentrate on carbon neutrality as their target. EU and have decided to become climate neutral by 2050. China target is to achieve carbon neutrality before 2060 [2]. In reality, the initial capital cost of RE is relatively high compared to conventional sources of energy. As well as, renewable projects need both long pay-back periods and high levels of financing [3]. Consequently, FD could be an important driver of higher RE consumption. Financial infrastructure can increase economic growth and enhance the demand for energy [4]. Hence, a high level of FD leads to developing financial markets and subsequently more funds available for investment [5]. Although, the rich literature highlights the relationship between FD and conventional energy consumption then still a gap in analyzing the connection between FD and RE .As a result, this study will help in fill the gap by analyzing the impact of FD on RE. This paper is among the first to quantitatively and analyze the impact of FD on RE generation. Consequently, this study analyzes how FD stimulates RE consumption. It brings important contributions to existing literature that is methodological and empirical as well:

- The study join a large body of existing literature seeking to explain the relationship between FD and RE consumption which is under-examined in the existing literature.
- The analysis contributes indirectly to existing literature on environmental effects of FD where the evidence on finance environment nexus is inconclusive.

Empirically, the relationship between FD and RE consumption has been enhanced in recent years and the results are mixed. Dynamic association between FD, natural resources, globalization, non-renewable, and RE consumption on GHG emission and economic growth have been illustrated for eight Arctic countries from 1990 to 2017. RE use can overcome GHG emissions' overall level and boost economic growth in the long run [6]. The impact of five banking sector performance indicators (return on asset, market capitalization, asset quality, managerial efficiency and financial stability) on RE consumption have been considered for a global panel consisting of 124 countries. According to their results, the share of RE consumption in high income countries is significantly and positively affected by an increase in bank size, a low level of non-performing loans and well-managed banks. The study shows that low levels of non-performing loans seem to decrease RE consumption as a share of total energy consumption for middle- and low- income countries [7]. Improvement in FD, RE and human capital index result in limiting carbon emissions has been analyzed. The negative association between FD and carbon emissions supports the positive school of thoughts of FD that promotes a SD. This study recommends the promotion of quality human capital and green FD along with increasing the shares of RE in electricity for achieving China 2030 climate targets. China's transformation from a low-income country to an emerging economy leads to carbon emission rise [8]. The nonlinear autoregressive distributed lags model have been used to investigate the influence of FD on RE consumption in the U.S. Financial institutions can be directed to provide loans but the rate of interest on borrowing needs to be discriminatory[9]. The long-run equilibrium relationship between the variables emissions in 69 countries has been supported. The study's long run estimates indicate that Income, FDI, and innovations are the negative and FD is a positive determinant RE consumption of countries [10]. The impact of FD development on RE consumption in 34 upper middle income developing countries have considered from 1994 to 2015. They show that FD has a positive effect on RE consumption but depends on economic development levels [11]. BELAÏD et al. (2021) have aimed to fill the gap by examining the impact of political stability, quality of governance and institutions, and FD on the deployment of RE production in 9 selected MENA countries using annual data over the period 1984-2014. These findings have revealed that political stability, governance effectiveness, and FD are essential drivers for promoting RE production in the MENA region [12]. The impact of five major factors affecting RE consumption: FD, environmental pollution, innovation, economic freedom, and real GDP per capita have been studied in the ASEAN 3 group. The ARDL panel approach was used to test panel data for the period 1998-2018. First, the results in the short and long term show that FD hinders RE consumption. The results confirmed that environmental pollution is inversely proportional to RE consumption. Innovations, research and development, technological progress help to increase RE consumption [13]. The positive effect of FD on RE appears to be statistically significant for high-income countries but insignificant for low- and middle-income countries. More developed financial markets are better in financing RE investment projects. Adapting to RE requires not just more finance, but also avoid the risks associated with RE. As a result, banks and other large financial institutions have not yet given full attention to RE. Hence, cooperatives and microfinance can contribute significantly to the development of RE [14]. The long-run asymmetric relationships between FD, trade openness; capital flows and RE consumption have been confirmed in the case of all three subsamples

namely, low-income countries, middle income countries and upper-middle-income panel. Two-step system generalized method of moments approach to a global sample of 55 countries in 2005–2014. They indicate that FD is a significant determinant of RE deployment [15]. The effect of FD on RE consumption using a panel data of 28 countries EU over the period 1990–2015 has been examined. RE consumption is given as a function of income, energy prices, FD and FDI. The results show that all three different dimensions of FD (banking sector, bond market, and capital market) have a positive effect on the share of RE consumption. Additionally, their results show that capital market development does not affect RE consumption in the EU and the bond market development has a positive impact [1]. The cross-sectional autoregressive distributed approach have been used to analyze panel time-series data over the period 1980–2016 for EU member countries. They have revealed that Stock market development [SMD] reduces carbon intensity through both production and consumption RE through market capitalization–induced technological innovation [16]. Stock market data in China from 1992 to 2013 through a time series analysis have shown that FD is critically important and explains over 40% of the variation in the changes in the share of RE [17].

## DATA SOURCES AND METHOD

### Data sources

**Table 1: Definition of data and its sources**

Indicator	Definition	Source
Electricity prod. (% of total)	Electricity production from renewable sources, excluding hydroelectric (% of total)	1
Domestic credit (% of GDP)	Domestic credit to private sector (% of GDP)	2
Private credit to GDP (%)	Private credit by deposit money banks and other financial institutions to GDP (%)	2
Liquid liabilities to GDP (%)	Liquid liabilities to GDP (%)	2
SM capitalization to GDP (%)	Stock market capitalization to GDP (%)	2
SM total value traded to GDP	Stock market total value traded to GDP (%)	2
SM turnover ratio (%)	Stock market turnover ratio (%)	2
GDP per capita	GDP per capita (constant 2010 US\$)	1
FDI flow (% of GDP)	Foreign direct investment, net inflows (% of GDP)	1
Ind. value added (% of GDP)	Industry (including construction), value added (% of GDP)	1
CO <sub>2</sub> per capita	CO <sub>2</sub> emissions (metric tons per capita)	1
Feed-in tariff policy	Feed-in tariff (incl. premium payment)	3
Net metering policy	Net metering	3
Tradable REC policy	Tradable REC	3
Fiscal Incentives policy	Capital subsidy, grant, or rebate	3
Public Financing policy	Public competitive bidding	3

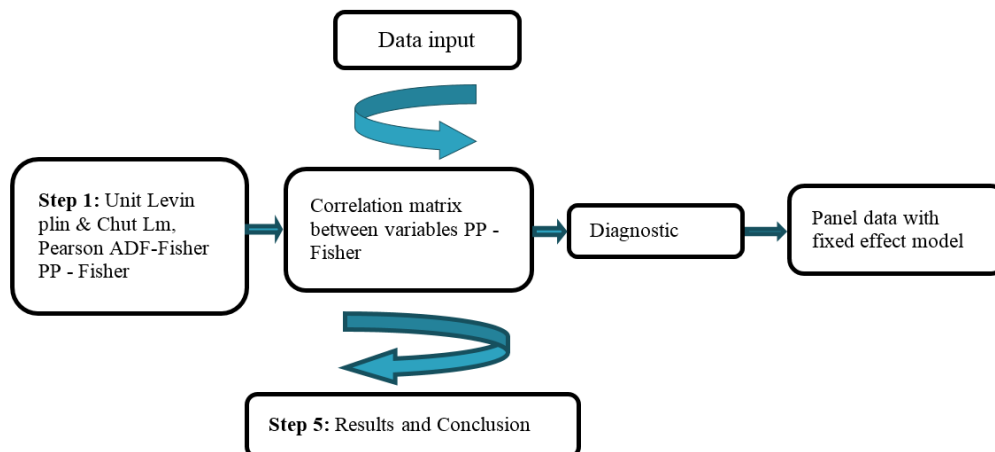
- 1: WDI; World Development Indicators (World Bank)
- 2: GFDD: Global Financial Development Database (World Bank)
- 3: GSR: Global Status Report (Renewable Energy Policy Network for the 21<sup>st</sup> Century)

## Method

This paper investigates the relationship among share of renewable electricity generation, FD according to different income levels. Panel data model for 93 developed and developing data from 19878 to 2014. The researcher takes into account homogeneous sample to reflect differences in different income levels, geographic levels, FD levels, RE expansion. Consequently, this helps to prevent any group of countries on controlling on the results causing biased results. This study includes 34 high income levels, Sample (2); 27 indicate to Upper Middle Income countries and Sample (3)10 indicate to Low Income countries & 12 Lower Middle Income countries. According to the literature review and the different hypothesis, this study relied on [18] where general model as in equation (1).

$$RE_{it} = C + \sum_{k=1}^K \beta_k X_t^k + \varepsilon_t \quad (1)$$

**Figure 1: Structure of the methodology**



Following [19-20], the study is relied on panel analysis with a fixed effects identification strategy. Share of electricity generation is one of types of RE deployment measurements. An index for the production of electricity from RE sources has been used contained (solar energy, wind energy, geothermal energy, as a percentage from the total production, excluding hydro energy). By contrast, FD is one of the following:  $Equity_{i,t}$ ,  $Credit_{i,t}$ , or  $Overall_{i,t}$ . The expansion of RE installation may depend not only on the financing environment, but also on the economic level for each country. The variables affected RE technology should be controlled. Economic growth may be positively correlated to RE development. Hence, per capita GDP for each country is used as a control variable. Foreign direct investment (FDI) is measured as net inflows of capital. Specifically, the transition to RE technologies requires high amount of investment and restructuring economic sectors. Therefore,  $Co_2$  emissions (metric tons per capita) are used as a control variable. Finally, value added as a percentage of GDP is used as a control variable to view heterogeneity between countries. All these control variables data is obtained from WDI

database. Specifically, the linear model of the FD and RE development relationships is expressed in equation (2):

$$RE_{it} = \beta_{io} + \beta_1 FD_{it} + \beta_2 GDP_{it} + \beta_3 FDI_{it} + \beta_4 CO_{2it} + \beta_5 VA_{it} + \lambda_i + u_t \quad (2)$$

$RE_{it}$ : Dependent variable, percentage share of renewable electricity generation

$FD_{it}$ : Independent variable (It is the level of financial development), the study relied on six indicators to describe FD. Three indicators were used to express the credit market development and the other three indicators for the description of stock market development.

$\beta_o$ : Constant of the equation

$\beta_1 \rightarrow \beta_5$ : Regression coefficient

$t$ : Time period from 1978 to 2014

$I$ : Sample of countries used is equal to 93 comprised developed and developing countries

$u_t$ : Error level (term)

$\lambda$ : Country fixed effect that absorbs country-specific features.

The sign and significance of  $\beta$  are checked to examine FD effect on the growth of renewable sectors. If  $\beta$  is significantly positive, the equity (credit or overall) market development is associated with disproportionately faster growth in renewable sectors that are highly dependent on external financing. Additionally, the signs of  $\beta_2$ :  $\beta_5$  is expected to be positive.

## RESULTS AND DISCUSSION

From Table 2, the analysis of correlation from degree 0 between the variables of the study is investigated by using bivariate correlation. It shows analysis of the variables from degree zero. By using bivariate correlation, it allows the preliminary examination of the supposed relationship. The study describes demonstrates effects of financial composite index of FD on RE deployment. The most control variable related to RE is industrial value added % of GDP with correlation coefficient - 17.8%. The second and third control variables relates with RE are per capita GDP and FDI as % of GDP with 15.4% and 8.7% respectively. The fourth control variable that relates with RE is per capita Co<sub>2</sub> emissions with - 5%. Finally, per capita Co<sub>2</sub> emissions is the least control variable related to RE. Finally, in case of correlation coefficients between independent variables don't exceed 62%, it means correlation coefficient was in between weak and intermediate relationship. It is good for the model for not occurrence of multicollinearity problem.

**Table 2: Correlation matrix between variables**

		1	2	3	4	5	6	7	8	9	10	11
Electricity prod. (% of total)	1	1										
Private credit to GDP (%)	2	0.3109 [13.50]***	1									
Domestic credit (% of GDP)	3	0.2896 [12.53]***	0.9872 [255.6]***	1								
Liquid liabilities to GDP (%)	4	0.1071 [4.442]***	0.7260 [43.49]**	0.7236 [43.19]	1							
SM capitalization to GDP (%)	5	0.0439 [1.627]	0.6306 [29.92]***	0.6349 [30.31]***	0.4159 [16.85]***	1						
SM total value traded to GDP	6	0.0869 [3.207]***	0.5953 [27.06]***	0.5954 [27.12]***	0.3474 [13.55]***	0.6690 [32.76]***	1					
SM turnover ratio (%)	7	0.0163 [0.599]	0.2798 [10.61]***	0.2827 [10.74]***	0.1701 [6.292]***	0.2006 [7.521]***	0.6086 [27.91]***	1				
GDP per capita	8	0.1541 [8.992]***	0.6242 [32.91]***	0.6086 [31.69]***	0.4035 [18.15]***	0.4722 [19.85]***	0.4962 [21.02]***	0.2387 [9.005]***	1			
FDI flow (% of GDP)	9	0.0868 [5.025]***	0.0939 [3.885]***	0.0931 [3.868]***	0.1518 [6.326]***	0.1186 [4.423]***	0.0612 [2.253]**	-0.0353 [-1.29]	0.1129 [6.531]***	1		
Ind. value added (% of GDP)	10	-0.1777 [-9.83]***	-0.1234 [-5.03]***	-0.1144 [-4.67]***	-0.0648 [-2.62]***	-0.0156 [-0.57]	-0.0112 [-0.41]	0.0341 [1.231]	0.0641 [3.511]***	-0.0707 [-3.86]***	1	
CO2 per capita	11	-0.0503 [-2.91]***	0.3360 [14.35]***	0.3265 [13.94]***	0.2174 [8.955]***	0.3813 [14.99]***	0.3590 [13.91]***	0.1752 [6.410]***	0.7242 [59.61]***	0.0175 [0.999]	0.3452 [19.74]***	1

**Table 3: Effects of financial composite index of FD on RE deployment**

Dependent Variable: Electricity prod from renewable sources (% of total) [in first difference]  
Methods: 1way-Fixed effects with white cross-section standard errors.

	Total Sample	Samle1	Up Sample2	Sample 3
	Reg (1)	Reg (2)	Reg (3)	Reg (4)
Financial depth overall	0.0345 [ 4.273]***	0.0342 [ 2.038]**	0.0422 [ 2.841]***	0.0552 [ 2.272]**
GDP per capita	2.56e-5 [ 7.460]***	0.0002 [ 3.775]***	1.31e-6 [ 0.238]	1.53e-5 [ 3.179]***
FDI flow (% of GDP)	-0.0041 [-2.902]***	-0.0038 [-0.675]	-0.0024 [-2.522]**	-0.0105 [-2.092]**
Ind. value added (% of GDP)	0.0001 [ 0.214]	0.0154 [ 7.049]***	0.0019 [ 2.633]***	-0.0024 [-0.338]
CO <sub>2</sub> per capita	-0.0837 [-5.997]***	0.4318 [ 4.384]***	0.0213 [ 2.026]**	-0.2057 [-5.251]***
CO <sub>2</sub> per capita square	0.0004 [ 1.019]			0.0036 [ 3.964]***
Feed-in tariff policy	0.0974 [ 4.659]***	0.2073 [ 2.025]**	0.0302 [ 0.889]	0.3282 [ 4.938]***
Net metering policy	0.0652 [ 2.593]***	0.4559 [ 2.392]**	0.0935 [ 2.972]***	-0.1499 [-1.949]*
Tradable REC policy	-0.0112 [-0.572]	1.6429 [ 6.002]***	-0.0469 [-1.894]*	0.0874 [ 1.162]
Fiscal Incentives policy	0.0478 [ 3.322]***	-0.2115 [-5.653]***	0.0453 [ 1.307]	0.0988 [ 1.375]
Public Financing policy	0.0496 [ 2.072]**	0.2460 [ 4.311]***	0.0868 [ 2.050]**	0.0219 [ 0.414]
Constant	0.2803 [ 3.459]***	0.4623 [ 3.983]***	-0.0276 [-0.507]	1.4758 [ 5.343]***
Adjusted R <sup>2</sup>	%68.3	%62.2	%64.3	%43
DW-stat.	1.8985	0.4348	2.2491	1.9813
Fisher test	(10.18)***	(126.3)***	(5.036)***	(10.54)***
Obs.	1228	267	416	545
No. of Countries	73	16	24	33
Residual variance test	(4.153)***	(224.1)***	(4.488)***	(4.463)***
Breusch-Pagan test	(128.2)***	(1162)***	(0.797)	(77.67)***
Hausman test	(55.15)***	(16.20)*	(25.66)***	(21.88)**
Time test	(31.09)	(13.38)	(24.32)	(42.41)**

- 1: Sample (1); indicate to Low & Lower Middle Income Countries
- 2: Sample (2); indicate to Upper Middle Income Countries
- 3: Sample (3); indicate to High Income Countries.

Table 3 illustrates estimation of overall FD indicator and RE according to income levels. Reg 1 views the composite index that includes the six variables of credit market and stock market. Subsequently, it contains six variables of FD. As shown in table 3, the effect of composite index of FD on RE generation on the income levels. Reg 1 confirms the acceptance of the main hypothesis of the study that overall FD has positive impact on RE generation at 1% significance



level. An increase of overall FD index % GDP with 1% leads to 3.45% increase of RE generation. Subsequently, evolution of FD leads to the expansion in RE that depends mainly on credit market which has dominance of FD. At low and lower middle income countries, an increase of 1% overall FD index leads to an increase of RE generation of 3.45%. Regarding the upper middle income countries, the increase of overall FD index with 1% cause to the increase in RE generation with 4.22% then increases to 5.52% in high income countries. Lastly, the high value of coefficient of determination adjusted of the four regressions in the fixed effect model. It interprets about more than 38% of the changes in RE generation. According to Durbin Watson (DW – Statistic) confirms nonexistence of serial correlation from degree (1) between residuals. DW – statistic calculated is around two and its more than the tabulated value. Fisher test shows the acceptance of the alternative hypothesis with the existence of statistical significance for the four regressions used at significance 1% level. But regarding, control variables in Reg (1) to Reg (4), it is clear that they coincide with some of what confirms the stationary and stability of the results of these variables regardless adding new variables in the model. The four regressions confirm the existence of positive impact of per capita GDP on RE generation. According to the Kuznets Curve, the increase in economic development and national income enhances structural change in industries and services. In addition to the increase of environmental awareness, technological improvement, environmental laws which decreases the pollution levels. Thus, as the income levels increases, it encourages the reduction of pollution through the dependence on RE resources. Per capita CO<sub>2</sub> emissions confirm the results of the regression model through the U curve. The per capita CO<sub>2</sub> emissions has negative relationship on RE at low levels of pollution whereas it has a positive relationship at high levels of pollution. At low levels of pollution, it leads to inaction of countries for applying RE especially of it requires high investment costs and restructuring economic sectors to cope with new sources for energy. On the other hand, the negative effect of FDI as a percentage of GDP on the RE generation at 1% significance because of the FDI is not interested with the environmental issues. Consequently, it depends on fossil fuel because it has low cost and the stability of its technology in comparative to RE. Finally, the five policies have positive impact on the RE generation according to the four regression models. Regarding, feed in tariff has high impact on the expansion of RE in comparison to the other policies in the sample.

### **Conclusion, recommendation and perspectives**

An economy's sustainable growth depends on the development of RE sectors. This study examines whether financial market development promotes the deployment of RETs. Using Panel data fixed effect model for 93 developed and developing data from 1978 to 2014. Our empirical findings show the importance of the FD on the expansion of RE. Consequently, this is consistent with the hypothesis of the study and economic theory. Composite index includes six variables of FD positively impact RE expansion. At low and lower middle income countries, an increase of 1% overall FD index leads to an increase of RE generation of 3.45%. Regarding the upper middle income countries, the increase of overall FD index with 1% cause to the increase in RE generation with 4.22% then increases to 5.52% in high income countries. Per capita GDP positively affect RE expansion. According to Kuznets curve, increase in economic growth leads to structural changes in industries to decrease pollution. Per capita CO<sub>2</sub> emission takes U shape curve as it has

negative impact on RE at low levels of pollution and vice versa. Hence, countries with low levels of pollution causes to inaction of government for RE as it requires huge investment and restructuring economic sectors and vice versa. Industrial value added positively affects RE development as increase in manufacturing, income pushes the society for restructuring to RET. Our results suggest that improvements in financial sectors are a significant determinant of RE deployment. This has important implications for policy makers, who should design institutional mechanisms with easier access to financing for firms in the RE sectors. Thus, we suggest that future studies can add other financial development variables that may influence RE development. Analyzing the impact of FD with another country group may provide different results. In addition, we have time limitations since the most current data related to RE consumption in the World Bank database is available until 2015. The main conclusion is that FD may become a critical factor to stop global climate change if countries allocate funds to environmentally friendly through policies and strategies.

## References

1. Anton SG, Nucu AEA. The effect of financial development on renewable energy consumption. A panel data approach. *Renewable Energy*. 2020; 147: 330-338.
2. Lahiani A, Mefteh-Wali S, Shahbaz M, VO XV. Does financial development influence renewable energy consumption to achieve carbon neutrality in the USA? *Energy Policy*. 2021; 158: 112524.
3. Wang J, Zhang S, Zhang Q. The relationship of renewable energy consumption to financial development and economic growth in China. *Renewable Energy*. 2021; 170: 897-904.
4. Sadorsky P. The impact of financial development on energy consumption in emerging economies. *Energy policy*. 2010; 38(5): 2528-2535.
5. Estrada G, Donghyun P, Ramayandi A. OKUNDU\_07.02.2018\_GÜZEL ÇALIŞMA\_Financial Development and Economic Growth in Developing Asia. WP 213/Asian Development Bank. 2010; 233(233): 1-63, [www.adb.org/economics](http://www.adb.org/economics).
6. Usman M, Jahanger A, Makhdam MSA, Balsalobre-Lorente D, Bashir A. How do financial development, energy consumption, natural resources, and globalization affect Arctic countries' economic growth and environmental quality? An advanced panel data simulation. *Energy*. 2022; 241: 122515.
7. Menyeh BO. Financing electricity access in Africa: A choice experiment study of household investor preferences for renewable energy investments in Ghana. *Renewable and Sustainable Energy Reviews*. 2021; 146: 111132.
8. Qin L, Hou Y, Miao X, Zhang X, Rahim S, Kirikkaleli D. Revisiting financial development and renewable energy electricity role in attaining China's carbon neutrality target. *Journal of Environmental Management*. 2021; 297: 113335.
9. Lahiani A, Mefteh-Wali S, Shahbaz M, VO XV. Does financial development influence renewable energy consumption to achieve carbon neutrality in the USA? *Energy Policy*. 2021; 158: 112524.
10. Khan A, Chenggang Y, Hussain J, Kui Z. Impact of technological innovation, financial development and foreign direct investment on renewable energy, non-renewable energy and the environment in belt & Road Initiative countries. *Renewable Energy*. 2021; 171: 479-491.
11. Shahbaz M, Topcu BA, Sarigül SS, VO XV. The effect of financial development on renewable energy demand: The case of developing countries. *Renewable Energy*. 2021; 178: 1370-1380.



12. Belaïd F, Elsayed AH, Omri A. Key drivers of renewable energy deployment in the MENA Region: Empirical evidence using panel quintile regression. *Structural Change and Economic Dynamics*. 2021; 57: 225-238.
13. Assi AF, Isiksal AZ, Tursoy T. Renewable energy consumption, financial development, environmental pollution, and innovations in the ASEAN+ 3 group: Evidence from (P-ARDL) model. *Renewable Energy*. 2021; 165: 689-700.
14. Le TH, Nguyen CP, Park D. Financing renewable energy development: Insights from 55 countries. *Energy Research & Social Science*. 2020; 68: 101537.
15. Qamruzzaman M, Jianguo W. The asymmetric relationship between financial development, trade openness, foreign capital flows, and renewable energy consumption: Fresh evidence from panel NARDL investigation. *Renewable Energy*. 2020; 159: 827-842.
16. Zeqiraj V, Sohag K, Soytaş U. Stock market development and low-carbon economy: The role of innovation and renewable energy. *Energy Economics*. 2020; 91: 104908.
17. Ji Q, Zhang D. How much does financial development contribute to renewable energy growth and upgrading of energy structure in China? *Energy Policy*. 2019; 128: 114-124.
18. Kim J, Park K. Financial development and deployment of renewable energy technologies. *Energy Economics*. 2016; 59: 238-250, doi.org/10.1016/j.eneco.2016. 08.012
19. Rajan R, Zingales L. Financial development and growth. *American Economic Review*. 1998; 88(3): 559-586.
20. Hsu PD, Lander ES, Zhang F. Development and applications of CRISPR-Cas9 for genome engineering. *Cell*. 2014; 157(6): 1262-1278.