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Does financial development support renewable energy or carbon emissions? A panel data analysis on emerging countries

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Abstract: We investigate the effect of financial development on renewable energy supply rate and CO_2 emissions in the period of 1997–2016. Domestic credit to the private sector, stock market traded value and foreign direct investment are proxies of financial development variables. Fixed and random effects models are estimated with the Parks Kmenta method for 19 emerging countries. According to empirical results, domestic credit to the private sector is statistically insignificant. Stock market development harms renewable energy supply. Unlike the first model, domestic credit to the private sector positively affects emissions. However, stock market development has no impact on emissions. Foreign direct investments reduce both the renewable energy supply rate and emissions. Foreign direct investments are one of the important financial elements of the emerging market countries by providing energy savings. Our findings provide a financial perspective to policymakers on renewable energy and low carbon in emerging countries.

Keywords: renewable energy; financial development; emerging countries.

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1 Introduction

Ecological degradation and climate change are important challenges of the 21st century. These challenges threaten life beyond the damage to human activities. Therefore, a consensus has emerged among scientists and policymakers on preventing the negative effects of climate change in the future [Charfeddine and Kahia, (2019), p.198]. All participants try to take measures on a global scale in mitigating climate change. These international efforts, which started with the United Nations Framework Convention on Climate Change, resulted in the Paris Agreement signed by 195 countries on 12 December 2015. As a result of the Paris Agreement, it is decided to limit global warming to 2°C. The Paris Agreement is an important turning point in mitigating climate change with the countries' national contributions and establishing long-term and cooperative policies. Thanks to Paris Agreement, countries set targets to reduce their greenhouse gas emissions, and these targets were updated at the conferences held after the agreement (UNFCCC, 2021).

The serious increases in the number of gases such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), which are among the natural greenhouse gases, are among the main causes of climate change. Misuse of land, activities in cities and industries, and other economic activities are anthropogenic causes of greenhouse gases. The period of 2011–2020 was the warmest decade in the world. Human impact on global warming increasing at a rate of 0.2°C per decade (EU, 2021). According to The Intergovernmental Panel on Climate Change IPCC's last report, the world temperature will warm up to 1.5°C in the 2030s. Even in the same years, the planet's temperature will exceed 1.6°C. In addition, the concentration of CO_2 in the atmosphere in 2019 was higher than at any time in 2 million years. Concentrations of the important greenhouse gases methane and nitrous oxide were higher than at any time in the 800,000 years. The report emphasises the importance of reducing carbon emissions. To limit temperature rise to 1.5°C, governments need to reduce by half their emissions by 2030. Hence, zero-carbon basis climate change planning should be prepared faster (IPCC, 2021). The effect of human activities on climate change has been examined with different themes. One of these themes is energy consumption. Energy consumption affects carbon emissions and the process of combating climate change [Kahouli, (2017), p.19]. Economic activities are an important element for energy utilisation with their effects and the economic development that started after the industrial revolution affected energy consumption for two reasons. Firstly, industrial production increased the volume of economic activities and energy consumption. Secondly, the increase in purchasing power increased energy consumption due to transportation and residential use. To deal with climate change, studies are carried out on the use of renewable energy sources and creating a sustainable economic model by scientists, policymakers, and businesses [Sadorsky, (2009), p.4021].

Due to the relationship between energy consumption and economic activities, some studies examine the effect of economic growth on energy consumption. These studies have reached different opinions about the relationship between energy consumption and economic growth (Armeanu et al., 2021; Mahmood et al., 2019; Rafindadi and Mika'Ilu, 2019; Sunde, 2018). Financial development can be defined as the increase in foreign direct investments, banking, and stock market transactions in a country. Economic growth and financial development have a complex and mutual relationship (Claessens and Laeven, 2005). Since the developed financial markets, businesses and households can access funds easily, increased investments, employment, and consumption also affect

energy consumption. Therefore, the importance of financial development in energy consumption is emphasised. Financial development variables are added to the models in which energy consumption and economic variables are examined (Karanfil, 2008; Sadorsky, 2011).

As a result of financial development, investments increase with fund allocation, financial risk management becomes easier, savings increase and they are managed more effectively, trade and liquidity opportunities of financial instruments increase [Čihák et al., (2012), p.5; Sadorsky, (2011), p.999]. Thanks to the confidence and increased investments, economic activities are also affected positively. As a result of the growing economy, purchasing power increases. Thus, financial development can affect energy consumption positively (Shahbaz and Lean, 2012). However, there is an important question in the literature about the impact of financial development on energy consumption. Does energy consumption with financial development increase conventional energy or renewable energy?

There are two opinions on this issue in the literature. According to the first opinion, financial development increases economic activities and consumption. This causes an increase in carbon emissions. The second opinion argues that financial development contributes to a sustainable transformation of the economy with renewable energy investments (Sadorsky, 2010; Tamazian and Rao, 2010). We aim to examine the impact of financial development on renewable energy consumption and carbon emissions in emerging market countries for the period of 1997–2016. Our study examines how financial development affects renewable energy and emissions in emerging countries. One of the two models established is examining the effect of financial development on carbon emissions, while the other model examines the impact of financial development on renewable energy supply rate.

Two motivations are the reason for our study. The first is awareness of renewable energy sources. Renewable energy sources are an important element in mitigating climate change. To reduce carbon emissions, the policies, related to renewable energy consumption, have gained importance (Dong et al., 2018). According to the British Petroleum database, primary energy consumption in the world increased by 1.9% between 2009–2019. Renewable energy consumption grew by 13.4% for the same period. Energy consumption decreased by 4.5% in 2020 with COVID-19. But renewable energy consumption increased by 9.7% in 2020 (BP, 2021). However, renewable energy sources are costly. In comparison to established fossil fuels, investing in renewable energy sources also involves additional costs such as infrastructure, start-up, and operation. Financial structures and financial development elements' (credit, stock market, foreign direct investments, etc.) effect on renewable energy investments of countries is significant [Eren et al., (2019), p.190]. Another motivation of the study is emerging countries that will affect the future of the world economy. These countries have not yet fully shaped their financial systems and economic structures. Nevertheless, these countries may be an important economic power in the world economy in the future. (IMF, 2021). Therefore, the impact of emerging countries' financial development on renewable energy can give an idea about the future of mitigating climate change.

Ecological problems involve risks that will cause vital consequences. However, the boost in population, urbanisation and economic competition may impose countries to consume more resources. Thus, sustainable growth has become one of the most debatable issues among researchers, policymakers and government in recent years [Bashir et al.,

(2022), p.541]. Since energy decisions are one of the key variables of sustainable growth, a large literature has emerged about the different dimensions of energy consumption. Because of the cost of environmentally friendly technology, innovative developments and energy trade effect, the impact of macroeconomic data on renewable energy consumption and carbon emissions has been extensively analysed (Ahmed et al., 2016; Usman et al., 2022a). Due to the interrelation connection between economic development and financial development, the effect of financial development variables on renewable energy and carbon emissions has been analysed. However, studies on the impact of financial development on renewable energy are rather limited. Our study contributes to the literature on the impact of financial development on renewable energy supply and emissions. Although the effects of economic and financial variables on renewable energy and carbon emissions are examined separately, the direction of the resource that emerges with the economic and financial development has not been analysed. This study is unique with its two models that examine how economic and financial development affect the energy decisions of emerging countries. Thus, financial indicators that are important for the low carbon target of emerging countries can be revealed and the impact of financial indicators between renewable energy and carbon emissions can be examined bilaterally. In addition, examining the 'impact' instead of the 'relationship' between the variables is another contribution of the study to the literature. Because of the financial development variables in the model and the selected country group, the study has important consequences for policymakers on renewable energy investments. The impact of financial development variables on renewable energy supply and carbon emissions is examined by panel data analysis.

This paper is organised as follows: Section 2 reviews the literature, Section 3 deals with methodology and data, Section 4 presents empirical results and we conclude this study in Section 5.

2 Literature review

There is empirical and theoretical evidence of the impact of financial development on renewable energy and environmental degradation. Theoretical background argues that financial improvements may facilitate access to capital through the credit and equity market effect [Kim and Park (2016), p.240]. Financial development can affect a country's economic growth model and, in conjunction with this model, its energy decision [Usman et al., (2022b), p.11]. Thanks to financial institutions that are well-organised and have a strong technological infrastructure, access to funds can be facilitated, capital costs can be reduced, and businesses can perform their risk management processes more effectively. Therefore, the efficiency of investments and consumption increase (Shahbaz and Lean, 2012).

Increasing investment and consumption contributes to energy utilisation. The theoretical basis includes two views on whether utilisation supports renewable or conventional energy. According to the first view, economic activities and household consumption increase as a result of financial development. For this reason, carbon emissions increase with traditional energy consumption. The second view argues that financial development will support the transition to renewable energy (Tamazian and Rao, 2010; Frankel and Rose, 2002). Both of these views state that the relationship between financial development and energy utilisation depends on intellectual capital,

government policies, existing technological infrastructure and capital structure (Usman et al., 2022b; Shahbaz et al., 2013).

The conceptual framework on the impact of financial development on renewable energy focuses on three key indicators: FDI, equity markets and credits. Through FDI, renewable energy technologies can be supported. FDI is an indicator that positively affects modernisation. Thus, increasing foreign investments are a positive impact on renewable energy technology, especially in countries with capital needs (Doytch and Narayan, 2016). An efficient equity market ensure accurate firm values and equity prices. For this reason, companies encourage investment in a reliable and efficient equity market. Developed equity markets positively affect trust as well as liquidity. Investors can participate in long-term technological investments in a reliable equity market. In addition, compliance with corporate governance principles is high in a developed market. Hence, market control and investor confidence are allocated. On the basis of the development of the credit market, an effective debt-to-credit relationship can be established. Credit institutions collect resources more easily and they support the right companies with good analysis and intelligence. A well-organised credit market reduces firms' cost of capital. Additionally, developed credit institutions can observe firms and establish long-term communication with these firms. In a mature credit environment, credit institutions can advise for firms on business activities to protect lenders' interests. Finally, developed credit markets can support technology investments. Well-resourced and well-managed financial institutions can contribute to the multi-staged and innovative technology investments [Kim and Park, (2016), pp.240–241; Hsu et al., 2014; Stulz, 2000; Beck and Levine, 2002].

The literature on the empirical results of relationships between financial development and energy consumption is divided into two groups. The first group examines the impact of financial development on conventional energy sources. The second group analyses the impact of financial development on renewable energy sources. A limited working group considers renewable energy sources and conventional energy use together. In our study, the effect of financial development on renewable energy consumption and carbon emissions is investigated. In our study, ‘impact’ is analysed.

2.1 Financial development and energy consumption

Thanks to financial development, households and businesses can access funds more easily. In addition, there may be diversity in financing instruments together with market confidence and public offerings. Thus, consumption increases with the volume of work. With this hypothesis, the effect of financial development on energy consumption has been examined [Sadorsky, (2011), p.1000].

Çoban and Topcu (2013) investigate how financial development affects energy consumption. The dynamic panel analysis carried out in 27 EU countries reveals that financial development did not affect energy consumption in the European Union countries during the 1990–2011 period. However, financial development has a positive effect on energy consumption in the old members. Sadorsky (2011) examines the impact of financial development on energy consumption in nine European countries. According to empirical results, stock market turnover has a positive effect on energy consumption. Sheraz et al. (2021) apply fixed effect ordinary least squares to examine the effect of financial development, human capital, and GDP on carbon emissions. According to the

author, financial development and human capital decrease carbon emissions in G20 countries. However, Shoaib et al. (2020) find that financial development has a positive effect on carbon emissions in G8 countries.

Due to the possible future role of emerging economies and their contribution to the economy, some studies examine the impact of financial development on energy consumption in emerging market countries. Sadorsky (2010) analyses the impact of financial development on energy consumption in 22 emerging countries for the period of 1990–2006. The author argues that variables related to the stock market have an impact on energy consumption. Cetin and Bakirtas (2020) find that financial development increases carbon emissions in emerging countries and regulations should be made in financial markets to transition sustainable economy. Destek (2018) investigates three dimensions of financial development in 17 emerging countries from 1991 to 2015. His results show that the bond market decreases energy consumption. Contrary to these studies, Saidi and Mbarek (2017) find that financial development reduces carbon emissions in the analysis of 19 developing countries. Nasir et al. (2019) analyse the role of financial development in environmental degradation in emerging ASEAN Countries. Findings show that financial development has a positive effect on carbon emissions. Ciftci et al. (2020) argue that financial development in emerging countries increases traditional energy consumption and environmental degradation. Hence, the financial sector must undergo a structural change along with the energy sector.

A group of studies examines the issue from the perspective of regional country groups. Gaies et al. (2019) analyse the contribution of financial development to energy consumption in MENA countries. Similarly, Al-mulali and Lee (2013) find a positive effect of financial development on energy consumption in the Gulf Cooperation Council. Baloch and Meng (2019) find that foreign direct investment has a positive effect on energy consumption in OECD countries. Yue et al. (2019) investigate the issue of 21 transitional countries. Empirical results show that financial intermediation development has a positive effect on energy consumption in all countries. However, stock market development decreases energy consumption in China and Poland. In addition, financial openness reduces energy consumption in the Kyrgyz Republic and Georgia.

In some studies, the effect of financial development on energy consumption is analysed in a single country. Cetin et al. (2018) argue that financial development affects energy consumption and carbon emissions. Similarly, Boutabba (2014) finds the effect of financial development on energy consumption and carbon emissions in India. Wang and Gong (2020) financial interrelations ratio and insurance depth have a positive effect on energy consumption in China.

2.2 Financial development and carbon emissions

One of the important issues in the mitigating climate change is to control greenhouse gases. Therefore, greenhouse gases, especially carbon emissions, require action in the world. According to OECD (2021a) carbon emissions in the world should be reduced by 45% in 2030 compared to 2010s to reach zero carbon emission target in 2050. Governments announce packages to reduce carbon emissions to achieve this target. The European Union aims to reduce carbon emissions by at least 55% by 2030, with a broad plan covering industry, transport, social life and the tax system (EU, 2022). Similarly, the USA has announced its plan to reduce carbon emissions by 50–52% by 2030 (White House, 2022). However, governments plan to consume twice the fossil fuel consumption

by 2030 to keep global warming below 1.5°C (UN, 2021). Current economic conditions and urbanisation are handicaps for governments to reduce carbon emissions. Additionally, the cost of transitioning to a sustainable economy is another risk for governments. Rapid urbanisation, the volume of economic activities and lack of capital increase the importance of finance for reducing carbon emissions in emerging countries more than developed countries (OECD, 2021b).

Due to the relationship between the transition to a sustainable economy and macroeconomic factors, the financial development variables of countries and carbon emissions are discussed in the literature. These studies intend to reveal the role of financial development in mitigating climate change.

Jiang and Ma (2019) analyse the impact of financial development on carbon emissions in a global level (155 countries), developed and emerging countries with system generalised method. In accordance with the empirical findings, at the global level and in emerging market countries, financial development has a significant and positive impact on carbon emissions. Acheampong et al. (2020) conclude that the effect of financial development on carbon emissions varies depending on the stage of financial economies. Financial development has a negative impact on carbon emissions in developed and emerging market countries. Adversely, financial development increases carbon emissions in frontier economies. Tamazian et al. (2009) examine the impact of FDI, stock market value, deposit money bank asset to GDP, financial openness and financial liberalisation on carbon emission in the BRICS countries. The random effect model shows that all financial development variables reduce carbon emissions. Tamazian and Rao (2010) argue that financial liberalisation has a positive impact on environmental quality. Al-mulali et al. (2015) express the role of credit to reduce carbon emissions. In compliance with the cointegration approach domestic credit to private sector affects carbon emissions in 129 countries.

Some studies examine the effect of financial development variables on carbon emissions in specific countries rather than country groups. Zhang (2011) emphasises that financial development indicators play an important role in carbon emissions in China. Stock market has a higher impact on carbon emissions, while FDI has a low impact on carbon emissions. Odugbesan and Adebayo (2020) study the impact of financial development on carbon emissions in Nigeria. Empirical results indicate that financial development has a long term positive effect on carbon emissions. Shahbaz et al. (2013) argue that credit variable reduce carbon emissions in Malaysia. Hasan et al. (2021) conclude that financial development short term and positive effect on carbon emissions. According to Salahuddin et al. (2018), financial development increases carbon emissions in Kuwait. Doganlar et al. (2021) investigate the long run impact of financial development on carbon emissions. Depending on the residual augmented least squares approach, financial development has a statistically significant effect on carbon emissions.

Studies on financial development and carbon emissions have findings compatible with the theoretical background. The impact of financial development on carbon emissions varies depending on the socioeconomic structure of countries and the organisation of the financial sector.

2.3 Financial development and renewable energy

Due to climate change and ecological problems, one of the important issues of the 21st century is renewable energy sources. Renewable energy is nature friendly and useful alternative to traditional energy sources (Eren et al., 2019; Lin et al., 2016). The transformation in energy issues is also reflected in the literature. Therefore, renewable energy consumption has been one of the variables added to the established models. In some of these studies, renewable energy is the independent variable against environmental degradation, while in some studies, renewable energy is the dependent variable (Rai et al., 2019; Başarir and Çakir, 2015).

As a result of awareness about renewable energy, the factors affecting renewable energy consumption are examined. One of these factors is financial development. Frankel and Rose (2002) argue that a developed financial market can increase nature-friendly energy investments. According to Stulz (2000), increasing credit opportunities with financial development affects renewable energy projects positively.

The relationship between financial development and renewable energy is analysed in different country groups. A group of studies deals with the issue in developed countries, especially in the European Union and OECD countries. Anton and Nucu (2020) examine the financial development effect on renewable energy consumption in European Union over the period 1990–2015. The banking sector, capital market, and bond market are used as three dimensions of financial development. Authors argue that all three dimensions affect renewable energy consumption in European Union. However, findings show that the capital market does not affect renewable energy consumption in new European Union members. Kim and Park (2016) include developed financial markets to examine how financial development affects renewable energy technology. They emphasise the debt and equity dimensions of financial development. Best (2017) argues that credit markets affect renewable energy positively in developed countries. Köksal et al. (2021) analyse the role of financial development on renewable energy in OECD countries. Their empirical results show that there is no strong financial development effect on renewable energy. Pham (2019) examines the issue in 22 OECD countries. According to empirical results, financial development has an important role in renewable energy consumption.

Emerging market countries have rapid growth potential but they haven't all characteristics of developed countries. The economic structure and financial system of these countries are still emerging. The potentials of the emerging market countries make important the future policies of these countries (Mody, 2003). Therefore, the structure of the energy sector of emerging countries is important in the fight against climate change. Some of the studies also examine the impact of financial development on renewable energy in emerging countries. Shahbaz et al. (2021) examine how financial development and economic growth affect renewable energy demand. They emphasise that economic growth harms renewable energy demand. However, financial development encourages renewable energy demand. Alsagr and Van Hammen (2021) deal with the issue in countries that include the geopolitical risk index. According to a two-step system generalised method of moments test, financial development and geopolitical risk affect positively renewable energy consumption. Wu and Broadstock (2015) include institutional quality to model that analyses the impact of financial development on renewable energy consumption. They argue that there is a positive impact of financial development on renewable energy when financial development is supported by institutional quality. Kutan et al. (2018) analyse the impact of financial development on

renewable energy consumption in four emerging market countries (Brazil, China, India, and South Africa). Foreign direct investments and stock market development are used as a proxy for financial development in the study. The authors emphasise that stock market development has an important role in renewable energy consumption. Paramati et al. (2018) emphasise that foreign direct investments and stock market development are essential factors that contribute to renewable energy consumption. Sun et al. (2020) analyse the relationship between financial development, human capital, and natural resources. The authors argue that financial openness and development have a positive impact on natural resources.

Some studies deal with the issue in each country individually. Burakov and Freidin (2017) examine the relationship between financial development and the use of renewable energy in Russia. Their empirical results show that there is no relationship between financial development and the use of renewable energy. According to Ji and Zhang (2019), the contribution of financial development to renewable energy is 42% in China. However, Wang et al. (2021) argue that financial development harms renewable energy in China. Eren et al. (2019) find that economic growth and financial development positively affect the use of renewable energy in India. Raza et al. (2020) show that financial development indicators increase renewable energy consumption in Iran.

Eventually, as a result of the zero-carbon target in the world, renewable energy sources gained importance. The financial dimension of the issue has started to be discussed in the literature in recent years. While some of the studies examine the effect of financial development on conventional energy consumption and environmental degradation, some other studies examine the effect of financial development on renewable energy consumption. Although the prevailing view is that financial development will contribute to renewable energy investments, some studies find a significant and positive impact of financial development on environmental degradation. Our study contributes to the literature by analysing how financial development affects energy consumption and environmental degradation in emerging countries.

3 Data and methodology

3.1 Data

We analyse the effect of financial development on renewable energy and carbon emissions with panel data analysis on annual time series. The analysis carries out on emerging market countries from 1997 to 2016. There is no official definition of the emerging market. We select IMF's emerging market countries group from different emerging market classifications. The IMF considers five elements when identifying emerging market countries: nominal GDP, population, income level (GDP per capita), the share of world trade, and share of world external debt. According to this classification, IMF identifies 20 emerging market countries (Duttagupta and Pazarbasıoglu, 2021). However, United Arab Emirates isn't included in the analysis due to a lack of data. The countries in our study are as follows: Argentina, Brazil, Chile, China, Colombia, Egypt, Hungary, India, Indonesia, Iran, Malaysia, Mexico, the Philippines, Poland, Russia, Saudi Arabia, South Africa, Thailand, and Turkey.

Emerging market countries play an important role in the world economy with their growth figures. However, emerging market countries' economic structures are not fully

established. For this reason, emerging market countries' attitudes about renewable energy investments and the relationship between their financial structure and environmental degradation are important for the future of mitigating climate change. According to IMF, advanced economies grew by an average of 0.68% in the 2016–2020 period, while emerging market economies grew by an average of 3.04% in the same period. Besides, IMF projections estimate that advanced economies will grow by 5.6% in 2021 and 4.9% in 2022. Emerging market countries will grow by 6.3% in 2021 and 5.2% in 2022, above the world average (IMF, 2021). Because of the growth rates and economic structures, the energy policies of developing countries have an important role in the mitigate against climate change. Energy security and climate change issues have increased awareness of renewable energy (Owusu and Asumadu-Sarkodie, 2016). According to British Petroleum data, primary energy consumption in the world increased by 1.9% between 2009–2019. Renewable energy consumption grew by 13.4% for the same period. Energy consumption decreased by 4.5% in 2020 with COVID-19. But renewable energy consumption increased by 9.7% in 2020 (BP, 2021). Emerging market countries have an important role in renewable energy investments and installed capacity. Emerging market countries invested 365 billion dollars to clean energy in 2019. The investment amount of developed economies was 390 billion dollars. Although emerging market countries exhibit similar performance to developed countries in terms of the investment amount, the share of clean energy in total energy investments of emerging market countries (35%) is lower than developed countries (47%). Emerging market countries haven't yet fully utilised their potential in clean energy investments (International Energy Agency, 2021). International Renewable Energy Agency's database lists the ten countries with the highest installed capacity in different renewable energy sources. China, Brazil, India, Indonesia, the Philippines, Russian Federation, Turkey, and South Africa are among the top ten in these different renewable energy sources (International Renewable Energy Agency, 2021).

We analyse the impact of financial development on renewable energy and environmental degradation. Therefore, two models are installed. In our first model, the effect of financial development on carbon emissions is examined, while in the second model we use, the effect on renewable energy is examined. CO_2 emissions (kg per 2010 US$ of GDP) and renewable energy % of primary energy supply are used as dependent variables. Domestic credit to private sector by banks (% of GDP), foreign direct investment inflow (% of GDP), and stock market total value traded to GDP (%) are proxies of financial development. In addition, explanatory variables are added to the model. Population growth (annual %), GDP growth (annual %) and industry (including construction), value added (% of GDP) is used as the explanatory variable. The sample data is gathered from the World Development Indicators, the Global Financial Development, the Financial Structure, and OECD databases.

Credits increase investment and consumption. Therefore, credits can increase the use of renewable energy or conventional energy (Anton and Nucu, 2020; Ganda, 2019). Domestic credit to the private sector by bank is a proxy of banking sector development. The effects of changes in domestic credits on the energy sector and environmental degradation are examined (Rafindadi and Mika'Ilu, 2019; Komal and Abbas, 2015; Anton and Nucu, 2020). While diversification is provided in financing with stock market development, liquidity also increases as a result of investor confidence. Stock market development is widely used as a financial development indicator (Sadorsky, 2010; Zhang et al., 2011). Foreign direct investment represents the international dimension of financial

development. Foreign direct investment promotes technology transfer, economic activities and modernisation. In addition, foreign direct investment can also increase domestic investments (Phiri and Ngeendepi, 2021). The impact of foreign direct investment on carbon emissions, conventional and renewable energy is investigated (Kutan et al., 2018; Ibrahiem, 2015). There are limited studies in which foreign direct investment is used as a financial development variable (Sadorsky, 2010; Doytch and Narayan, 2016; Ouyang and Li, 2018).

Table 1 List of variables

Variable name	*Abbreviations*	*Definition*
Renewable energy supply rate (%)	RE	Primary energy supply/total primary energy supply
CO_2 emissions	EM	kg per 2010 US$ of GDP
Domestic credit to the private sector by banks (% of GDP)	DCB	Domestic credit to the private sector by banks (loans, purchases of non-equity securities, trade credits, and other accounts receivable)/GDP
Stock market total value traded to GDP (%)	SMT	Stock market total value traded/GDP
Foreign direct investment, net inflows (% of GDP)	FDI	Foreign direct investment, net inflows/GDP
Industrial value-added as a share of GDP (%)	IND	Industrial value-added/GDP
Population growth (%)	POP	Annual population growth rate
GDP growth (%)	GDP	The annual percentage growth rate of real GDP

Source: World Bank (2021) and OECD (2021c)

Energy consumption and carbon emissions increase with economic activities. In addition, the need for energy arises with the expanding economic activities. For this reason, renewable energy sources can increase by providing energy diversity. Economic growth and industry are used as variables that represent economic activities. Generally, economic growth and industrialisation are included in the model together (Al-mulali and Ozturk, 2015; Paramati et al., 2018). Population growth is another factor that examines its effect on energy consumption and carbon emissions (Begum et al., 2015; Azam et al., 2015).

3.2 Methodology

Two models are established to examine the impact of financial development on renewable energy and environmental degradation. In the first model, the Renewable energy supply rate (RE) is a function of financial development (FD), GDP growth (GDP), population growth (POP), and industrial value-added as a share of GDP (IND). In the second model, CO_2 emissions (EM) are given as a dependent variable. Empirical models are as follows:

$$RE_{it} = \beta_0 + \beta_1 * FD_{it} + \beta_2 * GDP_{it} + \beta_3 * POP_{it} + \beta_4 * IND_{it} + \varepsilon_{it} \quad (1)$$

$$EM_{it} = \beta_0 + \beta_1 * FD_{it} + \beta_2 * GDP_{it} + \beta_3 * POP_{it} + \beta_4 * IND_{it} + \varepsilon_{it} \quad (2)$$

i refer to the country, t denoted the time, β_1–β_4 are regressors' coefficients, ε is the error term and β_0 is constant. According to the correlation between regressors and individual effect, panel data analysis has two approaches: fixed effect and random effect. The Hausman test is applied to determine which model is used in the analysis (Ahmed and Bhuyan, 2020; Ilorah and Ngwakwe, 2021). In the Hausman test of the first model, the p-value is greater than 5%. Therefore, the random effect is used in the first model. Since the p-value is less than 5%, the second model applies the fixed effect.

Table 2 Hausman test, cross-sectional dependence, autocorrelation and heteroscedasticity test

Model 1	
Panel A: Hausman test	
p-value	0.9355
Panel B: frees cross-sectional dependence test	
p-value	14.858*
Panel C: autocorrelation test	
Durbin Watson	1.9210783
Baltagi Wu LBI	1.9957327
Panel D: Levene test	
Prob > chi2	0.0000
Model 2	
Panel A: Hausman test	
p-value	0.0001
Panel B: Pesaran's cross-sectional dependence test	
p-value	0.0000
Panel C: autocorrelation test	
Durbin Watson	1.8319532
Baltagi Wu LBI	1.8675964
Panel D: modified Wald test	
Prob > chi2	0.9755

Notes: *0.2601, 0.1782 and 0.1360 are critical values of 1%, 5%, and 10% levels.

Based on the determination of our models, the cross-section dependence is analysed. Cross-section dependence is affected units from a unit that has cross-section dependence (Anton and Nucu, 2020). We apply Frees's cross-sectional dependence test to the first model and Pesaran's cross-sectional dependence test to the second model (Pesaran, 2004; Frees, 2004). Cross-section dependence is detected in both tests. Thus, second-generation unit root tests are used to analyse the stationarity of variables in our study.

In advance of the panel data analysis, autocorrelation and heteroscedasticity tests are applied. There is a significant relationship between the error term's consecutive values. The systematic relationship between variables negatively affects the analysis (Born and Breitung, 2016). Durbin Watson and Baltagi Wu tests are employed to examine the autocorrelation of the models. Durbin Watson and Baltagi Wu test values are less than 2. So, both models have autocorrelation problems.

The difference of the error terms' variance indicates the problem of heteroscedasticity. To determine whether there is a heteroscedasticity problem in the models, Levene's test is applied to the first model and the Wald test is applied to the second model (Levene, 1960; Arvanitis, 2018). According to Levene test, the p-value is less than 5%. The first model has heteroscedasticity.

In the existence of autocorrelation and heteroscedasticity, robust standard error estimators are applied. Hence the Parks-Kmenta estimator is used to eliminate autocorrelation and heteroscedasticity from the models. The equation is below (Parks, 1967; Kmenta, 1986):

$$Y_{it} = \beta_1 + \sum_{k=2}^{k} \beta_{it} X_{kit} + u_t \tag{3}$$

The method is an algorithm based on the generalised least squares method for the estimation of the linear regression model. Parks-Kmenta estimator is suitable when N is smaller than T (Maureen and Maxwell, 2020).

4 Empirical results

In advance of starting the panel data analysis, descriptive statistics, correlation, and stationarity of variables are presented. Table 3 shows descriptive statistics of variables.

Table 3 Descriptive statistics

Variable	*Obs.*	*Mean*	*Std. dev.*	*Min.*	*Max.*
RE	380	15.42908	13.55623	0	46.94
EM	380	0.6984737	0.3650522	0.17	1.77
DCB	380	50.29634	33.3915	8.87	166.65
SMT	380	27.07497	36.53934	0.31	331.27
FDI	380	3.175237	5.063254	–15.75	54.24
IND	380	34.20624	8.760677	18.35	66.76
POP	380	1.169447	0.7602974	–1.04	3.09
GDP	380	4.007737	3.661745	–13.13	14.23

Descriptive statistics include a strongly balanced panel dataset with 19 countries and 380 country-time observations. The average renewable energy supply rate is 15.43%. The lowest renewable energy supply rate is in Saudi Arabia (0%). The Philippines has the maximum renewable energy supply rate (46.94%). According to the descriptive statistics, the highest average renewable energy supply rate is in the Philippines (41.77%). However, the Philippines had a decreasing trend over the years. Brazil's renewable energy supply rate is the highest rate after the Philippines (41.57%). In addition, the renewable energy supply rate of Brazil is in a gradually increasing trend. The lowest emission is in Brazil (0.17). Maximum emissions emerge in China for the sample period (1.77). In addition, China has the highest average emissions over the all sample period (1.43). In the all sample period, the lowest average renewable energy supply rate is in Brazil (0.19).

Table 4 Correlation matrix

	RE	*EM*	*DCB*	*SMT*	*FDI*	*IND*	*POP*	*GDP*
RE	1.0000							
EM	–0.4190	1.000						
DCB	–0.0855	0.3286	1.0000					
SMT	–0.1619	0.2403	0.4118	1.0000				
FDI	–0.0458	–0.1568	0.0860	0.0230	1.0000			
IND	–0.2559	0.3674	0.2983	0.3572	–0.0846	1.0000		
POP	0.1225	–0.1132	–0.0326	0.1517	–0.2307	0.4066	1.0000	
GDP	0.0341	0.2267	0.1266	0.1572	–0.0123	0.1881	–0.0032	1.000

Table 5 Unit root test

	Lag	*CADF statistics*
Level		
RE	1	–4.213*,**,***
EM	1	–1.211
DCB	4	–2.220**,***
SMT	3	–2.743*,**,***
FDI	1	–2.123**,***
IND	4	–2.458*,**,***
POP	1	–1.572
GDP	1	–2.923*,**,***
1st difference		
RE(–1)	1	–5.389*,**,***
EM (–1)	1	–2.556*,**,***
DCB(–1)	4	–2.244*,**,***
SMT(–1)	3	–2.289**,***
FDI(–1)	1	–4.772*,**,***
IND(–1)	4	–0.689
POP(–1)	1	–4.161*,**,***
GDP(–1)	1	–3.971*,**,***

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

Table 4 presents the correlation matrix. The level of correlation between the variables doesn't exceed 50%. Therefore, multicollinearity cannot be expected in the analysis. The highest level of correlation is between renewable energy supply rate and emissions (41.90%). There is a negative correlation between financial development variables and renewable energy supply rate. The correlation between financial development variables and emissions is positive. However, the direction of the correlation between foreign direct investment and emissions is negative. The finding is reasonable because the linear relationship between credit and share market developments and emissions shows that these financial development factors encourage conventional energy resources and create a

negative relationship with the renewable energy supply rate in the total supply. There is a negative correlation between foreign direct investments and both dependent variables.

Table 6 Empirical results of the Parks Kmenta estimator

Variables	*Model 1*			*Model 2*		
	Coef.	*P val.*	*Std. er.*	*Coef.*	*P val.*	*Std. er.*
DCB	–0.003	0.499	0.005	0.002	0.000***	0.000
SMT	–0.038	0.000***	0.003	5.953	0.933	0.000
FDI	–0.114	0.000***	0.009	–0.001	0.053*	0.001
IND	–0.249	0.000***	0.029	0.004	0.844	0.001
POP	2.084	0.000***	0.288	–0.037	0.026**	0.017
GDP	0.169	0.000***	0.015	0.022	0.000***	0.001

Notes: *, **, and *** represent statistical significance at the level of % 10, % 5 and %1 respectively.

According to the cross-section dependence tests, there is a cross-section dependence in both models. Consequently, second-generation unit root tests are applied in the analysis of the stationarity of the variables. Second generation unit root tests analyse variables by the correlation between cross-section units. In our study, cross sectionally augmented Dicky Fuller (CADF) unit root test. Akaike information criteria is used to determine the optimal lag length (Pesaran, 2007).

Table 5 shows the unit root test. The calculated CADF values are compared to the critical values determined by Pesaran (2007). Except for emission and population variables, all variables are stationary at the level. These variables are stationary at the first difference. Therefore, CO_2 emissions (kg per 2010 US$ of GDP) and population growth variables are included with the first difference.

The two models have autocorrelation and heteroscedasticity difficulties. Parks Kmenta estimator is used to eliminate these difficulties. Model 1 examines the effect of financial development on the renewable energy supply rate, while the second model analyses the effect of financial development on emissions. In addition, Industrial value-added as a share of GDP, population growth, and GDP growth are used as control variables.

Model 1 reveals that domestic credit to the private sector by banks has no impact on the renewable energy supply rate. However, domestic credit to the private sector by banks is statistically significant at the 1% level in the second model. Developments in the banking system provide easier access to funds and encourage the use of credit. With the increase in credit volume, investments and consumption expand. Studies are arguing that domestic credit to the private sector by banks increases carbon emissions and environmental degradation. These studies emphasise that credits may increase conventional energy consumption and emissions due to the business effect and the household effect (Acheampong, 2019; Petrović and Lobanov, 2021; Maji et al., 2017). Our study supports these findings. Several studies concluded that credits affect renewable energy. In that regard, our study makes a difference from previous studies. According to Burakov and Freidin (2017), domestic credit to the private sector by banks has no statistically significant impact on renewable energy. Similar to the finding of Burakov and Freidin (2017), our findings show that the expansion in credit volume doesn't affect

clean energy, while it positively affects environmental degradation in selected countries. Stock market total value traded to GDP doesn't significantly affect emissions. In reverse, stock market development has a significant and negative impact on the renewable energy supply rate. According to Sadorsky (2011), since a well-functioning banking system also affects the stock market, the impact of two variables is interrelated on energy consumption. In addition, Sadorsky (2011) argues that stock markets aren't fully efficient in emerging countries. Because the banking system of emerging market countries is not as efficient as developed countries. Based upon this, our findings show that the impact of the banking system on renewable energy may have negatively affected the stock markets' effect.

According to empirical determination, foreign direct investments should be assessed separately from other financial development variables. Foreign direct investments are statistically significant at the 5% level in the second model while it is significant at the 1% level in the first model. Foreign direct investments reduce renewable energy supply and carbon emissions. Foreign direct investments contribute to technology transfer, modernisation, and know-how sharing between countries. While studies are arguing that foreign direct investment increases emissions with the increase in economic activities, some studies show that renewable energy investments will be positively affected by foreign direct investments (Doytch and Narayan, 2016; Hanif et al., 2019). Another view about foreign direct investment is the energy-saving effect. As stated by this view, energy consumption and emissions are reduced by technology transfer and modernisation (Mielnik and Goldemberg, 2002). There are studies showing that foreign direct investments reduce renewable energy consumption and emissions (Demena and Afesorgbor, 2020; Zhu et al., 2016; Khan et al., 2021). Our findings are compatible with previous studies.

The estimated coefficients of GDP growth are positive and the variables are significant at a 1% level for the two models. Energy consumption increases as a result of expanding economic activities and the purchasing power provided by economic development. Similar to previous GDP growth and the renewable energy consumption is negative. Similar to previous studies' findings, GDP growth increases energy requirements. Hence, the renewable energy supply and emission increase (Kais and Sami, 2016; Apergis and Payne, 2011). Industrial value-added as a share of GDP has no impact on emissions. Some studies show that industrialisation, which is generally included in the analysis together with economic growth, has a positive effect on carbon emissions (Opoku and Boachie, 2020; Dong et al., 2019). Our findings show that GDP growth increases emissions. Industrial value-added as a share of GDP has a significantly negative impact on the renewable energy supply rate. In selected countries, renewable energy sources are not used sufficiently in the industrial sector. Population growth is statistically significant at the 5% level in the second model while it is significant at the 1% level in the first model. Even though population growth increases the renewable energy supply rate, emissions are affected negatively by population growth. The prevailing view in former studies is that population growth increases energy consumption and emissions (Martínez-Zarzoso et al., 2007; Shi, 2003; Azam et al., 2015). However, some studies argue that population growth harms emissions (Liu et al., 2015; Liddle, 2014). Population growth means a potential increase in energy needs and emissions. However, economic development and adequate awareness may enable the population to engage in environmentally friendly activities [Liu et al., (2015), p.906]. In emerging countries, emissions decrease with population growth, while the renewable energy supply rate

increases. As a result of the increasing energy demand in these countries, the use of clean energy may be increased by diversifying energy sources. In this context, the demographic structure, educational status, and economic characteristics of the population should also be examined in further studies.

5 Conclusions

Clean energy and energy diversity are some of the important terms of recent years. While energy acts a critical role in national economies, it is also an important element of geopolitical relations. Besides, energy, which is one of the emission sources, is also important for the low emission target in the world. Therefore, energy consumption, transition to renewable energy, and emissions are discussed in governments, international organisations, and academia. Transition to renewable energy has investment and consumption dimensions. For this reason, financial development is significant on renewable energy and emission. There are two views on the impact of financial development on renewable energy and emissions. The first view argues that financial development increases emissions with expanding economic activity and household consumption. According to the second view, renewable energy investments are increased with financial development.

Emerging countries have developed country potential but they need capital. The policies of these countries can affect the future due to their unsettled economic structures and financial systems. Therefore, examining the effect of financial development on renewable energy and emissions in emerging countries may give important results for energy policies and mitigating climate change. We investigate the impact of financial development on renewable energy supply rate and CO_2 emissions in emerging market countries classified by IMF.

According to empirical results, financial development variables don't have a positive effect on renewable energy. Domestic credit to private sectors banks doesn't affect the renewable energy supply rate. However, domestic credit to private sectors banks increases emissions. The banking system development in emerging market countries contributes to environmental degradation. For low emissions and energy diversification, the banking system should be reorganised and the credit channel should support clean energy in the emerging countries. Stock market development increases emissions, while it isn't statistically significant in the main model. Conversely, stock market development has a significant and negative impact on the renewable energy supply rate. The results of domestic credit and share market in both models support Sadorsky's (2011) view. According to Sadorsky (2011), a well-functioning banking system also shapes stock markets, and these two factors have an interrelation impact on energy consumption. Emerging countries need capital and these countries haven't a financial system at the level of developed countries. Therefore, emerging countries should review their financial structures, particularly the banking system, in the context of clean energy and low carbon objectives. Foreign direct investment negatively affects both dependent variables. As a result of technology transfer, foreign direct investment saves energy. For emerging countries, foreign direct investment is a key financial element in mitigating environmental degradation and climate change. GDP growth increases emissions and renewable energy supply rate with its expanding production volume and purchasing

power. Industrial value-added as a share of GDP has a negative and significant impact on the renewable energy supply. The share of renewable energy in the industrial sector isn't sufficient in emerging countries. Industrial development negatively affects renewable energy supply and increases emissions. This finding indicates that conventional energy sources are more dominant in industrial activities in emerging market countries. Population growth increases renewable energy supply while reducing emissions. Commonly, population growth is expected to increase energy production and emissions. Liu et al. (2015) argue that awareness about the environment increases with developments in the economic and education levels of the population. Our findings support this view. In further studies, the population variable can be handled in a complex by including the urban population, demographic and economic characteristics of the population.

This study has some limitations. Financial development is analysed in terms of banking, stock markets, and foreign direct investments. In further studies, the bond market and savings can be analysed. There is a cross-section dependence problem of the model in our study. The CS.ARDL model can be used to handle the cross-section dependence problem. However, we study the impact rather than the relationship. In consequence, the CS.ARDL method was not applied. Besides, the period is also an important limitation of the study. The most current data is available in 2016. Therefore, we have a time limitation. An analysis with more recent data may reflect the economic, social, and environmental changes that have occurred in recent years. The application of our model in different country groups and the comparison of the results will conduce to the literature.

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