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The Relationship Between Renewable Energy Consumption and Stock Market Capitalisation and Carbon Emissions: Insights from G20 Countries[1]

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Yenilenebilir Enerji Tüketimi ve Piyasa Kapitalizasyonu ile Karbon Emisyonu Arasındaki İlişki: G20 Ülkeleri Örneği”[2]

Abstract

The research question of whether carbon emissions affect the economic growth and financial development of countries is discussed in the literature. Based on this, this study examines the relationship between carbon emissions (CO_2) market capitalisation and renewable energy consumption, which are financial development indicators. The model established with the carbon emissions, renewable energy consumption, market value, fixed capital investments and gross domestic product indicators of the G20 countries between 1992 and 2018 was tested with panel data cointegration analysis and panel causality analysis. As a result of the empirical analysis, it has been found that there is a statistically significant and negative relationship between renewable energy consumption, market capitalisation and carbon emissions, and there is a bidirectional causality relationship between market capitalisation and carbon emissions. The results are that the effective use of energy and the developments in the financial system will contribute to sustainable development policies.

Keywords : Carbon Emissions, Renewable Energy, Stock Market Capitalisation, Panel Data Analysis.

JEL Classification Codes : Q56, Q2, O16, C23.

Öz

Karbon emisyonlarının, ülkelerin ekonomik büyümelerini ve finansal gelişimlerini etkileyip etkilemediği araştırma sorusu literatürde tartışılmaktadır. Buna dayanarak bu çalışmanın amacı, finansal gelişmişlik göstergelerinden olan piyasa kapitalizasyonları ve yenilenebilir enerji tüketimi ile karbon emisyonu (CO_2) ilişkisini incelemektir. G20 ülkelerinin 1992-2018 dönemleri arasındaki karbon emisyonu, yenilenebilir enerji tüketimi, piyasa kapitalizasyonu, sabit sermaye yatırımları ve gayrisafi yurtiçi hâsıla göstergeleri ile kurulan model panel veri eşbütünleşme analizi ve panel nedensellik analizi ile test edilmiştir. Ampirik analizler sonucunda yenilenebilir enerji tüketimi, piyasa kapitalizasyonu ile karbon emisyonu arasında istatistiksel olarak anlamlı ve negatif yönde bir ilişkinin olduğu, ayrıca piyasa kapitalizasyonu ile karbon emisyonu arasında çift yönlü nedensellik ilişkisi

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1 *This is improved and revised version of the study that presented at the 21st International Business Congress.*
2 *Bu çalışma, 21. Uluslararası İşletme Kongresi'nde sunulan çalışmanın geliştirilmiş ve gözden geçirilmiş halidir.*

olduğuna ulaşılmıştır. Sonuçlar, enerjinin etkin kullanılması ile finansal sistemde yaşanacak olan gelişmelerin sürdürülebilir kalkınma politikalarına katkı sağlayacağı yönündedir.

Anahtar Sözcükler : Karbon Emisyonu, Yenilenebilir Enerji, Piyasa Kapitalizasyonu, Panel Veri Analizi.

1. Introduction

Environmental problems such as global warming, unexpected increases in sea levels, significant melting of glaciers, and extinction of living species that have emerged in the last century have started to pose a global threat. Carbon emissions are considered the leading cause of these problems. Among the carbon emissions, carbon dioxide (CO_2), known to be the most damaging to the environment and living things, constitutes 76.7% of carbon emissions (Alam et al., 2021; Paramati et al., 2017). Most carbon emissions are due to fossil fuel consumption such as coal, natural gas and oil (Roberts et al., 2019). As a result of the development of the economy and industry and the increasing energy demand, a significant amount of CO_2 was released into the environment. The disadvantage of traditional energy consumption being non-renewable is that it significantly harms the environment and nature. As a result of these disadvantages, it has become attractive to offer a clean and sustainable world if low-carbon renewable energy sources are used with increasing concerns (Bhattacharya et al., 2016). Since renewable energy sources do not produce carbon emissions at a minimum and/or at all, they cause minimal damage to the environment (Apergis & Lau, 2015; Bhattacharya et al., 2016). Sustainability in energy use refers to the use of clean and inexhaustible energy. There is a positive relationship between the economic development of developed and developing countries and the amount of carbon emissions (Li et al., 2020). G20 countries, which are the most developed in the world in industry and technology, are the countries that consume the most energy and produce the most carbon emissions in parallel. Therefore, reducing CO_2 emissions depends on the activities of the G20 countries whose economies are most developed to reduce carbon emissions and efficiently use energy. Carbon emissions hinder economic growth, so research on reducing carbon emissions has gained momentum among economists (Zafar et al., 2019). According to the research conducted by New Energy Finance (2021), sectors have allocated emission budgets to zero their carbon emissions in 2050. It is desirable to reduce emissions by 30% by 2030 compared to 2019 and by 75% by 2040. Investment in renewable energy sources increased by 27% compared to 2020 to reach $755 billion (BloombergNEF, 2021). Therefore, one possible solution is investing in renewable energy projects to prevent increased CO_2 emissions. Stock market capitalisation is among the most important sources of financing for renewable energy investments (Alam et al., 2015; Bhattacharya et al., 2016; Paramati et al., 2017). The development of stock markets provides investors with additional sources of financing so that investors can invest in renewable energy sources with higher investment capital (Bhattacharya et al., 2016; Minier, 2009). Carbon emissions also hinder the economic growth and financial development of countries. In line with the activities carried out to reduce carbon emissions, the increasing financial need arising from the increase in investments made in renewable energy sources and the reduction of carbon emissions to encourage financial development and economic growth (Apergis & Danuletiu, 2014) is extremely important for policymakers, firm owners and investors.

The motivation of the study is to establish the relationship between renewable energy consumption, stock market capitalisation, gross domestic product and fixed capital investments with carbon emissions based on all these reasons. The study investigates the relationship between financial development and economic growth indicators, stock market capitalisation, renewable energy consumption, gross domestic product (GDP) and CO_2 emissions of fixed capital investments. Unlike other studies, the study examines the relationship between CO_2 emissions, stock market capitalisation and renewable energy consumption, not based on a region or a country, but within the framework of G20 countries, which include developed and developing countries and play a vital role in the global economy. It also differs from other studies, especially by examining the relationship between the stock market capitalisation of G20 countries and carbon dioxide emissions. If we look at the rest of the study, in the second part, similar studies that have been done before are mentioned, and in the third part, the dataset and methodology of the research are discussed. Empirical findings are included in the 4th part of the research, and finally, the results and recommendations are presented in the 5th part.

2. Literature Review

Recent studies have characterised countries' energy use from natural resources as successful environmental performance. Consumption of these renewable energy sources is one of the activities that reduces carbon emissions. Studies conducted in recent years have also sought to answer the question of how there is a relationship between carbon emissions and renewable energy consumption and financial development indicators (Alam et al., 2015; De Haas & Popov, 2019; Grileiro, 2019; Sadorsky, 2010a; Yuping et al., 2021; Zafar et al., 2019; Zeqiraj et al., 2020; Zeren & Koc, 2014). Richmond and Kaufmann (2006) investigated the relationship between income, energy mix and carbon emissions between 1973 and 1997 for 36 countries that accounted for 95% of the world's energy demand, including 20 developed (Organisation for Economic Cooperation and Development (OECD) countries) and 16 developing (non-OECD) countries. The study found that policymakers did not take measures to reduce carbon emissions and that there was a negative correlation between renewable energy sources and carbon emissions. Apergis et al. (2010) sought answers to whether there is a causality relationship between CO_2 emissions, nuclear energy consumption, renewable energy consumption and economic growth. According to the findings of the study conducted between 1984 and 2007 in 19 different countries, there is a long-term relationship between carbon emissions, nuclear energy, renewable energy, and economic growth. In the long term, nuclear energy consumption reduces emissions. In addition, nuclear energy plays an important role in reducing CO_2 emissions. In addition, a bidirectional causality relationship between renewable energy consumption and economic growth has been revealed. It has also shown that it will reduce the risks of foreign-dependent countries in energy. Alam et al. (2015) investigated the relationship between energy demand

and growth between 1975 and 2011 through indicators of financial development for South Asian Regional Cooperation Organization (SAARC) countries (Bangladesh, Bhutan, Afghanistan, India, Maldives, Nepal, Pakistan, and Sri Lanka). According to the study's findings, there is a significant relationship between energy consumption, economic growth, and financial development. At the same time, financial development indicators have been found to impact energy demand significantly. Paramati et al. (2017), in their study with data from G20 countries between 1991 and 2002, examined the magnitude of stock market capitalisation, fixed capital investments, foreign direct investments, and the impact of renewable energy consumption on CO_2 emissions. According to the empirical findings, a strong long-term relationship exists between CO_2 emissions, foreign direct investments and renewable energy consumption. The consumption of renewable energy sources has been shown to reduce CO_2 emissions compared to conventional energy sources. On the other hand, the development of stock markets minimises CO_2 emissions. Therefore, it has been stated that policymakers should pay attention to developing policies that encourage firms to use energy efficiency and green energy technologies. Zafar et al. (2019) analysed the data of G-7 and N-11 countries for 1990-2016. They examined the impact of the development of stock market capitalisation and the development of the banking sector on carbon emissions. N-11 countries have a strong positive relationship between the development of stock market capitalisation and carbon emissions due to inefficient, traditional energy use, while in G-7 countries, there has been a strong negative relationship due to firms' use of green technology. On the other hand, a strong negative relationship was found between banking development level and carbon emissions for both country groups. Zeqiraj et al. (2020) sought answers to the question of how there is a relationship between the stock market and low carbon emissions in European Union countries. It has identified two different channels that affect this relationship: renewable energy and the use of new technology. From 1980-2016, a long-term relationship existed between equity markets and low carbon emissions in European Union member states and the use of renewable energy and new technology-supported low carbon emissions. In another study examining the relationship between carbon emissions and the development of financial systems, Haas and Popov (2021) found that as equity markets in 48 countries developed and deepened, the sectors that caused intense carbon emissions focused more on green technologies. Alam et al. (2021) examined the relationship between R&D studies and stock market capitalisation, green energy consumption, and CO_2 emissions in their study conducted in 30 OECD countries. The findings of the research revealed that there is a long-term and positive relationship between R&D activities, stock market capitalisation, and green energy consumption, while they have a negative effect on the growth of CO_2 emissions. If we look at the studies in the literature, while equity markets in developed countries are the largest market among financial markets, financial markets in developing countries are mostly based on the banking sector. Increasing the level of development of financial markets increases economic growth, and more energy consumption is needed with economic growth (Tamazian et al., 2009). As financial development increases, consumers' desire to receive high energy-consuming requests and needs such as cars, homes, and dishwashers will increase. On the other hand, the increase in financial development makes it easier for firms to obtain the financial capital they need. It causes them to use less costly capital. The development of the stock market is also significant for firms. In addition to the source of financing with debt, firms also need equity financing. The development of stock markets allows firms to diversify their financial portfolios. Stock market capitalisation is an economic indicator of countries and indicates economic growth and prosperity. In addition, as the size of stock market capitalisation increases, the capital cost will decrease, and the optimum capital structure will be approached to increase efficiency by ensuring the efficient use of resources (Bekaert et al., 2001; Dasgupta et al., 2001; Gurley & Shaw, 1955; Sadorsky, 2010b; Solomon et al., 2009; Xu, 2000). However, for the studies carried out within the framework of the G20 countries, apart from the consumption of renewable energy sources, carbon emissions, and economic growth, the stock market capitalisation is also included in the model, unlike other studies.

It aims to examine the relationship between the use of renewable energy resources, which leads to the efficient use of resources, and market capitalisation, which is one of the financial development indicators, and carbon emissions, and also to explain whether the 19 largest economies of the world support the EKC hypothesis. In this study, the data of the G20 countries for 1992-2018 are included in the analysis. The relationship of stock market capitalisations, renewable energy consumption, fixed capital investments and GDP with carbon emissions is investigated. The variables of the model are introduced first, and the identifier statistics are given. After horizontal cross-sectional dependency tests, unit root tests, correlation tests, homogeneity tests, appropriate cointegration analysis and causality analysis were performed, the results were interpreted.

3. Data and Methodology

This study aims to examine the relationship between carbon emissions and renewable energy consumption and stock market capitalisation of G20 countries (Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Türkiye, the United Kingdom, and the United States) from 1992 to 2018 due to restrictions on the availability of data. G20 countries emit the most CO_2 emissions, so we included them in the analysis (Kong et al., 2022). Also, we use control variables, which are the gross domestic product and fixed capital investments (Paramati et al., 2017; Zafar et al., 2019). The study was taken from 1992 to 2018 due to restrictions on data availability. In this study, the variables used definitions and sources given in Table 1 below.

Table: 1
Variables

Variables	Calculation Method	Data Source
Dependent Variable		
$LnCO_2$	CO_2 Emission (kt)	World Bank Database
Independent Variables		
LnREN	Renewable Energy Consumption	International Energy Agency (IEA) Database
SMC	The Ration of Stock Market Capitalization to GDP	World Bank Database
LnGDP	Gross Domestic Product (Constant 2015 US$)	World Bank Database
GFC	The Ration of Fixed Capital Investments to GDP	World Bank Database

The following model has been developed to examine the relationship between stock market capitalisation, renewable energy consumption and CO_2 emissions. Following the methodologies of Shahbaz et al. (2013) and Rahman and Alam (2022), the underlying model has been employed for our empirical inspection. The logarithms of the variables were taken to avoid the variable variance problem and to produce efficient and systematic results (Ashwin Kumar et al., 2016; Bhat et al., 2022; Wang & Dong, 2021).

$$LnCO_2 = f\{LnREN, SMC, LnGDP, LnGFC\} \quad (1)$$

The function in Eq. (1) can be transformed into an econometric model by including an error term and a constant term given in Eq. (2):

$$LnCO_{2_{it}} = \beta_0 + \beta_1 LnREN_{it} + \beta_2 LnGDP_{it} + \beta_3 SMC_{it} + \beta_4 GFC_{it} + \varepsilon_{it} \quad (2)$$

i=1, …, N; t=1, …, T

Where CO_2 denotes the carbon emissions used as a proxy of environmental pollution, renewable energy consumption (REN) refers to the consumption of renewable resources such as biomass, hydro, geothermal, wind and southern energy. SMC is financial development used as a proxy of the market capitalisation of listed domestic firms (% of GDP). β_0 is constant, ε_{it} is error term, t denotes the number of periods and i indicates the number of countries. β_1, β_2, β_3 and β_4 show the long-term coefficients of the variables.

4. Preliminary Statistics

Table 2 presents the average renewable energy consumption, carbon emissions and stock market capitalisation of individual G20 between 1992 and 2018. G20 countries are responsible for 80% of total greenhouse gas emissions worldwide. At the same time, as a country and international organisation, it carries out many activities and makes regulations to prevent the climate crisis.

It was determined that China emitted the most greenhouse gas emissions in the G20 countries between 1992 and 2018 (6108837.40). It is followed by the United States (5328955.18) and Russia (1577250.37). However, in recent years, environmental regulations and developments have reduced carbon emissions, especially in developed countries. According to the 2002 Climate Transparency Report, per capita emissions decreased between 2015 and 2019 in G20 countries except India, Türkiye, China, Russia, and South Korea. Although efforts have been made to reduce greenhouse gas emissions, thousands of people died in many countries, especially China, India, Germany and the USA, due to climate impacts worldwide between 1999 and 2018. Japan, China, and South Korea are the G20 countries that spend the most from public resources on fossil records to prevent the climate crisis and reduce greenhouse gas emissions.

This study examined G20 countries, one of the world's leading economic groups with high greenhouse gas emissions but working to prevent the climate crisis. In this context, the impact of G20 countries' renewable energy consumption and stock market activities on greenhouse gas emissions is being investigated. The study findings will add value to knowledge and provide important policy implications for G20 countries.

Table: 2
Average Greenhouse Gas Emissions, Renewable Energy and Stock Market Capitalization of Individual G20 Countries Between 1992 and 2018

Countries	CO_2	REN	SMC
Argentina	148827.80	9.80	14.15
Australia	351280	8.25	92.94
Brazil	348301.90	45.32	37.68
Canada	519184.10	21.93	117.67
China	6108837	20.77	37.18
France	6108837	11.00	67.98
Germany	808026.70	8.01	40.92
India	1341736	46.00	53.90
Indonesia	357983.30	39.92	30.35
Italy	406136.70	9.33	32.75
Japan	1178187	4.65	75.22
Mexico	412867.40	10.72	28.38
Russian Federation	1577250	3.53	33.90
Saudi Arabia	350134.10	0.01	59.02
South Africa	357706.70	13.50	193.94
South Korea	490473	2.82	60.64
Türkiye	258421.10	16.57	21.40
United Kingdom	493087.40	3.24	115.98
United States	5328955	6.56	118.26

5. Findings

The panel data analysis method is used in the study because it has both unit and time dimensions. Cross-section dependency and heterogeneity tests affect the selection of estimation techniques used in panel data models. According to the results of cross-sectional dependence tests and heterogeneity tests, it is decided which tests will be used: unit root analysis, cointegration relationship, cointegration estimator and causality analysis.

Cross-sectional dependence tests

Cross-section dependency determines whether a shock in one country affects other countries. Because if the panel consists of groups of countries with similar characteristics, cross-sectional dependence is important for countries (Nazlioglu et al., 2011). Before proceeding to the panel data analysis tests, the cross-sectional dependence of the series is first tested. The cross-sectional dependence of the variables is tested with the Pesaran (2004) CD test. The cross-section dependency test is used, so the null hypothesis is "no cross-section dependence" (Breusch & Pagan, 1980; Pesaran, 2004; Pesaran et al., 2008).

Table 3 summarises the results of the cross-sectional dependence of the series. Suppose the null hypothesis is rejected due to the Pesaran CD test. In that case, second-generation panel unit root tests are used, which allow correlation between the series belonging to the units (Yerdelen-Tatoğlu, 2018).

Breush-Pagan Lagrange Multiplier (LM), Pesaran CD and LM_{adj} tests are used to test the cross-sectional dependence of the *LnCO₂ = f {LnREN, LnGDP, GFC, LnSMC}* model. Breush-Pagan LM tests $Cov = (u_{it}, u_{jt}) = 0$, for all *t*, *i≠j* under the null hypothesis of "no cross-section dependence" (Breuer et al., 2001). The result of the cross-section dependency statistics of the model is presented in Table 4.

Table: 3
Pesaran's (2004) Cross-Section Dependency

CD (Pesaran, 2004)	*CD* - Statistics
$LnCO_2$	14.26***
LnREN	2.50***
LnGDP	63.32***
SMC	31.40***
GFC	3.82***

*Notes: *** p<0.01, ** p<0.05, * p<0.10.*

Table: 4
Breush Pagan's (1980) LM Test, Pesaran's (2004) CD_{LM} Test and Pesaran Ullah and Yamagata's (2008) NLM (LM_{adj}) Cross-Sectional Dependency

	Statistics
CD LM (Breusch - Pagan, 1980)	275***
CD LM (Pesaran, 2004, CD LM)	11.18***
LM_{adj} (Pesaran et al., 2008)	6.52***

*Notes: *** p<0.01, ** p<0.05, * p<0.10.*

According to the result of the cross-sectional dependence test, the null hypothesis was rejected, and it was concluded that there was a cross-section dependency in the variables. This result reveals that the second-generation panel unit root analysis should be used to test the stationarity of the series. According to Breush Pagan's (1980) LM test, Pesaran's (2004) CD LM test and Pesaran, Ullah and Yamagata's (2008) LM_{adj} test results, the null hypothesis is rejected at 99% confidence interval. It was concluded that there is a correlation between units in the model.

Panel unit root test

Since there is a cross-section dependency in all the variables, in other words, there is a correlation between the units, the second-generation panel unit root analysis of the series, the cross-section extended Im, Pesaran and Shin (CIPS) test is used. Pesaran (2007) proposed a new technique, cross-sectional extended Im, Pesaran and Shin (CIPS), which is robust to cross-sectional dependence and produces more consistent and reliable results than conventional unit root tests. The CIPS test is considered the horizontal section extended version of the IPS test, and the flat section represents the average of the extended Dickey-Fuller (CADF) test (Pesaran, 2007). The unit root hypothesis tested with the CIPS test is $H_0: \beta_i = 0$ for all cross sections. The result of the CIPS test statistics is presented in Table 5.

Table: 5
Panel Unit Root Test

I(0)		I(1)	
Variables	Statistics	Variables	Statistics
$LnCO_2$	-1.94	Δ $LnCO_2$	-3.10***
LnREN	-1.46	Δ LnREN	-3.68***
LnGDP	-2.01	Δ LnGDP	-2.71***
GFC	-1.89	Δ GFC	-3.20***
LnSMC	-1.89	Δ LnSMC	-3.11***

*Notes: *** p<0.01, ** p<0.05, * p<0.10.*

According to the results of the table, it is concluded that all variables are non-stationary at level but become stationary when the first differences are taken. In other words, the series is determined to be I(1). This result reveals that the first difference of the variables should be taken.

Slope homogeneity tests

After the cross-section dependence of the model, whether the slope coefficient is heterogeneous is tested. The heterogeneity of the slope coefficients is analysed by the Delta test developed by Pesaran and Yamagata (2008). It is analysed by delta test. The delta test, which tests homogeneity, is determined in two dimensions, $\tilde{\Delta}$ and $\tilde{\Delta}_{adj}$. Delta test null hypothesis is established as $H_0: \beta_i = \beta$ "slope parameters are homogeneous" (Pesaran & Yamagata, 2008). The result of the Homogeneity test statistics is presented in Table 6. According to the probability value results of the delta homogeneity test Δ and Δ_{adj} statistics, the null hypothesis was rejected, and it was concluded that the slope parameters were heterogeneous.

Table: 6
Slope Homogeneity Tests

	Delta Statistics
Δ	22.97***
Δ_{adj}	26.05***

*Notes: *** p<0.01, ** p<0.05, * p<0.10.*

Panel cointegration test

Due to the heterogeneity and cross-section dependency of the model, the existence of a long-term relationship was tested with the Gengenbach, Urbain and Westerlund (2016) panel cointegration test. Gengenbach, Urbani and Westerlund's (2016) panel cointegration test was used to test the long-term cointegration relationship. Gengenbach, Urbani and Westerlund's (2016) panel cointegration test developed a cointegration test based on the importance of the error correction term in a panel error correction model with non-stationary common factors (Gengenbach et al., 2016). This equation tests the hypothesis $H_0: \alpha_{y1} = \cdots = \alpha_{yN} = 0$ (Gengenbach et al., 2016). It is established as the null hypothesis is that there is "no cointegration relationship in the panel". The results of the panel cointegration test statistics are presented in Table 7.

Table: 7
Panel Cointegration Test

d y	Coef.	t-bar	Prob.
y(t-1)	-1.30	-3.76	<=0.05

According to Gengenbach, Urbain and Westerlund (2016), the model has a cointegration relationship. Accordingly, firms' renewable energy consumption and market capitalisation affect carbon emissions in the long run. After finding that CO_2, REN, SMC, GDP and GFC are cointegrated, we estimate the long-run coefficient for the impact of renewable energy and stock market capitalisation on carbon emissions for G20 countries.

Long-term panel cointegration estimation

The Dynamic Ordinary Least Squares Mean Group (DOLSMG) estimated the cointegration estimator in the model, which was found to have a long-term cointegration relationship. DOLSMG is an estimator considering cross-section dependence and homogeneity (Pedroni, 2001). In the long-term relationship estimation, the variables are transformed by taking the difference from the cross-sectional averages, and the analysis is made with the DOLS estimator for the model units and the DOLSMG estimator for the whole panel (Yerdelen-Tatoğlu, 2018). The results of the long-term panel cointegration estimation statistics are presented in Table 8.

Table: 8
Long-Term Panel Cointegration Estimation

	Δ LnREN	Δ LnGDP	Δ SMC	Δ GFC
Model	-0.13*** [-8.33]	0.91*** [5.86]	-0.08*** [-8.37]	0.00*** [2.60]

*Notes: *** p<0.01, ** p<0.05, * p<0.10.*

For the full panel of G20 countries, renewable energy negatively and significantly affects carbon emissions. The increase in renewable energy in G20 countries reduces carbon emissions. For the full panel of G20 countries, stock market capitalisation negatively and significantly affects carbon emissions. An increase in market capitalisation, an indicator of financial development, reduces carbon emissions. For the entire panel, GDP and GFC positively and statistically significantly affect carbon emissions. The increase in growth causes an increase in carbon emissions as it increases consumption and production.

Panel causality test

This study aims to analyse the causal relationship between renewable energy and stock market capitalisation with carbon emissions from 1992 to 2018. As a testing methodology, the causality Dumitrescu-Hurlin, allowing for heterogeneity and cross-sectional dependency, is utilised. The panel causality test hypothesis is established as "H_0: X is not the cause of Y" (Dumitrescu & Hurlin, 2012). For the Dumitrescu-Hurlin panel causality test, lag lengths were selected according to the Akaike information criterion. The

AIC information criterion was set to be two optimal lag lengths for all tests. Dumitrescu-Hurlin panel causality test results are reported in Table 9.

Table: 9
Dumitrescu-Hurlin Panel Causality

			Whnc	Zhnc (Asymptotic)	Ztild (Semi-Asymptotic)
ΔLnREN	→	Δ $LnCO_2$	3.25***	6.94***	5.58***
Δ $LnCO_2$	→	Δ LnREN	0.47	-1.61	-1.61
Δ SMC	→	Δ $LnCO_2$	1.90*	2.80***	2.09**
Δ $LnCO_2$	→	Δ SMC	2.59**	4.91***	3.87***
ΔLnGDP	→	Δ $LnCO_2$	0.78	-0.66	-0.81
Δ $LnCO_2$	→	Δ LnGDP	1.29	0.92	0.51
Δ GFC	→	Δ $LnCO_2$	0.96	-0.10	-0.34
Δ $LnCO_2$	→	Δ GFC	0.88	-0.35	-0.55

*Notes: *** p<0.01, ** p<0.05, * p<0.10.*

Table 9 shows a unidirectional causality relationship between renewable energy consumption and carbon emissions. It has been determined that there is a bidirectional causality relationship between stock market capitalisation and carbon emissions. A causality relationship between GDP and CO_2 could not be reached. In addition, a causal relationship between GFC and CO_2 could not be determined. Accordingly, it is found that using renewable energy sources affects carbon emissions. On the other hand, the amount of carbon emissions does not affect the consumption of renewable energy sources. According to the bidirectional causality relationship between stock market capitalisation and carbon emissions, an increase or decrease in stock market capitalisation, an indicator of financial development, affects carbon emissions. On the other hand, an increase or reduction in carbon emissions causes a change in stock market capitalisation.

6. Conclusions and Policy Recommendations

6.1. Conclusions

The study analyses the relationship between renewable energy consumption, stock market capitalisation and carbon emissions of G20 countries between 1992-2018. In addition, the control of GDP and fixed capital investments were also used as variables in the study. G20 countries are included in the analysis since they have the highest CO_2 emissions (Kong et al., 2022). The variables were tested with panel data analysis. According to the cointegration test results of Gengenbach, Urbain, and Westerlund (2016), there is a long-running negative panel cointegration relationship between renewable energy consumption, stock market capitalisation, and carbon emissions in G20 countries. Stock market capitalisation is an important part of global financial development. Accordingly, countries must reduce carbon emissions to adapt to international financial development. On the other hand, a positive long-run panel cointegration relationship is found between GDP fixed capital investments and carbon emissions. Our results support the EKC hypothesis, and carbon emissions and economic growth are related in the long run (Mahmoodi & Dahmardeh, 2022). Our results show that reducing countries' carbon emissions can increase their economic growth in the long run. Moreover, Dumitrescu and Hurlin's panel causality analysis finds a bidirectional relationship between the market capitalisation of G20 countries and carbon emissions; a unidirectional relationship is established from renewable energy consumption to carbon emissions. Accordingly, increases or decreases in carbon emissions affect market capitalisation and, thus, the level of financial development. Similarly, increases and decreases in market capitalisation affect carbon emissions. This is likely due to the high cost of investments required to reduce carbon emissions and the need for additional funds. On the other hand, no causality relationship was found between the control variables and carbon emissions.

6.2. Policy Recommendations

Activities to reduce carbon emissions in developed and developing countries continue without compromising financial and economic development. However, fossil fuels are still consumed in developing countries. Therefore, policymakers need to take action to encourage the consumption of renewable energy sources. Only some studies in the academic literature examine the relationship between market capitalisation and carbon emissions, one of the indicators of financial development. The motivation of this study is to increase the use of renewable energy resources by the decision-making mechanisms of countries, to provide incentives for sustainable economic development and to raise awareness of the increasing global problems and climate crises in recent years.

On the other hand, since renewable energy consumption and stock market capitalisation are related to carbon emissions in the long run, it is expected that the micro and macro-financial markets of countries will expand, and the stock market capitalisation of firms will increase if policymakers support activities to reduce carbon emissions. As long as countries use technologies to use their resources efficiently, there is an increase in firms' financial and market capitalisation in the long run, thus creating similar expectations in countries. Our study provides significant findings for policymakers and firms. Here, our findings show that the development of market capitalisation supports low carbon emissions. Our findings are in line with those of Apergis et al. (2010), Alam et al. (2015), Paramati et al. (2017), Zeqiraj et al. (2020), Alam et al. (2021), and in the opposite direction to those of Zafar et al. (2019). Therefore, policymakers should incentivise firms to use technologies that increase renewable energy consumption. As a result of these incentives, firms are expected to increase their stock market value and obtain additional financing to invest in technologies suitable for renewable energy consumption. In parallel, efficient energy use and improvements in the financial system are expected to contribute to sustainable development policies. Therefore, policymakers need to realise the potential of stock exchanges to minimise CO_2 emissions. In this context, it is necessary to develop effective and sustainable policies to ensure that all listed firms adopt energy efficiency and green technologies in their production activities.

References

Alam, A. et al. (2015), "Does financial development contribute to SAARC's energy demand? From energy crisis to energy reforms", *Renewable and Sustainable Energy Reviews*, 41, 818-829.

Alam, M.S. et al. (2021), "The impacts of R&D investment and stock markets on clean-energy consumption and CO2 emissions in OECD economies", *International Journal of Finance and Economics*, 26(4), 4979-4992.

Apergis, N. & M.C.K. Lau (2015), "Structural breaks and electricity prices: Further evidence on the role of climate policy uncertainties in the Australian electricity market", *Energy Economics*, 52, 176-182.

Ashwin Kumar, N.C. et al. (2016), "ESG factors and risk-adjusted performance: a new quantitative model", *Journal of Sustainable Finance and Investment*, 6(4), 292-300.

Bekaert, G. et al. (2001), "Emerging equity markets and economic development", *Journal of Development Economics*, 66(2), 465-504.

Bhat, M.Y. et al. (2022), "Domino-effect of energy consumption and economic growth on environmental quality: role of green energy in G20 countries", *Management of Environmental Quality: An International Journal*, 33(3), 756-775.

Bhattacharya, M. et al. (2016), "The effect of renewable energy consumption on economic growth: Evidence from top 38 countries", *Applied Energy*, 162, 733-741.

BloombergNEF, (2021), New Energy Outlook 2022, <https://about.bnef.com/new-energy-outlook/>, 09.02.2021.

Breuer, J.B. et al. (2001), "Misleading inferences from panel unit-root tests with an illustration from purchasing power parity", *Review of International Economics*, 9(3), 482-493.

Breusch, T.S. & A.R. Pagan (1980), "The Lagrange Multiplier Test and its Applications to Model Specification in Econometrics", *The Review of Economic Studies*, 47(1), 239-253.

Dasgupta, S. et al. (2001), "Pollution and capital markets in developing countries", *Journal of Environmental Economics and Management*, 42(3), 310-335.

De Haas, R. & A.A. Popov (2019), "Finance and Carbon Emissions", *SSRN Electronic Journal*, 2318.

Dumitrescu, E.I. & C. Hurlin (2012), "Testing for Granger non-causality in heterogeneous panels", *Economic Modelling*, 29(4), 1450-1460.

Gengenbach, C. et al. (2016), "Error Correction Testing in Panels with Common Stochastic Trends", *Journal of Applied Econometrics*, 31, 982-1004.

Grileiro, J. (2019), *Exploiting an Investment Opportunity Based on ESG Score*, Católica-Lisbon School of Business & Economics.

Gurley, J.G. & E.S. Shaw (1955), "Financial Aspects of Economic Development", *The American Economic Review*, 45(4), 515-538.

Kong, Y. et al. (2022), "Peaking Global and G20 Countries' CO2 Emissions under the Shared Socio-Economic Pathways", *International Journal of Environmental Research and Public Health*, 19(17), 11076.

Li, Z. et al. (2020), Analysis of Stock Market Development and CO2 Emissions on OECD Countries via an Empirical Model", *Clean - Soil, Air, Water*, 48(4), 1-12.

Mahmoodi, M. & N. Dahmardeh (2022), "Environmental Kuznets Curve Hypothesis With Considering Ecological Footprint and Governance Quality: Evidence From Emerging Countries", *Frontiers in Environmental Science*, 10(March), 1-11.

Minier, J. (2009), "Opening a stock exchange", *Journal of Development Economics*, 90(1), 135-143.

Nazlioglu, S. et al. (2011), "Nuclear energy consumption and economic growth in OECD countries: Cross-sectionally dependent heterogeneous panel causality analysis", *Energy Policy*, 39(10), 6615-6621.

Paramati, S.R. et al. (2017), "The effects of stock market growth and renewable energy use on CO2 emissions: Evidence from G20 countries", *Energy Economics*, 66, 360-371.

Pedroni, P. (2001), "Purchasing power parity tests in cointegrated panels", *Review of Economics and Statistics*, 83(4), 727-731.

Pesaran, M.H. & T. Yamagata (2008), "Testing slope homogeneity in large panels", *Journal of Econometrics*, 142(1), 50-93.

Pesaran, M.H. (2004), "General Diagnostic Tests for Cross Section Dependence in Panels", *SSRN Electronic Journal*, 1240.

Pesaran, M.H. (2007), "A Simple Panel Unit Root Test in the Presence of Cross-Section Dependence", *Journal of Applied Econometrics*, 22(2), 265-312.

Pesaran, M.H. et al. (2008), "A bias-adjusted LM test of error cross-section independence", *Econometrics Journal*, 11(1), 105-127.

Roberts, D. et al. (2019), *IPCC, 2018: Global Warming of 1.5°C*.

Sadorsky, P. (2010a), "The impact of financial development on energy consumption in emerging economies", *Energy Policy*, 38(5), 2528-2535.

Sadorsky, P. (2010b), "The impact of financial development on energy consumption in emerging economies", *Energy Policy*, 38(5), 2528-2535.

Solomon, S. et al. (2009), "Irreversible climate change due to carbon dioxide emissions", *Proceedings of the National Academy of Sciences of the United States of America*, 106(6), 1704-1709.

Wang, Q. & Z. Dong (2021), "Does financial development promote renewable energy? Evidence of G20 economies", *Environmental Science and Pollution Research*, 28(45), 64461-64474.

Xu, Z. (2000), "Financial development, investment, and economic growth", *Economic Inquiry*, 38(2), 331-344.

Yerdelen-Tatoğlu, F. (2018), *Panel Time Series Analysis*, Beta Publishing.

Yuping, L. et al. (2021), "Determinants of carbon emissions in Argentina: The roles of renewable energy consumption and globalization", *Energy Reports*, 7, 4747-4760.

Zafar, M.W. et al. (2019), "The role of stock market and banking sector development, and renewable energy consumption in carbon emissions: Insights from G-7 and N-11 countries", *Resources Policy*, 62, 427-436.

Zeqiraj, V. et al. (2020), "Stock market development and low-carbon economy: The role of innovation and renewable energy", *Energy Economics*, 91, 104908.

Zeren, F. & M. Koc (2014), "The nexus between energy consumption and financial development with asymmetric causality test: New evidence from newly Industrialized countries", *International Journal of Energy Economics and Policy*, 4(1), 83-91.