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Relationship Between Financial Development and Carbon Emissions: Empirical Evidence from Türkiye with Fractional Frequency Fourier Approaches

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Abstract

This study empirically analyzes the relationship between carbon emissions, one of the most important indicators of environmental pollution, and financial development. Using data from Türkiye for the period 1995-2019, the fractional frequency Fourier ADL cointegration method -previously unused in similar studies- is employed for the analysis. The results, which also account for economic growth, demonstrate a cointegration relationship between the variables. Additionally, the FMOLS method is utilized for model estimation, concluding that financial development and growth lead to increased carbon emissions. The study suggests that loans provided to the financial sector should be directed towards technological investments that reduce carbon emissions

Keywords: Carbon Emissions, Financial Development, Fractional Frequency Fourier Cointegration.

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1. INTRODUCTION

Climate change is one of humanity's most important challenges in the 21st century. Climate change is seriously affecting both nature and people, especially with the melting of glaciers and rising sea levels. Climate change, defined as the unexpected changes in the climate, occurs because of rising average temperatures, in other words, global warming. Climate scientists point to the "greenhouse effect" as the main cause of global warming (Ozturk & Acaravci, 2010). This is because greenhouse gas increases exacerbate the natural greenhouse effect by increasing the gas density in the atmosphere, which leads to a gradual increase in the earth's temperature (Bilgili et al., 2016; Koçak, 2017).

Given the importance of environmental protection, the United Nations Framework Convention on Climate Change is considered an important development (Say & Yucel, 2006). The first significant step of the Convention was the Kyoto Protocol, which entered into force in 2005. This protocol, which imposes binding obligations on developed countries to reduce greenhouse gas emissions, did not become a global agreement. The reason behind this is that the world's largest emitters, such as India, Canada, and the USA, did not ratify the protocol. The Paris Agreement was signed in 2015 under the United Nations Framework Convention on Climate Change (Alam et al., 2012). The main objective of both the Kyoto Protocol and the Paris Agreement is to reduce greenhouse gas emissions. These global steps highlight the universal importance of reducing greenhouse gas emissions and, more broadly, environmental degradation.

The relationship between economic development and environmental degradation has an inverted U shape, as emphasized by Grossman and Krueger (1991). Accordingly, although environmental degradation increases in the initial period of economic growth, it decreases after a certain threshold. In addition to economic growth, financial development is an important factor in reducing greenhouse gases. According to Tamazian et al. (2009), financial development is a key explanatory variable in understanding the link between economic growth and the environment. The financial sector increases technological development in the energy field, affecting greenhouse gas emissions and energy consumption (Yang et al., 2015).

The theoretical expectation for the effects of financial development, which is one of the determining factors influencing carbon emissions, is not unidirectional. While financial development encourages investment in clean energy projects by lowering financing costs, it also negatively affects environmental quality by encouraging industrialization and energy consumption. Therefore, the relationship between financial development and carbon emissions has become an important issue that needs to be examined in various dimensions.

Given the issue's importance, the main objective of this study is to empirically examine the relationship between carbon emissions and financial development. There are a significant number of studies on the subject in the literature. However, this study differs from other studies in the analysis

methods used. Thus, this study can be considered a pioneering work in addressing the subject with a different method. The analysis results are important in terms of contributing to the literature on the subject and guiding future studies.

In this study, firstly, the relationship between carbon emissions and financial development and growth is analyzed theoretically and Türkiye's situation is presented in this context. Then, the empirical literature on the subject is presented. Finally, after introducing the empirical analysis methods, the results of the analysis are interpreted and policy implications are identified.

2. CARBON EMISSIONS, FINANCIAL DEVELOPMENT AND TÜRKİYE

Climate change can be characterized as one of the biggest problems facing humanity in the current century. Increases in greenhouse gases, including burning fossil fuels such as coal, oil, natural gas and large-scale deforestation, cause changes in global temperature and precipitation (Ozturk & Acaravci, 2010). Carbon emissions constitute approximately ¾ of greenhouse gas emissions, which are one of the most important causes of climate change and environmental degradation.

Environmental degradation is one of the issues that have come to the forefront in terms of the sustainability of economic growth. The increase in greenhouse gases triggers environmental degradation in both developed and developing countries. In most countries, industrialization based on non-renewable energy consumption leads to increased environmental degradation and affects development in the long run (Solarin, 2019, p. 6167).

Energy and environmental sustainability are crucial for economic growth and social welfare. At this point, policies to increase economic growth should not come at the expense of environmental degradation (Khobai and Sithole, 2022, p. 516). Due to increasing environmental degradation, a large literature has emerged on the relationship between carbon emissions and economic growth. This literature is based on the Environmental Kuznets Curve (EKC) approach. According to this approach, although environmental degradation occurs in the early stages of development, increased economic development after a certain stage reduces carbon emissions (Grossman & Helpman, 1991; Stern, 2004).

The economic growth of countries causes them to use energy intensively. This situation leads to an increase in carbon emissions. On the other hand, economic growth and development trigger the emergence of energy-efficient and low-carbon technologies that replace carbon-intensive technologies. In this context, while the relationship between growth and carbon emissions is positive in the short run, it is negative in the long run. In fact, both GDP per capita and carbon emissions increased in Türkiye in the 1995-2019 period, and this increase has accelerated in the last decade (World Bank, 2023)

Today, the increase in the production of countries, in other words, the increase in income, causes environmental pollution. However, carbon emissions are not a concept that depends only on the income level of countries. Energy consumption, foreign trade (or trade openness), and financial development also affect carbon emissions. At this point, studies on the subject have expanded the factors affecting

carbon emissions from the perspective of issues such as financial development, openness to foreign trade, and trade intensity (Zhang, 2011).

The first empirical studies in the literature on the relationship between financial development and the environment are by Aufderheide and Rich (1988) and Schmidheiny and Zorraquin (1998). In their study, Aufderheide and Rich (1988) pointed out that the World Bank's financial assistance ignored the countries' environmental aspects. Similarly, Schmidheiny and Zorraquin (1998) emphasized in their study that environmental problems are ignored in short-term loans provided by financial institutions.

The impact of financial development on environmental quality can be divided into two groups. The first group focuses on the fact that financial development deteriorates environmental quality. Accordingly, the acceleration of economic financial development triggers investments and development in the industrial sector. This, in turn, leads to accelerated economic development and increased energy demand. Thus, greenhouse gas emissions in countries increase (Sekali & Bouzahzah, 2019). According to Sadorsky (2011), financial development expands credit availability for energy-intensive consumer goods (such as cars and refrigerators), accordingly, energy use and greenhouse gas emissions increase. In addition, financial development can stimulate technological development, leading to an increase in excessive demand for natural resources. This excessive increase, called the rebound effect, accelerates technological developments and increases energy efficiency in all areas of the economy or, in other words, reduces the energy/output ratio (energy intensity). Increasing energy efficiency leads to increased production and energy use (Yuixang & Chen, 2011; Koçak, 2017). Therefore, increasing energy consumption due to the rebound effect increases environmental pollution.

The second group focuses on the positive impact of financial development on environmental quality. In this context, financial development leads to lower financial intermediation costs. In addition, it allows investments to be directed towards clean energy projects with risk diversification (Nasir et al., 2019, p. 132). The reasons why financial development reduces carbon emissions can be summarized as follows (Tamazian, et al., 2009; Dasgupta, et al., 2001; Islam, et al., 2013; Doytch, 2020):

- Updating production technology and equipment is important for enterprises wanting to increase their market competitiveness. In this respect, a well-developed financial system effectively reduces the financing constraints of enterprises and allows them to update their production technology and equipment. This indirectly reduces production costs and carbon emissions.

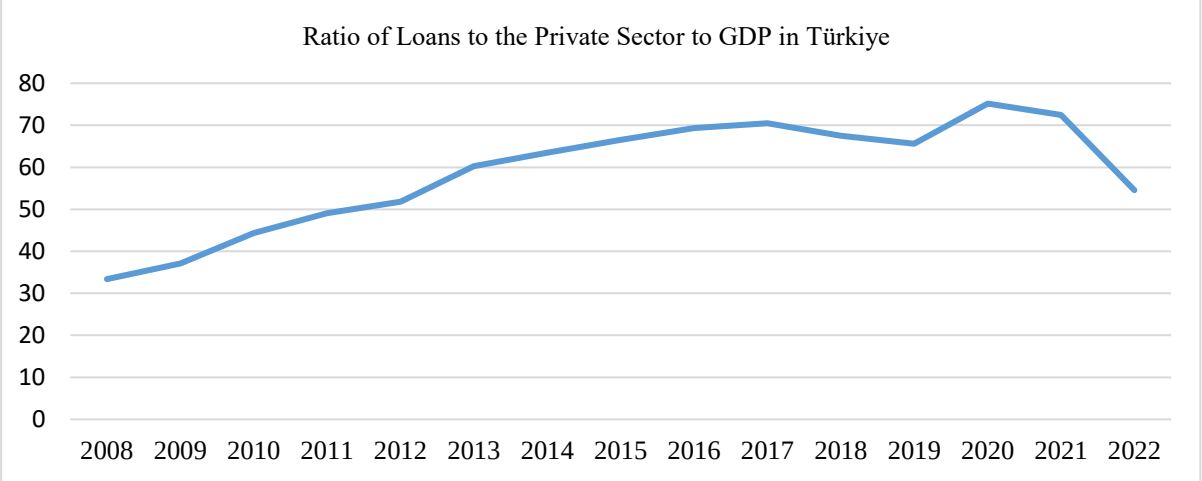
- Financial institutions provide funding for projects that can help improve energy infrastructure and reduce carbon emissions.

- Listed companies have a good image in terms of reducing carbon emissions by using environmentally friendly technologies. It has been demonstrated in some studies (such as Konar and Cohen, 2001) that there is a relationship between the environmental performance of businesses and their stock market values.

• Foreign direct investments, one of the impact channels of financial development on the environment, can improve environmental quality by enabling new knowledge and technological developments despite some negative effects. According to this view, whose theoretical basis is formed by the pollution halo hypothesis, multinational companies from developed countries that generally make these investments apply environmentally protective production methods in the countries where they invest.

Studies focusing on the relationship between carbon emissions and financial development in the literature support the view that financial development has both positive and negative effects. Differences in the country, data range, and methodology affect the different results of the studies. In the literature, various variables such as private sector loans, money supply (M2), fixed capital investments, and loans provided by banks to the private sector are used as indicators of financial development. Figure 1 shows the change in the ratio of loans to the private sector to GDP, which is the most widely used variable among these variables in empirical studies, for the case of Türkiye.

Figure 1. Ratio of Loans to the Private Sector to GDP in Türkiye (2008-2022)

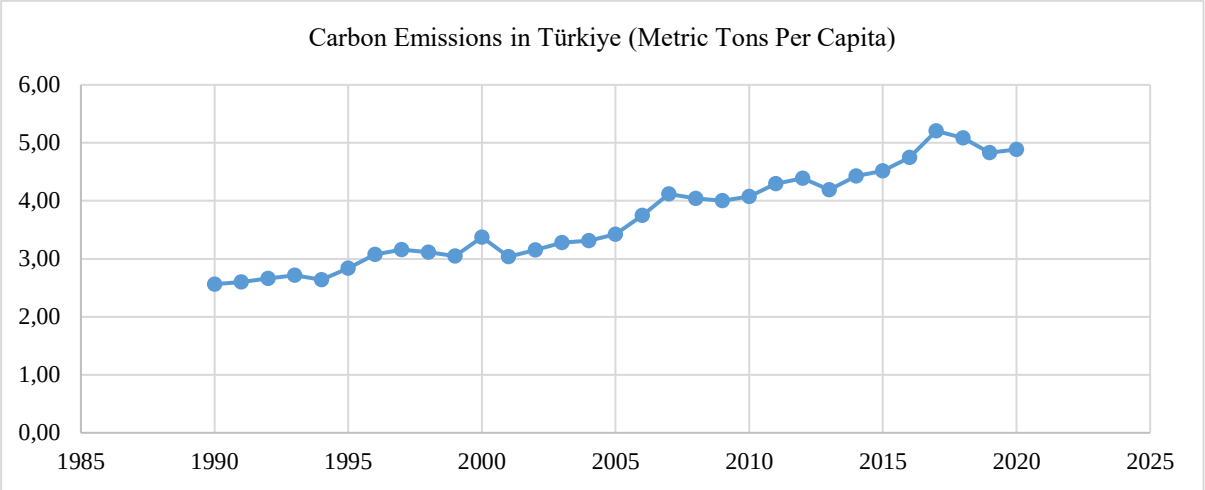


Source: Created with data obtained from the World Bank (2023) database.

Figure 1 shows that loans to the private sector have increased over the years. Although these loans decreased in 2018 and 2019, they increased again in 2020. In 2018 and 2019, the most important reason for the decline in loans to the private sector was the financing crisis. In 2022, there was a decline in these loans again.

As mentioned earlier, greenhouse gas emissions are one of the most important causes of climate change. Carbon emissions constitute a large portion of greenhouse gas emissions. China, the USA, and the EU countries rank first in carbon emissions worldwide, and Türkiye is among the top 20 countries. Figure 2 shows the carbon emissions (metric tons per capita) in Türkiye for the period 1990-2020.

Figure 2. Carbon Emissions in Türkiye (1990-2020)



Source: Created with data obtained from the World Bank (2023) database.

According to Figure 2, although carbon emissions in Türkiye have fluctuated over the years, the general trend has been upward. This increase, which is largely driven by the energy and industrial sectors, has accelerated more in the last decade. The year with the highest carbon emissions was 2017.

3. LITERATURE REVIEW

There is a large literature on environmental pollution and its economic implications. In recent studies, carbon emissions and carbon footprints have been considered important indicators of environmental degradation. Most studies focusing on the relationship between financial development and the environment analyze the growth variable as one of the explanatory variables. At this point, it is important to present the empirical literature review in more detail.

One of the first studies to examine the impact of financial development on carbon emissions is the study by Tamazian et al. (2009). This study on BRIC (Brazil, Russia, India, and China) countries used data from the period 1992-2004 and panel data analysis. As a result of the analysis, it is found that financial development in BRIC countries leads to a decrease in the amount of carbon emissions. Shahbaz, Tiwari & Nasir (2013), and Tang & Tan (2015) also reached the same conclusion. On the other hand, Boutabba (2014), Shahzad et al. (2017), Jiang & Ma (2019), and Rjoub et al. (2021) find that financial development increases the amount of carbon emissions.

When the studies in the existing literature are analyzed, it is evident that a large number of studies examine the relationship between carbon emissions and growth. However, the ARDL method and traditional analysis methods are mostly used in the analysis methods. In this respect, this study is expected to significantly contribute to the literature. This is because, unlike the studies in the literature, this study examines the issue with up-to-date analysis methods.

The literature on the relationship between environmental quality and growth/development is mainly based on the hypothesis that environmental damage starts to decrease as a country develops.

Therefore, the theoretical foundations of the literature focus on the EKC approach. In this approach, the environment-income relationship is expressed in the inverted U-shape proposed by Kuznets. In the literature, the study of Grossman and Kruger (1991) is one of the main studies that empirically reveals the relationship between environment and income. According to Grossman and Kruger (1991), economic growth affects the environment through three channels. These are scale effect, composition effect, and technical effect. Examples of studies examining the impact of growth on carbon emissions include Perman & Stern (2003), Lean & Smyth (2010), Saboori & Sulaiman (2013), Apergis & Ozturk (2015), Khobai & Sithole (2022).

The literature also includes studies examining the impact of growth and financial development on carbon emissions. Table 1 summarizes the studies on the relationship between carbon emissions and these two variables, which are among its important determinants.

Table 1. Studies on the Effects of Growth and Financial Development on Carbon Emissions

Author(s)	Country/Countries	Period	Method	Results
Pao & Tsai (2011)	Brazil, Russia, India, China	1997-2007	OLS	Financial development contributes to the increase in carbon emissions. Moreover, the EKC hypothesis is confirmed.
Jalil & Feridun (2011)	China	1953-2006	ARDL	Financial development reduces carbon emissions. Moreover, the EKC hypothesis is confirmed.
Shahbaz et al. (2012)	Malaysia	1971-2008	ARDL	Financial development reduces carbon emissions.
Shahbaz et al. (2013)	Indonesia	1975 Q1-2011 Q4	VECM	Financial and economic development increase carbon emissions.
Rault (2015)	MENA Countries	1990-2011	Panel Data	It was revealed that the neutrality hypothesis was supported.
Farhani & Ozturk (2015)	Tunisia	1971-2012	ARDL	Financial development contributes to the increase in carbon emissions. Moreover, the EKC hypothesis could not be confirmed.
Li et al. (2015)	102 Countries	1980-2010	GMM	There is an "inverted U-shape" between carbon emissions and growth.
Al-Mulali et al. (2015)	93 Countries	1980-2008	OLS, GMM	Financial development reduces carbon emissions. However, the EKC hypothesis is confirmed for high-income countries.
Seker et al. (2015)	Türkiye	1974-2010	Hatemi-J Cointegration, ARDL	Financial development contributes to the increase in carbon emissions. Moreover, the EKC hypothesis is confirmed.
Ng et al. (2016)	ASEAN Countries	2000-2010	Panel Data	Financial and economic development positively affects carbon emissions.
Dogan & Turkekul (2016)	USA	1960-2010	ARDL	The financial development variable is insignificant. The EKC hypothesis could not be confirmed.
Siddique (2017)	Pakistan	1980-2015	ARDL	Financial development and growth increase carbon emissions.
Cetin et al (2018)	Türkiye	1960-2013	Granger Causality	A long-run causal relationship exists between financial development, growth and carbon emissions.
Temelli & Sahin (2019)	10 Emerging Markets	1995-2014	Durbin-H panel Cointegration, AMG	A significant relationship exists between growth and carbon emissions.
Pala & Barut (2021)	E7 Countries	1990-2014	Panel Data	It is concluded that financial development improves environmental quality in Russia, Indonesia and Türkiye.

Table 1 (cont.)

Author(s)	Country/Countries	Period	Method	Results
Afsar &Yüksel (2022)	Türkiye	1980-2019	NARDL	It is concluded that negative shocks to financial development lead to increased carbon emissions.
Gultekin (2023)	Türkiye	1980-2020	ARDL	Both economic growth and financial development increase carbon emissions.

4. EMPIRICAL ANALYSIS

In this section, information on the data set and the model is provided first. Then, unit root analysis and cointegration analysis is presented respectively. Finally, the estimation results is interpreted statistically and economically.

4.1. Data Set and Model

For the empirical analysis, carbon emissions are modeled as the dependent variable. Data for Türkiye for the period 1995-2019 are used. The data range in the study is created based on the availability of data. In the study, information and communication technologies (ICT) and economic complexity variables are also added to the model as control variables. Therefore, it can be considered that this study is a candidate to be one of the pioneer studies in terms of the model created and the method used. Thanks to the created model, different indicators affecting carbon emissions are analyzed together. Shahbaz et al. (2012), Shahbaz et al. (2013), Akay et al. (2015) and Gökmenoglu and Taspınar (2016) are utilized in the construction of the model. The model created as a result of the existing literature review is as follows:

$$In\ CO2_t = \beta_0 + \beta_1 LnFD + \beta_2 LnG + \beta_3 LnICT + \beta_4 LnECI + \varepsilon_t \quad (1)$$

The symbols and data sources of the variables used in the model are tabulated. Information on the variables is shown in Table 2:

Table 2. Data and Sources

Variables	Symbol	Data Sources
Carbon Emissions (Metric Tons per capita)	CO_2	World Bank
GDP (Constant 2015 US$)	G	World Bank
Financial Development Index	FD	International Monetary Fund
Fixed telephone subscriptions (per 100 people)	ICT	World Bank
Economic Complexity Index	ECI	Atlas Database

4.2. Stationarity Analysis

The fractional frequency Fourier ADF unit root test introduced by Bozoklu et al. (2020) is based on the Enders and Lee (2012a) test. While the frequency value takes integer values in the Enders and Lee (2012a) test, it takes fractional values in this test. The proposed model for the unit root test is as follows (Konat et al., 2022, p. 579):

$$\Delta y_t = \delta_1 + \delta_2 t + \delta_3 \sin\left(\frac{2\pi kt}{T}\right) + \delta_4 \cos\left(\frac{2\pi kt}{T}\right) + \rho y_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta y_{t-1} + e_t \quad (2)$$

As suggested in Christopoulos and Leon-Ledesma (2011) and Omay (2015), the frequency value takes fractional values rather than integer values. The frequency values suggested by Bozoklu et al. (2020) are in the range of [0.1, 0.2,..., 5]. In the test, nonlinearity is tested as $\delta_3 = \delta_4$=0

The prerequisite for the fractional frequency Fourier ADF unit root test is that the trigonometric terms are significant. Otherwise, it would be healthier to prefer the conventional ADF test. While the null hypothesis for the significance of the trigonometric terms emphasizes that the terms are insignificant, the alternative hypothesis emphasizes significance.

The hypotheses for the fractional frequency Fourier ADF unit root test are as follows:

H_0=Series has unit root.

H_1=Series are not unit-rooted.

Table 3 presents the fractional frequency Fourier ADF unit root test results for the variables. Accordingly, before determining whether the variables are unit-rooted or not, the significance of the trigonometric terms should be tested. At this point, the calculated value is compared with the table's critical values. If the calculated value is greater than the table's critical values, it is concluded that the trigonometric terms are significant. However, if the calculated test statistic value is not greater than the table value, it is concluded that the series are non-stationary. At the point where the trigonometric terms are insignificant, the results of conventional unit root analysis should be considered.

Table 3. Fractional Frequency Fourier ADF Unit Root Test Results

Variables	Frequency	Min SSR	F Test	Appropriate	FADF Test
CO_2	0.5	0.531	6.549*	1	-3.461
ΔCO_2	4.8	0.620	7.318*	5	-3.684***
G	2.8	0.028	6.269	1	0.905
FD	0.8	0.432	4.297	1	-2.885
ICT	0.8	2.955	14.178***	1	-2.870
ΔICT	0.6	3.654	8.838**	1	-4.229**
ECI	0.7	0.080	6.215	2	-3.134

Notes: ***, **, * denote significance levels at 1%, 5% and 10%. For trigonometric terms, we refer to Enders and Lee (2012b). For table values, Bozoklu et al. (2021) are used.

Table 4 presents the results of the conventional ADF unit root test. Accordingly, it is concluded that the variables are not stationary at level but at first difference. At this point, the necessary precondition for cointegration analysis is met.

Table 4. ADF Unit Root Test Results

Variable	Test	Test
CO_2	-0.811	-4.387***
G	-0.071	-4.350***
FD	-0.622	-7.960***
ECI	-1.016	-5.564***
ICT	-1.096	-2.000

Notes: ***, **, * denote significance levels at 1%, 5% and 10%.

4.3. Cointegration Analysis

The cointegration tests developed by Engle and Granger (1987), Johansen and Juselius (1990), Boswijk (1994), and Banerjee et al. (1998) do not take structural breaks into account. The Fourier ADL cointegration test proposed by Banerjee et al. (2017) considers structural breaks. In this test, dummy variables are used. In addition, smooth structural transitions are considered in the Fourier ADL test.

In their study, Ilkay et al. (2021) use the Fourier ADL cointegration test proposed by Banerjee et al. (2017). At this point, the autoregressive distributed lag model used is as follows:

$$\Delta\gamma_{1t} = d(t) + \delta_1 y_{1,t-1} + \gamma' y_{2,t-1} + \mu\Delta y_{2t} + e_t \quad (3)$$

In the above model, Δ denotes the first difference. In the model, γ_{1t} stands for the dependent variable, while δ_1 stands for a scalar. Deterministic terms are expressed as follows:

$$d(t) = \beta_0 + \alpha_1 \sin\left(\frac{2\pi kt}{T}\right) + \alpha_2 \cos\left(\frac{2\pi kt}{T}\right) \quad (4)$$

In the above equation, T: Number of observations, t: Trend term, π: 3.1416, and k: Frequency.

$$\Delta\gamma_{1t} = \beta_0 + \alpha_1 \sin\left(\frac{2\pi kt}{T}\right) + \alpha_2 \cos\left(\frac{2\pi kt}{T}\right) + \delta_1 y_{1,t-1} + \gamma' y_{2,t-1} + \mu\Delta y_{2t} + e_t \quad (5)$$

Equation (5) is obtained by substituting equation (4). In their study, Ilkay et al. (2021) estimated equation (3) to determine the optimal value for k.

Banerjee et al. (2017) proposed the Fourier ADL cointegration test. In this study, the frequency value takes values in the range [1, 2, ..., 5]. However, Ilkay et al. (2021) suggest that the frequency value should vary in the range [0.1, 0.2, ..., 5] as emphasized by Christopoulos and Leon-Ledesma (2011). That is, the frequency value takes fractional values instead of integers. Therefore, this method is characterized as the fractional frequency Fourier ADL method.

The hypotheses examining the existence of cointegration are as follows:

H_0 = There is no cointegration relationship.

H_1 = There is a cointegration relationship.

Structural breaks are extremely important in cointegration analyses. Because neglecting structural breaks causes the hypothesis that should be accepted to be rejected or the hypothesis that

should be rejected to be accepted. At this point, it is necessary to know the exact break dates in cointegration tests performed with the help of dummy variables. At this point, Banerjee et al. (2017) proposed the Fouirer ADL test to allow for unknown forms of nonlinear breaks. Therefore, the biggest advantage of the test is that it eliminates the problems of cointegration testing performed with the help of dummy variables. In addition, in traditional cointegration tests, failure to reject the basic hypothesis occurs in case of structural break. The results are erroneous in traditional cointegration tests that do not take structural breaks into account.

After concluding that the variables in the model are stationary as of their first difference, cointegration analysis is started. For the integrity of the analysis, the fractional frequency cointegration analysis method is preferred after fractional frequency unit root analysis. Table 5 presents the results of the cointegration analysis. Accordingly, the fractional frequency is determined as 2.6. The fact that the calculated value is greater than the table critical values reveals the existence of a cointegration relationship. In other words, there is a long-run relationship between the variables. Fractional frequency Fourier ADL, Fourier ADL and traditional cointegration tests are comparatively tested and tabulated to analyze the cointegration relationship. Accordingly, while the cointegration relationship is determined according to fractional frequency Fourier ADL and traditional cointegration analysis; according to the Fourier ADL test, no cointegration relationship can be detected. Since the analyses are handled with fractional frequency, it is accepted that there is a cointegration relationship by taking into account the result of the fractional frequency Fourier ADL cointegration test.

Table 5. Fractional Frequency Fourier-ADL Cointegration Analysis Results

Model	$t_{ADL}^{F}(\hat{k})$	$\hat{k}$	**AIC**	**Cointegration**
CO_2= f (FD, G, ICT, ECI)	-4.900**	2.6	-1.875	✓
	Fourier ADL Critical Values			
1%			-5.181	
5%			-4.476	
10%			-4.098	

Notes: ***, **, * denote significance levels at 1%, 5% and 10%. Table values are based on Ilkay et al. (2021).

Table 6. Fourier-ADL Cointegration Analysis Results

Model	$t_{ADL}^{F}(\hat{k})$	$\hat{k}$	**AIC**	**Cointegration**
CO_2= f (FD, G, ICT, ECI)	-4.189	4	-1.755	X
	Fourier ADL Critical Values			
1%			-5.427	
5%			-4.703	
10%			-4.329	

Notes: ***, **, * denote significance levels at 1%, 5% and 10%. Table values are based on Ilkay et al. (2021).

Table 7. Granger Cointegration Test Results

		Level Values of Residuals (u_t)	
		t-statistics	Probability
ADF test statistics		-3.587	0.014
Test Critical Values	%1	-3.769	
	%5	-3.004	
	%10	-2.642	

4.4. Model Estimation Results

After establishing the existence of a cointegration relationship between the variables, the next step is the model estimation. According to the coefficient estimation results, as seen in Table 8, 9 and 10, GDP, financial development, and ECI positively affect carbon emissions. In other words, increases in GDP, financial development and ECI lead to increases in carbon emissions. The results are theoretically and statistically significant.

Table 8. Estimation of Coefficients (DOLS)

Model	**CO_2= f (FD, G, ICT, ECI)**		
Variables	**Coefficients**	**Standard Errors**	**Probability Values**
FD	2.415	1.044	0.033**
G	1.832	0.748	0.025**
ICT	-0.027	0.0244	0.271
ECI	0.847	0.344	0.025**
C	-0.062	0.042	0.160
sin	0.109	0.037	0.009***
cos	0.012	0.042	0.776

Notes: ***, **, * denote significance levels at 1%, 5% and 10%.

Table 9. Estimation of Coefficients (FMOLS)

Model	**CO_2= f (FD, G, ICT, ECI)**		
Variables	**Coefficients**	**Standard Errors**	**Probability Values**
FD	2.741	1.015	0.015**
G	1.605	0.721	0.040**
ICT	-0.015	0.025	0.557
ECI	0.764	0.335	0.036**
C	-0.051	0.042	0.239
sin	0.097	0.036	0.016**
cos	0.012	0.042	0.763

Notes: ***, **, * denote significance levels at 1%, 5% and 10%.

Table 10. Estimation of Coefficients (CCR)

Model	CO_2= f (FD, G, ICT, ECI)		
Variables	**Coefficients**	**Standard Errors**	**Probability Values**
FD	1.924	1.060	0.088*
G	1.836	0.760	0.028**
ICT	-0.035	0.024	0.168
ECI	0.625	0.349	0.092*
C	-0.066	0.043	0.146
sin	0.102	0.038	0.017**
cos	-0.006	0.043	0.880

Notes: ***, **, * denote significance levels at 1%, 5% and 10%.

5. CONCLUSION

Environmental pollution has become one of the most important problems in the world today. In addition, countries' environmental policies, energy consumption and renewable and non-renewable energy resources are among the issues that are emphasized. Reducing carbon emissions, which is considered one of the important indicators of environmental pollution, is among the main policy objectives of countries in the long run. In this context, the impact of determinants such as economic growth and financial development on carbon emissions is also one of the important issues empirically analyzed in the literature. Considering the importance of the issue, this study analyzes the impact of financial development on carbon emissions in Türkiye. Unlike other studies, the empirical analyses in this study are carried out with up-to-date analysis methods. Therefore, it is considered that the study contributes to the literature in terms of original value and the methodology used.

The study uses data for the period 1995-2019 to analyze the impact of financial development on carbon emissions. In the empirical analysis, fractional frequency tests are preferred for the sake of methodological integrity for unit root and cointegration analysis. As a result of the analysis, the variables are found to be stationary at first difference. In this case, the next step is the cointegration analysis. The cointegration relationship is comparatively tested and tabulated according to fractional frequency Fourier ADL, Fourier ADL and traditional cointegration tests. Accordingly, while the cointegration relationship is determined according to fractional frequency Fourier ADL and traditional cointegration analysis; according to the Fourier ADL test, no cointegration relationship can be detected. Since the analyses are handled with fractional frequency, it is accepted that there is a cointegration relationship by taking into account the result of the fractional frequency Fourier ADL cointegration test.

As a result of the cointegration analysis, the existence of a cointegration relationship between the variables is determined. Finally, according to the FMOLS, DOLS and CCR estimation results, financial development, GDP and economic complexity variables are found to be statistically significant. Theoretically, a direct relationship exists between financial development, growth and carbon emissions. In other words, financial development and growth are found to increase carbon emissions. In this

context, the results of the analysis support most of the studies in the literature. Some of these studies are as follows: Shahbaz et al. (2013), Ng et al. (2016), Siddique (2017) and Gultekin (2023).

The the study's results reveal the importance of the use of loans provided to the financial sector for the purchase of machinery and equipment that lead to the reduction of carbon emissions. Therefore, policymakers should consider financial factors when formulating policies to reduce carbon emissions, and in this context, they should support lending policies with favorable conditions. Similarly, necessary policy steps should be taken to provide funds to encourage investments in renewable energy and energy efficiency. In this context, the green certificate application, which is also available in countries such as China, Sweden and Australia, can be implemented. The sale of this certificate given to the renewable energy investor for each unit of electricity produced provides additional income depending on the price. The most important advantage of this system is that the policy target for renewable energy can be achieved at a very low cost. In addition, funds such as the Renewable Energy Fund can be established, which is implemented in some countries and is based on the creation of a fund from the fees received from other activities, especially for installing renewable energy production facilities such as solar energy systems. Although the fund has risks such as using its resources in areas other than its intended purpose and mismanagement, it may be possible to eliminate or minimize such risks through practices such as requesting performance documents from companies and providing financing to projects whose feasibility is deemed rational (Akdag & Gozen, 2020)

Development pressures in developing countries do not allow for the development of energy-saving technologies. In these countries, the preference is for expanding the scale of production with credit facilities, which in the long run leads to an increase in the cost of environmental pollution. At this point, governments must provide the necessary financial resources for industrial transformation. In Türkiye, energy consumption is largely based on non-renewable and inefficient energy sources. This leads to significant increases in greenhouse gas emissions. With the right policies to be implemented, industries should be directed towards renewable energy consumption.

This study makes an important contribution to the literature regarding methodological differences. However, the literature can be expanded with empirical studies using different variables representing environmental quality. In this context, future studies can be developed for countries at different income levels by using alternative analysis methods and alternative variables.

The study does not necessitate Ethics Committee permission.

The study has been crafted in adherence to the principles of research and publication ethics.

The authors declare that there exists no financial conflict of interest involving any institution, organization, or individual(s) associated with the article. Furthermore, there are no conflicts of interest among the authors themselves.

The authors contributed equally to the entire process of the research.

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