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Investigating the Long-Run Effects of Monetary Policy on Climate Change: Evidence from Türkiye

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Abstract

The effects of global climate change on the economy have made environmental sustainability an essential element of macroeconomic policy frameworks. In recent years, while the position of central banks in combating climate change has been discussed, the consequences of monetary policy implementations in terms of climate change have become increasingly prominent in the literature. The aim of this study is to analyse the effects of monetary policy implementations on climate change in Türkiye. In the study spanning the period 1990-2023, short- and long-run effects are investigated by means of ARDL bounds test and causality relationships between variables are analysed by Toda-Yamamoto test. The findings reveal that monetary expansion triggers climate change in Türkiye. Moreover, causality analyses suggest that there is a bidirectional relationship between the variables. In accordance with these results, it is of utmost importance to design policies by prioritising the effects of monetary policy on environmental sustainability. The central bank may incorporate climate-friendly green monetary policy instruments into its strategies while pursuing its main objective of price stability.

Keywords: climate change, monetary policy, green monetary policy, ARDL

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Para Politikasının İklim Değişikliği Üzerindeki Uzun Dönem Etkilerinin Araştırılması: Türkiye'den Kanıtlar

Öz

Küresel iklim değişikliğinin ekonomi üzerindeki etkileri, çevresel sürdürülebilirliği makroekonomik politika çerçevelerinin önemli bir unsuru haline getirmiştir. Son yıllarda, iklim değişikliğiyle mücadelede merkez bankalarının konumu tartışılırken, para politikası uygulamalarının iklim değişikliği açısından sonuçları da literatürde giderek daha fazla öne çıkmaktadır. Bu çalışmanın amacı, para politikası uygulamalarının iklim değişikliği üzerindeki etkilerini Türkiye özelinde analiz etmektir. 1990-2023 dönemini kapsayan çalışmada, kısa ve uzun dönemli etkiler ARDL sınır testi aracılığıyla araştırılmış, değişkenler arasındaki nedensellik ilişkileri ise Toda-Yamamoto testi ile incelenmiştir. Elde edilen bulgular, Türkiye'de parasal genişlemenin iklim değişikliğini tetiklediğini göstermektedir. Ayrıca, nedensellik analizleri değişkenler arasında çift yönlü bir ilişki olduğunu ortaya koymaktadır. Bu bulgular doğrultusunda, para politikasının çevresel sürdürülebilirlik üzerindeki etkileri dikkate alınarak politika tasarımının yapılması büyük önem taşımaktadır. Merkez bankası, temel hedefi olan fiyat istikrarını gözetirken, iklim dostu yeşil para politikası araçlarını stratejilerine dahil edebilir.

Anahtar Kelimeler: iklim değişikliği, para politikası, yeşil para politikası, ARDL

1. INTRODUCTION

The present condition of climate change necessitates that nations adopt swift and definitive policies to facilitate the transition to a low-carbon economy (Ramlogan and Nelson, 2024). Scenario analyses foresee that the global average temperature increase could reach 4°C by the 22nd century if greenhouse gas emissions (GHG) are not reduced (Intergovernmental Panel on Climate Change, 2014). As a matter of fact, according to annual global temperature data dating back to 1850, 2024 was recorded as the hottest year measured in history. In 2024, temperatures were 0.72°C above the average of the 1990-2020 period and 1.6°C above the pre-industrial period. Thus, 2024 was the first calendar year in which the 1.5°C limit was exceeded (Climate Copernicus, 2025). These developments show that the Paris Agreement's goal of limiting the global temperature increase to 1.5°C is jeopardised by current trends and the risk of exceeding this limit has increased significantly (Pretis et al., 2018).

Climate change has comprehensive and negative impacts on environmental and social systems. Environmentally, climate change leads to ecosystem deterioration, loss of biodiversity, reduction of water resources and food security problems, and socially, it causes social injustice, health issues and climate migration. In addition, it threatens economic development through climate-relevant sectors such as agriculture, fisheries and tourism (Intergovernmental Panel on Climate Change, 2022; Iyke, 2024). On the other hand, human impact stands out as the main cause of the changes observed in the climate system. It is unarguably accepted that GHG accumulated in the atmosphere since the industrial revolution are caused by human activities (Intergovernmental Panel on Climate Change, 2021, p.4-5).

Countries have reached a consensus on ecological protection and low-carbon economic development in the light of sustainable development goals. Accordingly, the Paris Agreement was signed in 2015, committing to a reduction in GHGs. At the COP28 held in the United Arab Emirates in November 2023, signatory countries emphasised the importance of moving away from fossil fuels and took important steps towards a global transition towards renewable energy. It was also underlined that the transition from fossil fuels to renewable energy must be realised globally in order to achieve the net zero target by 2050. The meeting aimed to double energy efficiency and double renewable energy capacity by 2030 (Zhang et al., 2025). As a continuation of this process, the COP29 summit held in Baku in 2024 focused on structural issues such as strengthening climate finance mechanisms and developing carbon market infrastructure. Thus, it was aimed to increase the institutional and financial capacity for the implementation of the objectives of the Paris Agreement (Niftiyev, 2024; World Economic Forum, 2024).

In this regard, how countries will finance their efforts to reduce GHGs during the transition to a low-carbon economy and what roles governments as well as central banks can play in this process is a matter of great debate. Within the framework of climate change mitigation and adaptation policies, government support has been an important source of green finance.

However, when the policy texts of central banks are analysed, it is seen that climate-related issues are not on the agenda of most of them (Perrault and Schupak, 2024; Wu et al., 2024). For instance, the Federal Reserve Bank (Fed) Governor Powell stated that it is not appropriate to use monetary policy and supervisory tools to promote a low-carbon economy or to achieve climate goals in the absence of clear legislation. Moreover, he emphasised that the Fed is not and will not be a climate policymaker (Federal Reserve Bank, 2023). On the other hand, at a meeting of leading insurance companies held at Lloyds in 2015, Mark Carney, former Governor of the Bank of England, emphasised that climate change is a major risk factor for global stability. Stating that the risks related to climate change could cause the "Tragedy of the Horizon"[2], Carney (2015) initiated a crucial debate that will affect the mandate of central banks and their own operations (Thiemann et al., 2023). In this context, Christine Lagarde, the Governor of the European Central Bank (ECB), emphasised that the lack of any reduction in CO_2 emissions poses significant risks to price stability and warned that indifference towards the protection of biodiversity and the fight against climate change jeopardises the sustainability of economies. Along with this, she stated that climate change should be fully incorporated into the monetary policy framework by attaching importance to climate change within the scope of maintaining price stability, which is the central bank's primary objective (Lagarde, 2022; 2024).

While the potential role of central banks in combating climate change is still a controversial issue, the impact of monetary policy on climate change has increasingly become a subject of research. Indeed, the power of central banks to steer economies by regulating money supply, interest rates and liquidity conditions may lead to various consequences in terms of climate change. Accordingly, monetary policy has the potential to indirectly affect environmental sustainability through macroeconomic indicators such as aggregate demand, investment, consumption and economic growth (Ramlogan and Nelson, 2024; Tang et al., 2024). Monetary policy encompasses the strategies employed by central banks to influence the money supply. The main objective of most central banks is to achieve price stability. In addition, financial stability, low unemployment and sustainable economic growth are also among the objectives of central banks (Central Bank of the Republic of Türkiye, 2019). The interaction between the aggregate money supply and interest rates in an economy is directly related to monetary policy. Monetary policy can be implemented in two ways: expansionary or contractionary. As such, central banks raise or cut policy interest rates, which has various effects on money supply, aggregate consumption expenditures and income (Borio and Hofmann, 2017). The possible effects of monetary policy on CO_2 emissions can be explained through consumer and producer behaviour. Cutting interest rates increases the demand for durable consumer goods by facilitating consumers' access to credit; this leads to an increase in industrial production and a rise in fossil fuel consumption. For producers, low interest rates encourage new capital investments and the establishment of production facilities. Increased production capacity may lead producers to prefer cheaper fossil fuels instead of clean technologies in order to gain cost

[2] This concept implies that the long-term impacts of climate change are not sufficiently considered by central banks that make decisions based on short-term time horizons (Carney, 2015, p.4).

advantage, leading to an increase in CO_2 emissions. As a result, expansionary monetary policy may stimulate economic activity while at the same time causing an upward pressure on emission levels (Qingquan et al., 2020). On the other hand, low interest rates can reduce the financing costs of the private sector and increase the capacity of firms, especially those operating in highly climate-sensitive sectors, to invest in low-carbon technologies. Such investments increase energy efficiency, promote the use of renewable energy and reduce the environmental impacts of production processes. Therefore, providing favourable financial conditions may contribute to reducing CO_2 emissions in the long-run (Pradeep, 2021). In this context, central banks can use monetary policy instruments in line with environmental objectives (Depoorter, 2024). The policy framework that considers the risks related to climate change while pursuing the price stability and financial stability objectives of central banks is referred to as green monetary policy. Thus, central banks can reshape their policy instruments to support the green transformation of the economy by accounting for the effects of climate change on macroeconomic stability (Ülkü, 2023). Prioritising low-carbon assets in central banks' balance sheets (Boneva et al., 2022), accepting green bonds as collateral (Network for Greening the Financial System, 2021), considering climate change-related risks in credit policies (Volz, 2017) or introducing green differentiated reserve requirement ratios (Campiglio, 2016) are among the instruments of green monetary policy.

Given the above background, in today's world where CO_2 emissions have reached serious levels on a global scale, it becomes important to investigate the short and long-run effects of monetary policy on CO_2 emissions. This study aims to analyse the short and long-run effects of monetary policy on climate change in Türkiye from 1990 to 2023 using the Autoregressive Distributed Lag (ARDL) bounds test method. The study also analyses the causality relationships between monetary policy and climate change through Toda-Yamamoto causality test.

The study is anticipated to enhance the literature in four primary ways. Initially, research examining the implications of monetary policy for climate change remains nascent in the literature. A review of this literature spanning the last five years reveals that Türkiye-specific studies are extremely limited. In this respect, this is one of the pioneering studies that comprehensively analyses Türkiye-specific country dynamics. Secondly, the analysis is based on a more recent and longer time series period compared to similar studies in the literature. Third, this study employs a more extensive range of control variables compared to existing literature and systematically assesses the impacts of income, energy consumption, renewable energy, and monetary policy on CO_2 emissions. Finally, the ARDL bounds test method used in this study provides the flexibility to analyse short and long-run relationships within the same model structure and maintains its validity even when the variables have different degrees of integration.

The following sections of the study are organised as follows: The second section presents the literature review. In the third section, the data set is introduced and the econometric methodology is explained. Following the fourth section, which presents the findings of the analyses, the study is completed with conclusions and policy recommendations.

2. LITERATURE REVIEW

In the literature investigating the dynamics of climate change, demographic factors, the structure of energy resources and macroeconomic indicators are mostly addressed. In this context, population (Uzair Ali et al., 2022), urbanisation (Cetin et al., 2018), globalisation (Yang et al., 2021), energy consumption (Halicioglu, 2009; Karış, 2017; Huang and Ren, 2024), renewable energy (Li and Su, 2017; Mukhtarov, 2024), income (Acaravci and Ozturk, 2010; Mitić et al., 2017), international trade (Artan et al., 2015; Muhammad et al., 2020), foreign direct investment (Kömürcüoğlu and Değer, 2022), and financial development (Uzar and Eyuboglu, 2019) stand out as the main determinants of climate change. On the other hand, studies investigating the impact of monetary policy on CO_2 emissions are still very new and limited in the literature. A summary of the literature on these studies is presented in Table 1.

Table 1. Studies on monetary policy and climate change

Author(s)	Country & Period	Dependent Variable & Monetary Policy Proxy	Method	Findings
Ozili (2025)	63 countries (from America, Europe, Africa and Asia) & 2009-2023	CO_2 from fossil fuel energy consumption & Lending interest rate	Panel fixed effect regression	Monetary policy adversely affects only the Americas.
Wu et al. (2024)	39 countries & 2000-2019	CO_2 & M2 money supply	PSTR approach	A positive and non-linear relationship was found between money supply and CO_2.
Lau et al. (2024)	BRICS & 1990-2018	CO_2 & Broad money (% of GDP)	Kao and Pedroni cointegration tests, PMG-ARDL and FMOLS, Driscoll-Kraay estimations	Expansionary monetary policy has been determined to enhance environmental quality.
Tang et al. (2024)	China & 1982-2022	CO_2 and EFP & Real interest rate	Wavelet power spectrum, wavelet coherence, quantile regression and quantile-on-quantile analyses	It is found that the impact of monetary policy on CO_2 varies over time. Contractionary monetary policies, even if they cause a short-run increase in CO_2, are effective in reducing CO_2 in both the medium and long-run.
Sharma et al. (2023)	India & 1970-2019	CO_2 & Call money rate	NARDL	The impacts of positive and negative shocks in monetary policy on CO_2 are identified as positive and negative, respectively.

Bildirici et al. (2023)	Türkiye & 1978-2021	CO_2 & Weighted average policy interest rate	ARDL, NARDL, traditional and nonlinear Granger Causality tests	Long-run relationships were found between the variables. A positive relationship exists between monetary policy and CO_2. There exists no causality between CO_2 and monetary policy.
Attílio et al. (2023)	United States, United Kingdom, Japan and the Eurozone & 1990:M1-2018:M12	CO_2 & Short and long-run interest rates	GVAR methodology	The impact of monetary contraction on CO_2 is found to be dampening in both the short and long-run, except for the UK.
Bletsas et al. (2022)	95 countries & 1998-2019	CO_2 and GHG & M3 and Money-market interest rate	Panel fixed and random effects, GLS, Driscoll Kraay, and FMOLS	The coefficients of the variables used to represent monetary policy are found to be statistically insignificant.
Mahmood et al. (2022)	6 Gulf Cooperation Council economies & 1990-2019	CO_2 consumption-based and CO_2 territory & Money supply	Pedroni, Kao and Maddala and Wu's cointegration tests, PMG, FMOLS, and DOLS	Boosts in the money supply diminish CO_2 in the long-run while raising it in the short-run.
Shobande (2022)	East African Community & 1990-2019	CO_2 & Real interest rate	Kao, Pedroni and Westerlund cointegration tests Panel Granger causality tests	Monetary policy is found to be an important policy in reducing CO_2. A bidirectional causality relationship is also found between both variables.
Yousaf et al. (2022)	China & 1990-2020	EFP & Central banks' discount policy rate	Johansen cointegration test, ARDL, FMOLS, DOLS, Granger causality	There is a long-run relationship between the variables. Contractionary monetary policy is found to reduce CO_2. Unidirectional causality is also found from monetary policy to CO_2.
Pradeep (2021)	India & 1971-2014	CO_2 & Interbank interest rates	ARDL	A positive and statistically significant relationship between interest rates and CO_2 for both the short- and long-run.
Ullah et al. (2021)	Pakistan & 1985-2019	CO_2 & Discount rate	ARDL and NARDL	Negative-positive shocks in monetary policy increase CO_2 in the short-run. In contrast, positive shocks in monetary policy decrease CO_2 in the long-run.
Qingquan et al. (2020)	14 selected Asian countries & 1990-2014	CO_2 & Real interest rate	Pedroni and Kao cointegration tests, panel FMOLS and DOLS	Statistically significant and positive relationship between expansionary monetary policy and CO_2 in the long-run.
Muhafidin (2020)	Indonesia & 1973-2018	CO_2 & Interest rate	ARDL, Granger causality test	An increase in interest rates is found to increase CO_2 in the long-run. A bidirectional causality relationship is found between both variables.

Note: EFP: Ecological Footprint, PSTR: Panel Smooth Transition Regression, NARDL: Nonlinear ARDL, PMG-ARDL: Pooled Mean Group-ARDL, FMOLS: Fully Modified Ordinary Least Square, DOLS: Dynamic Ordinary Least Square, GVAR: Global Vector Autoregressive, GLS: Generalized Least Squares

Table 1 reveals that empirical research examining the implications of monetary policy for climate change has only been done in the past five years. According to Table 1, CO_2 emissions are frequently used as an indicator of climate change. In addition to this, there are also studies on environmental indicators such as EFP and GHG. On the other hand, it is noteworthy that the indicators used to represent monetary policy varies. In this context, it has been observed that interest rates are frequently preferred in the literature, while studies using money supply have also been encountered. The findings obtained from the studies vary according to the country group, the variable used and the methodology. Although there is no consensus in the literature on the direction of the effect of monetary policy on climate change, it can be argued that monetary policy undeniably influences environmental sustainability. Therefore, it is very important to consider monetary policy in the context of environmental policies.

Compared to the studies in the literature, this study analyses the impact of monetary policy on climate change in Türkiye and within a longer time series. In addition, unlike the analyses in the existing literature, which are mostly conducted with a limited number of variables, in this study, the determinants of CO_2 emissions are addressed with a wider set of control variables; thus, both the statistical strength and the explanatory power of the models constructed are significantly increased.

3. DATA and RESEARCH METHOD

The aim of this study is to analyse the short-run and long-run effects of monetary policy on climate change in Türkiye for the period 1990-2023 through the ARDL bounds test approach. Accordingly, the models in equations (1) and (2) are estimated.

Model I: $LCO_{2t} = \beta_0 + \beta_1 LGDPP_t + \beta_2 LEC_t + \beta_3 LREN_t + \varepsilon_t$ (1)

Model II: $LCO_{2t} = \beta_0 + \beta_1 LGDPP_t + \beta_2 LEC_t + \beta_3 LREN_t + \beta_4 LMS_t + \varepsilon_t$ (2)

In Equations (1) and (2), t denotes the time, β denotes the estimation coefficients, ε denotes the error term and L denotes the logarithm of the relevant variable. In the analysis, CO_2 emissions were used to represent climate change and were included as the dependent variable in both models. As it is known, increases in CO_2 emissions cause global warming by increasing radiative forcing. Global warming, in turn, leads to physical changes such as melting of glaciers, sea level rise and acidification of oceans, and this process accelerates climate change by further increasing GHGs through feedback mechanisms (Stern, 2008). In addition, following the literature, income (LGDPP), energy consumption (LEC) and renewable energy (LREN) are considered as control variables. In this context, in Model I, only income, energy consumption, and renewable energy variables, which are traditional determinants of CO_2 emissions, are used. In Model II, the money supply (LMS) variable representing the monetary policy is included in the model and the effect of this variable on CO_2 emissions is analysed separately.

The explanations and sources of the variables used in the analysis are presented in Table 2.

Table 2. The descriptions of the variables and sources

Variables	Abbreviations	Descriptions	Source
Carbon dioxide emissions	CO_2	Per capita CO_2	Our World in Data
Money supply	MS	Broad money (% of GDP)	World Bank-World Development Indicators
Economic growth	GDPP	GDP per capita (constant 2015 US$)	
Energy consumption	EC	Primary energy consumption per capita	Energy Institute (2024)
Renewable energy	REN	Annual changes and share of total are calculated using exajoules figure	

In the study, firstly, the stationarity levels of the variables were determined by using the Augmented Dickey Fuller (ADF) and Philips-Perron (PP) unit root tests. Then, the short and long-run effects of monetary policy on CO_2 are analysed through ARDL bounds test. At the last stage of the analysis, the Toda-Yamamoto causality test was employed to examine the causal links between the variables. Figure 1 illustrates the methodical procedure diagram of the investigation.

Figure 1. Methodological procedure diagram

The ARDL bounds test developed by Pesaran and Shin (1999) and Pesaran et al. (2001) has several advantages over conventional cointegration tests (Engle and Granger, 1987; Johansen 1995). First, the bounds test allows for the investigation of long-run relationships between variables without requiring them to be stationary at the same level. Therefore, there is no need to detect the stationary levels of the variables before proceeding to the bounds test. However, the critical values calculated by Pesaran et al. (2001) for the bounds test are valid if the variables are I(0) and/or I(1). Therefore, it should be determined by unit root tests that the variables are not stationary at I(2) level (Eriçok and Yılancı, 2013, p.95). Secondly, since the ARDL approach uses an unrestricted error correction model, it has superior statistical properties compared to the Engle and Granger (1987) cointegration test. Finally, the ARDL method can be applied to studies with small samples and provides more reliable results than traditional cointegration tests (Narayan and Narayan, 2005, p.429).

The ARDL bounds test consists of two stages. Firstly, the existence of a long-run relationship between variables is tested by F-statistics. For this purpose, the unconstrained error correction model estimated for Models I and II are shown in equations (3) and (4) (Tandoğan, 2017).

$$\Delta LCO2_t = \alpha_0 + \sum_{i=1}^{m} b_i \, \Delta LCO2_{t-i} + \sum_{i=0}^{m} c_i \, \Delta LGDPP_{t-i} + \sum_{i=0}^{m} d_i \, \Delta LEC_{t-i} + \sum_{i=0}^{m} e_i \, \Delta LREN_{t-i} + \vartheta_0 LCO2_{t-1} + \vartheta_1 LGDPP_{t-1} + \vartheta_2 LEC_{t-1} + \vartheta_3 LREN_{t-1} + \varepsilon_t \quad (3)$$

$$\Delta LCO2_t = \beta_0 + \sum_{i=1}^{n} f_i \, \Delta LCO2_{t-i} + \sum_{i=0}^{n} g_i \, \Delta LGDPP_{t-i} + \sum_{i=0}^{n} h_i \, \Delta LEC_{t-i} + \sum_{i=0}^{n} j_i \, \Delta LREN_{t-i} + \sum_{i=0}^{n} k_i \, \Delta LMS_{t-i} + \varphi_0 LCO2_{t-1} + \varphi_1 LGDPP_{t-1} + \varphi_2 LEC_{t-1} + \varphi_3 LREN_{t-1} + \varphi_4 LMS_{t-1} + \epsilon_t \quad (4)$$

The optimal lag lengths determined by Akaike Information Criterion (AIC) are *m, u, l,* and *p* for Model I and *n, r, s, v,* and *z* for Model II.

In the next stage, long- and short-run coefficients are estimated for the variables that are found to have cointegration relationship. The models used in the long-run coefficient estimation for Models I and II are given in equations (5) and (6).

$$LCO2_t = \alpha_0 + \sum_{i=1}^{m} b_i \, \Delta LCO2_{t-i} + \sum_{i=0}^{u} c_i \, \Delta LGDPP_{t-i} + \sum_{i=0}^{l} d_i \, \Delta LEC_{t-i} + \sum_{i=0}^{p} e_i \, \Delta LREN_{t-i} + \varepsilon_t \quad (5)$$

$$LCO2_t = \beta_0 + \sum_{i=1}^{n} f_i \, \Delta LCO2_{t-i} + \sum_{i=0}^{r} g_i \, \Delta LGDPP_{t-i} + \sum_{i=0}^{s} h_i \, \Delta LEC_{t-i} + \sum_{i=0}^{v} j_i \, \Delta LREN_{t-i} + \sum_{i=0}^{z} k_i \, \Delta LMS_{t-i} + \epsilon_t \quad (6)$$

The error correction model (ECM) considered in the estimation of short-run coefficients is as shown in equations (7) and (8) for Models I and II, respectively.

$$\Delta LCO2_t = \alpha_0 + \sum_{i=1}^{m} b_i \, \Delta LCO2_{t-i} + \sum_{i=0}^{u} c_i \, \Delta LGDPP_{t-i} + \sum_{i=0}^{l} d_i \, \Delta LEC_{t-i} + \sum_{i=0}^{p} e_i \, \Delta LREN_{t-i} + \mu ECM_{t-1} + \varepsilon_t \quad (7)$$

$$\Delta LCO2_t = \beta_0 + \sum_{i=1}^{n} f_i \, \Delta LCO2_{t-i} + \sum_{i=0}^{r} g_i \, \Delta LGDPP_{t-i} + \sum_{i=0}^{s} h_i \, \Delta LEC_{t-i} + \sum_{i=0}^{v} j_i \, \Delta LREN_{t-i} + \sum_{i=0}^{z} k_i \, \Delta LMS_{t-i} + \Omega ECM_{t-1} + \epsilon_t \quad (8)$$

In order to analyse the dynamics between monetary policy and climate change more comprehensively, it is important to determine the causality relationships between the variables in the model. However, the ARDL bounds test, which provides long-run and short-run coefficient estimation results, does not provide any information on the direction of causality between variables. For this reason, the Toda and Yamamoto (1995) causality test is often preferred when dealing with variables that are integrated at different levels. A major limitation of the standard Granger causality test is that it can only be validly applied when all variables are integrated of the same order, typically I(0) or I(1) (Kömürcüoğlu and Akyazi, 2024). The equation for the Toda-Yamamoto causality test is constructed according to the extended VAR model estimation (k+dmax) and includes two different lag lengths. In the standard VAR model, *k* denotes the optimal lag length, while *dmax* represents the highest order of integration among the variables. After the VAR system is estimated, the null hypothesis is tested against the alternative hypothesis through the Wald test (Koçak, 2021; Mert and Çağlar, 2023).

4. FINDINGS and DISCUSSION

Prior to initiating the empirical investigation, the stationarity levels of the variables are assessed and displayed in Table 4. The ADF and PP unit root results in Table 4 reveal that LCO_2, LGDPP, LEC and LREN variables are stationary at first difference (I(1)), while LMS variable is stationary at level (I(0)). In other words, none of the variables are stationary at I(2) level.

Table 4. Unit root tests

Variables	ADF		PP	
	Constant	Constant-Trend	Constant	Constant-Trend
LCO_2	−1.337	−2.049	−1.530	−2.102
LGDPP	0.665	−2.577	1.970	−2.472
LEC	−0.827	−3.206	−0.874	−3.204
LREN	−0.679	−2.334	−0.303	−2.334
LMS	−2.016	-4.209^{**}	−1.983	-3.911^{**}
$DLCO_2$	-5.997^{***}	-6.049^{***}	-6.511^{***}	-7.758^{***}
DLGDPP	-5.737^{***}	-5.781^{***}	-6.501^{***}	-7.636^{***}
DLEC	-7.185^{***}	-7.111^{***}	-8.039^{***}	-8.268^{***}
DLREN	-6.851^{***}	-6.754^{***}	-7.563^{***}	-7.624^{***}
DLMS	-4.358^{***}	-4.425^{***}	-12.879^{***}	-18.809^{***}

Note: *** and ** denote significance levels at 1% and 5%, respectively. “D” denotes the first difference.

In the first stage of the ARDL approach, the validity of a cointegration relationship between the variables was examined by the bounds test. Table 5 shows the bounds test results for Models I and II. While the F-statistic is greater than the upper critical value of the table at 5% significance level for Model I (7.841>5.980), it is greater than the upper critical value of the table at 1% significance level for Model II (8.376>7.578). Therefore, for both models, the null hypothesis of no long-run relationship among the variables is rejected, indicating the presence of cointegration.

Table 5. Model I and II bound test results

Models	F-statistic	Narayan (2005) critical values	Decision
Model I (4, 3, 4, 3)	7.871**	%5 I(0)= 4.683 I(1)=5.980	Cointegrated
Model II (2, 0, 1, 4, 4)	8.376***	%1 I(0)=5.856 I(1)=7.578	Cointegrated

Note: *** and ** denote significance levels at %1 and 5%, respectively.

In order to test the validity and reliability of Models I and II, the diagnostic tests in Table 6 were performed. According to the diagnostic test results, there is no autocorrelation and heteroscedasticity problem in the models. In addition, for both models, the error terms are normally distributed and there is no model fitting error.

Table 6. Diagnostic test results

Tests	Model I	Model II
Breusch-Godfrey LM Test	1.397	1.720
Breusch-Pagan-Godfrey Test	1.135	0.318
Jarque-Bera Normality Test	1.131	3.331
Ramsey RESET Test	0.232	0.300

The short and long-run coefficient estimation results of Models I and II are shown in Table 7.

Table 7. ARDL estimation results

Panel A			
Model I ARDL (4, 3, 4, 3)			
Variables	Long-run coefficients	Variables	Short-run coefficients
LGDPP	0.178^{***} (0.042)	C	17.663^{***} (2.795)
LEC	1.374^{***} (0.044)	Trend	-0.016^{***} (0.003)
LREN	-0.255^{***} (0.008)	ΔLCO_2	0.249^{***} (0.074)
		ΔLGDPP	0.722^{***} (0.085)
		ΔLEC	0.012^{***} (0.075)
		ΔLREN	-0.190^{***} (0.015)
		ECT_{t-1}	-1.711^{***} (0.271)

Panel B			
Model II ARDL (2, 0, 1, 4, 4)			
Variables	Long-run coefficients	Variables	Short-run coefficients
LGDPP	0.210^{***} (0.053)	C	13.431^{***} (1.815)
LEC	1.077^{***} (0.053)	Trend	-0.011^{***} (0.001)
LREN	-0.233^{***} (0.010)	ΔLCO_2	0.130^{**} (0.056)
LMS	0.183^{***} (0.034)	ΔLGDPP	0.267^{***} (0.071)
		ΔLEC	1.053^{***} (0.070)
		ΔLREN	-0.054^{***} (0.015)
		ΔLMS	0.067^{***} (0.020)
		ECT_{t-1}	-1.273^{***} (0.172)

Note: *** denotes significance levels at 1%. Values in parenthesis indicate standard error estimates.

When Table 7 is analysed, it is seen that the long-run coefficients of LGDPP, LEC and LREN variables in both models are statistically significant at 1%. The coefficients of LGDPP and LEC variables are positive, while the coefficient of LREN variable has a negative sign. Accordingly, increases in LGDPP and LEC increase CO2 in the long-run, while increases in LREN decrease CO2. According to Panel B of Table 7, which includes the results of Model II, the long-run coefficient of the LMS variable is statistically significant at the 1% level and has a positive sign. This finding reveals that increases in money supply (expansionary monetary policy) boosts CO_2 emissions.

For the error correction mechanism to function, the coefficient of the error correction term (ECT_{t-1}) must be statistically significant and negative. As seen in Table 7, the ECT_{t-1} for Models I and II are negative and statistically significant at 1%. These coefficients are between −1 and −2. Accordingly, deviations from the long-run equilibrium are expected to rebalance in oscillations rather than linearly (Alam and Quazi, 2003).

CUSUM and CUSUMQ figures for Models I and II are presented in Figures 2 and 3, respectively.

Figure 2. CUSUM and CUSUMQ graphics for Model I

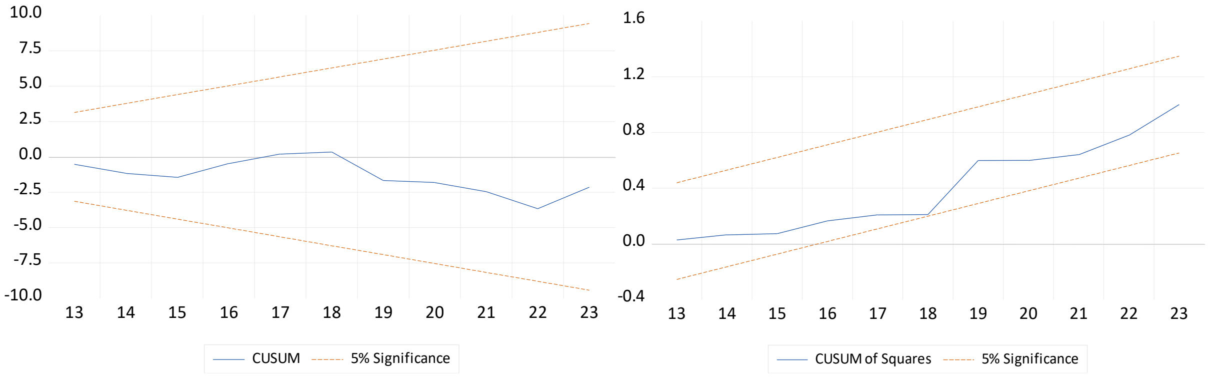
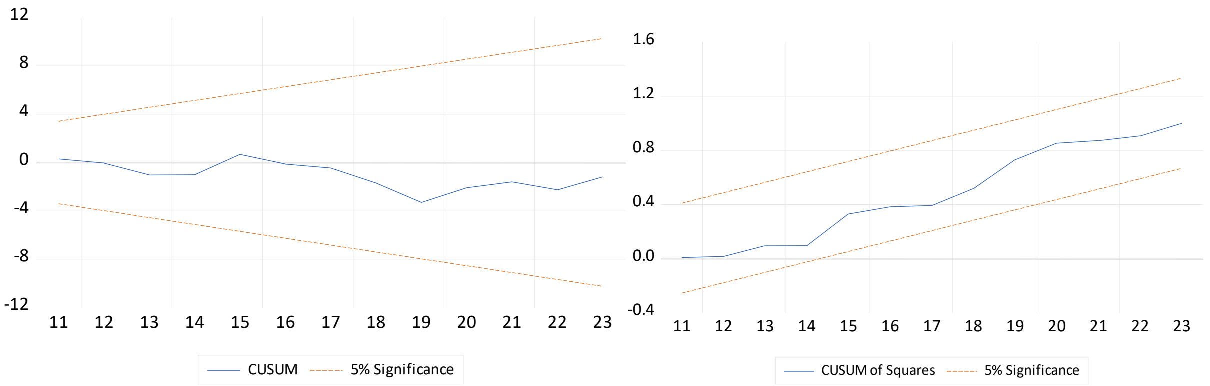


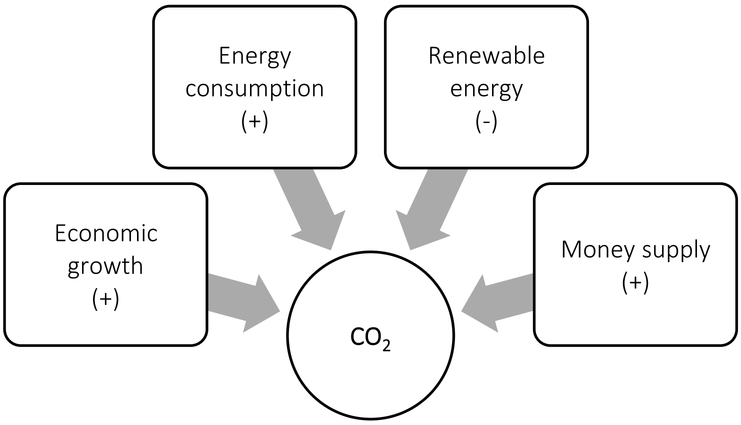
Figure 3. CUSUM and CUSUMQ graphics for Model II



The graphs show that the blue lines, indicating the coefficient estimates, remain within the dashed red lines representing the 95% confidence intervals. Therefore, it can be said that the estimated coefficients for Models I and II are stable and there is no structural break in the models.

Figure 4 displays the long-run coefficient estimation results obtained from the ARDL method.

Figure 4. Summary of estimates results



Toda-Yamamoto causality test was performed to investigate the causality relationships between the variables and the findings are shown in Table 8.

Table 8. Toda-Yamamoto causality test results

H_0 Hypothesis	χ^2 values	p value	Decision
LGDPP↛LCO_2	9.497	0.023	LGDPP↔LCO_2
LCO_2↛LGDPP	9.341	0.025	
LEC↛LCO_2	15.494	0.000	LEC→LCO_2
LCO_2↛LEC	2.867	0.238	
LREN↛LCO_2	5.649	0.130	LCO_2→LREN
LCO_2↛LREN	6.359	0.095	
LMS↛LCO_2	20.687	0.000	LMS↔LCO_2
LCO_2↛LMS	6.865	0.076	

Note: ↛, →, and ↔ represent no causality, unidirectional, and bidirectional causality, respectively.

As seen in Table 8, there is a statistically significant bidirectional causality relationship between CO_2 emissions and economic growth at 5% level. There is a unidirectional causality relationship from energy consumption to CO_2 emissions, which is significant at 1% level. On the other hand, while no causality relationship was found from renewable energy consumption to CO_2 emissions, a unidirectional causality relationship was found from CO_2 emissions to renewable energy, which is significant at the 10% level. Finally, a bidirectional causality relationship was found between money supply and CO_2 emissions, but when the direction of this relationship is analysed, it is seen that the causality is statistically stronger from money supply to CO_2 emissions.

5. DISCUSSION and CONCLUSION

Despite global recognition of climate change, total energy-related carbon dioxide levels reached an all-time high of 37.8 Gt in 2024 (International Energy Agency, 2025). While many countries have announced comprehensive plans to reduce GHGs and net zero emission targets, the more widespread use of money supply as a policy tool to support economic recovery, especially after COVID-19 (Pehlivan et al., 2021; Ülger Danacı, 2022), suggests that central banks should take into account the possible effects of monetary policy on climate change. In this study, the impact of monetary policy on climate change in Türkiye is analysed for the period 1990-2023. In the analysis, money supply is used to represent monetary policy and CO_2 emissions are used to represent climate change. In the study, short and long-run effects are investigated through ARDL approach, while the direction of causality relationships between variables is analysed by Toda-Yamamoto test. The results of the analysis reveal that there is a long-run relationship between monetary policy and climate change. Accordingly, increases in money supply increase CO_2 emissions in Türkiye. At the same time, bidirectional causality relations were found between these variables.

These results are consistent with the findings of studies such as Wu et al. (2024), Bildirici et al. (2023), Yousaf et al. (2022) and Qingquan et al. (2020). The positive effect of increases in money supply on CO_2 emissions can be explained through various channels. First, increases in the money supply may stimulate economic activities through investment and consumption, leading to an increase in energy consumption and thus fossil fuel CO_2 emissions. Secondly, the increased income level as a result of monetary expansion may trigger household consumption, leading to higher CO_2 emissions in energy-intensive sectors such as housing, transport and industry. Finally, expansionary monetary policy may increase emissions by incentivising climate-insensitive investments and technologies through credits. Besides, increases in per capita income (Çomuk et al., 2023) and energy consumption (Doğanlar et al., 2021), which are included as control variables in both models, are found to boost CO_2 emissions, while increases in renewable energy (Karaaslan and Çamkaya, 2022) are found to diminish CO_2 emissions. The results obtained are highly in line with the literature and also strongly point to the necessity of sustainable energy policies.

As an indicator of monetary policy, money supply increases lead to carbon emissions, which reveals the necessity of developing a green monetary policy (Qingquan et al., 2020). Therefore, it is possible to make some recommendations to policymakers. First of all, selective policy instruments can be used to reduce CO_2 emissions without contradicting the central bank's primary objective of price stability. According to Roy (2024), loans can be directed from high-carbon intensive sectors to low-carbon sectors through selective policies. In this context, a green loan program can be launched for commercial banks. For example, higher interest rates can be set for producers that rely on carbon-intensive resources for more than half of their production (Mughal et al., 2021; Sharma et al., 2023). Such policies aim to reduce CO_2 emissions by reducing firms' reliance on carbon-intensive technologies and encouraging them to engage in climate-sensitive projects (Mahmood et al., 2022). Similarly, central banks can lower the cost of borrowing for green projects through green quantitative easing (QE). According to Dafermos et al. (2018), instead of buying any bond, central banks can buy bonds issued by companies or governments that aim to finance climate-sensitive projects such as renewable energy, energy efficiency, and sustainable agriculture. Unlike conventional QE, the aim of green QE is not to support economic growth but to contribute to the fight against climate change. Finally, by drawing attention to climate change through verbal guidance, central bankers can raise the awareness of green market actors and emphasize the importance of investments.

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