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The Impact of Monetary Policy on Environmental Degradation: A Comparative Analysis of Advanced and Emerging Economies[1]

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Para Politikasının Çevresel Bozulma Üzerindeki Etkisi: Gelişmiş ve Gelişmekte Olan Ekonomilerin Karşılaştırmalı Analizi[2]

Abstract

This study examines the impact of monetary policy on environmental degradation by applying the two-step system generalised method of moments (GMM) methodology and utilising panel data from 58 countries (1995-2021). Additionally, a comparative analysis of advanced and emerging economies is conducted. The findings reveal that while expansionary monetary policy significantly increases environmental degradation in emerging economies, no significant relationship is observed in advanced economies. This underscores the critical need to integrate sustainability into monetary policy frameworks. It is vital for long-term sustainable growth that central banks assess the environmental impacts of their activities, prioritise green investments, and promote green financial instruments.

Keywords : Environmental Degradation, Monetary Policy, Emerging Economies, Advanced Economies, Two-Step System GMM.

JEL Classification Codes : E52, Q54, Q56.

Öz

Bu çalışma, para politikasının çevresel bozulma üzerindeki etkilerini iki aşamalı sistem genelleştirilmiş momentler (GMM) metodolojisini uygulayarak ve 58 ülkeden (1995-2021) elde edilen panel verileri kullanarak incelemektedir. Ayrıca, gelişmiş ve gelişmekte olan ekonomiler için karşılaştırmalı bir analiz yapılmıştır. Bulgular, genişletici para politikasının gelişmekte olan ülkelerde çevresel bozulmayı anlamlı şekilde artırırken, gelişmiş ekonomilerde anlamlı bir ilişki gözlemlenmediğini ortaya koymaktadır. Bu durum, para politikası çerçevelerine sürdürülebilirliğin entegre edilmesi gerektiğini vurgulamaktadır. Merkez bankalarının, faaliyetlerinin çevresel etkilerini değerlendirmesi, yeşil yatırımları önceliklendirmesi ve yeşil finansal araçları teşvik etmesi uzun vadeli sürdürülebilir büyüme için hayati önem taşımaktadır.

Anahtar Sözcükler : Çevresel Bozulma, Para Politikası, Gelişmekte Olan Ekonomiler, Gelişmiş Ekonomiler, İki Aşamalı Sistem GMM.

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[2] *Bu makale, birinci yazarın ikinci yazarın danışmanlığında yürütülen “Yeşil Para Politikası Üzerine Üç Makale” başlıklı doktora tezinden üretilmiştir.*

1. Introduction

Today, global warming and climate change are among the most pressing challenges the world faces, with their effects becoming increasingly severe. In response to these challenges, governments worldwide have implemented various policies and taken significant measures. Since the adoption of the Paris Agreement on climate change and the UN 2030 Agenda for Sustainable Development in 2015, countries have been working toward transitioning to low-carbon economies. The European Green Deal aims to make Europe the first continent to achieve climate neutrality by 2050 (The European Central Bank [ECB], 2020).

Climate change impacts economic outcomes, including output, productivity, and investment, and poses challenges for monetary policy. Inflationary pressures may arise from a reduction in the supply of goods or productivity shocks caused by climate-related events (Batten, 2018). Furthermore, climate change risks can make it challenging for central banks to distinguish between climate-related shocks and temporary economic fluctuations, thereby affecting the effectiveness of policy tools. The unpredictability of climate-related shocks also presents challenges for communication, credibility, and integrating climate risks into macroeconomic models and forecasts (Network for Greening the Financial System [NGFS], 2020).

Given the impact of climate change on inflation and the financial system, it is clear that central banks, which are primarily responsible for ensuring price and financial stability, need to take more proactive measures. Recently, some central banks have recognised the urgency of the issue, begun focusing on the challenges posed by climate change and started implementing policies addressing it. The Bank of England (BOE) was the first to draw attention to the risks that climate change may pose to financial stability. Mark Carney, the governor, addressed these risks in his 2015 speech at Lloyd's of London. Additionally, the BOE has set a target to achieve net-zero greenhouse gas (GHG) emissions by 2040 and issued guidelines on managing climate risks across its operations. At the Paris ‘One Planet Summit’ in 2017, eight central banks and supervisors established the NGFS. As of May 2024, NGFS comprises 141 members and 21 observes (NGFS, 2024). The ECB is implementing capital requirements for climate-related financial risks and has identified key areas such as the transition to a green economy and assessing climate impacts (ECB, 2020). Additionally, the Bank of Japan is promoting sustainability through its operations and offering zero-interest loans for low-carbon transitions (Shirai, 2023). The Federal Reserve has also increased its focus on climate risk, established specialised committees, and encouraged renewable energy investments (Green Central Banking, 2024).

The fact that environmental pollution poses challenges for monetary policy raises the question of whether monetary policy influences environmental degradation. It is well established that central banks' policies affect economic activity, which in turn affects environmental pollution levels. Understanding how monetary policy affects the environment is crucial for integrating environmental considerations into monetary policy and supporting greener economic growth and sustainability. Addressing environmental pollution through monetary policy not only helps achieve climate goals but also enhances overall economic resilience against environmental shocks.

Despite growing attention to the relationship between monetary policy and environmental degradation, a notable gap remains in the literature regarding the impact of monetary policy on environmental degradation. While much of the existing research focuses on the environmental effects of economic activities, the environmental implications of monetary policy have only recently begun to be examined. Most of these studies suggest that expansionary monetary policies tend to accelerate environmental degradation (Qingquan et al., 2020; Chishti et al.,2021; Nguyen et al., 2022). However, since the topic is relatively new in the literature, available research remains limited, making definitive conclusions challenging. Given the importance of the issue, this study aims to contribute to filling the existing literature gap by investigating the impact of monetary policy on environmental degradation. We will conduct a panel data analysis for 58 countries spanning the period from 1995 to 2021, based on available data.

Additionally, the Environmental Kuznets Curve (EKC) hypothesis suggests that there is an inverted-U relationship between economic growth and environmental quality, where environmental degradation initially increases but eventually declines after reaching a certain income level (Grossman & Krueger, 1991; Panayotou, 1993). Considering the EKC hypothesis, the effects of monetary policy on environmental degradation may also vary between advanced and emerging economies. Therefore, this study will conduct a comparative analysis to examine how monetary policy affects environmental degradation in both advanced and emerging economies, aiming to provide a significant contribution to the literature in this aspect.

We will employ the two-step system generalised method of moments (GMM) methodology for dynamic panel data analysis, which offers significant advantages and is a powerful tool for panel data analysis. Firstly, in the context of our research question, when examining the impact of monetary policy on the environment, the likelihood of encountering endogeneity is high, primarily due to potential simultaneity between economic activity and environmental outcomes. Moreover, the challenge of identifying the most appropriate monetary policy tools to represent monetary policy, as well as the potential for measurement errors in environmental degradation, may also lead to endogeneity. GMM effectively addresses the endogeneity problem by utilising appropriate instruments and moment conditions (Arellano & Bover, 1995). Furthermore, the two-step system GMM estimation procedure provides robust standard errors that account for heteroskedasticity and autocorrelation, both of which are common in panel data settings (Arellano & Bover, 1995).

In the following sections, we will first present the theoretical background of the study, followed by a review of the relevant literature. We will then explain the data and present the empirical analysis. Finally, we will conclude with the results and policy recommendations.

2. Theoretical Background

To understand the relationship between monetary policy and the environment, we start with the Cobb-Douglas production function:

$$Y_t = AL_t^{\alpha} K_t^{\beta} \tag{1}$$

where Y represents production, A denotes technology, L stands for labour, and K is capital. Johnson (1969) and Fischer (1974) integrated money supply into the production function. Johnson (1969) examined the impact of the money supply on production costs, arguing that firms are compelled to hold money to manage liquidity needs and cover input costs. Fischer (1974) further developed this concept by incorporating money supply into economic models, showing that monetary policy affects both production and economic growth through its impact on firm behaviour. More recently, Prescott and Wessel (2018) have integrated the money supply into the production function through a theoretical framework and model analysis. Therefore, this study follows this approach and uses the production function as shown in the following equation:

$$Y_t = AL_t^{\alpha} K_t^{\beta} M_t^{\theta} \tag{2}$$

where M represents money supply.

Furthermore, the literature focusing on environmental degradation and economic activities suggests a significant relationship between the two. Thus, environmental indicators can be modelled as a function of production.

$$E_t = f(Y_t) \tag{3}$$

where E represents an indicator of environmental degradation. We assume that the money supply is independent of the fundamental aspects of the economy, such as A, L, and K, in the short run. In addition, several other factors also affect environmental indicators, so we rewrite Model 3 as in the following equation (4).

$$E_t = \varphi(f(Y_t), M_t, z_t) \tag{4}$$

In our analysis, the vector z consists of trade openness, the share of renewable energy consumption in total energy, energy consumption per capita, and financial development. According to the relevant literature, while a positive relationship is expected between money supply, economic activities, trade openness, energy consumption, and environmental degradation, it is anticipated that renewable energy consumption and financial development negatively affects environmental degradation (Qingquan et al., 2020; Chishti et al., 2021; Nguyen et al., 2022; Gulistan et. al., 2020; Uddin, 2021; Ling et al., 2020; Tachie et al., 2020; Majeed & Luni, 2019; Magazzino et al., 2022; Tamazian et al., 2009; Khan et. al., 2021).

3. Literature

A growing number of studies have examined the impact of monetary policy on environmental pollution. While most of these studies use panel data methodology to reveal this relationship, very few focus on a single country with time series data.

Qingquan et al. (2020) estimated the impact of monetary policies on CO_2 emissions along with control variables, including income, remittances, urbanisation, fossil fuels, and human capital. He studied selected Asian economies from 1990 to 2014. Pedroni and Kao cointegration tests, a fully modified panel, and panel dynamic least squares techniques were employed in the empirical analyses. The results demonstrated that a long-term cointegration exists between monetary policies, human capital, urbanisation, fossil-fuel consumption, remittances, and CO_2 emissions in Asian economies. The findings also revealed that expansionary monetary policies contribute to CO_2 emissions, while contractionary monetary policies decrease CO_2 emissions in the long term. Additionally, the results suggested that while human capital mitigates CO_2 emissions, fossil-fuel consumption, remittances, and income increase CO_2 emissions in the long term.

Chishti et al. (2021) investigated the relationship between macroeconomic policies, including both fiscal and monetary policies, and CO_2 emissions in Brazil, Russia, India, China, and South Africa (BRICS) for the period 1985-2014. They also explored the impacts of aggregate domestic consumer spending per capita, fossil fuel consumption, and renewable energy consumption on CO_2 emissions. The Kao and Westerlund cointegration tests, panel ordinary least squares (OLS), dynamic OLS, fully-modified OLS, and pooled mean group panel Autoregressive Distributed Lag (ARDL) methods were conducted. The sample of the study comprises the following variables: CO_2 emissions, real interest rates, tax revenue as a percentage of GDP, fossil fuel energy consumption, renewable energy consumption, aggregate domestic consumption spending per capita, and exports minus imports, all divided by the total population. The results revealed that expansionary fiscal and monetary policy increases CO_2 emissions. Additionally, while aggregate domestic consumer spending and the use of fossil fuels increase CO_2 emissions, renewable energy consumption helps reduce CO_2 emissions.

Mughal et al. (2021) examined the impact of monetary and fiscal policies on the environment in the Association of Southeast Asian Nations countries. They analysed data from a panel for the period 1990-2019. To reveal the relationship, they employed a nonlinear panel ARDL approach. While CO_2 emissions are used as an environmental indicator, the central bank policy rate serves as a proxy for monetary policy, and government expenditure as a percentage of GDP is used as a proxy for fiscal policy. The findings suggest that expansionary monetary and fiscal policies lead to increased CO_2 emissions, whereas contractionary monetary and fiscal policies result in reduced CO_2 emissions in the long run. Additionally, expansionary monetary and fiscal policies increase CO_2 emissions, while contractionary monetary and fiscal policies have an insignificant impact on emissions in the short run.

Nguyen et al. (2022) analysed the impact of monetary policy on CO_2 emissions in 14 selected emerging countries that have undergone rapid economic and financial growth. They examined the period from 1998 to 2018 using panel data. The authors employed OLS, Dynamic OLS, Fully Modified OLS, Panel Quantile Regression, and a two-step system GMM. In the model, CO_2 emissions per capita were used as the dependent variable, serving as a proxy for climate change mitigation efforts. The real interest rate, as an indicator of monetary policy, domestic credit to the private sector by banks, trade as a percentage of GDP, GDP per capita, and aggregate domestic consumption spending per capita were included in the model as independent variables. The results showed that contractionary and expansionary monetary policies both eliminate and exacerbate environmental degradation, respectively. Moreover, the ecological effects of monetary policy are most pronounced in the middle to large quantiles of CO_2.

Attilio et al. (2023) explored the impact of monetary policy on CO_2 emissions, presenting a stylised dynamic Aggregate Demand-Aggregate Supply model with Global Value Chains and carbon emissions. To uncover the relationship between monetary policy and CO_2 emissions, the Global Vector Auto Regressive (GVAR) method was applied. The authors focused on four regions: the U.S., the U.K., Japan, and the Eurozone and used eight other countries to identify the international economy. The sample covered the period from January 1990 to December 2018. In the study, CO_2 emissions were used as the dependent variable, while the short-term interest rate, long-term interest rate, stock market value, price level, and gross capital formation were used as independent variables. The findings showed that contractionary monetary policy is linked to a reduction in domestic emissions in both the short and long term. On the other hand, this effect does not spread to other economies.

Wu et al. (2024) examined the impact of monetary policy on carbon emissions in OECD countries. They used panel data covering the period from 2000 to 2019 and employed the Panel Smooth Transition Regression method. Carbon emissions were modelled as the dependent variable, and the country’s money supply (M2) was the independent variable. Additionally, GDP per capita, total factor productivity and labour population were used as other control variables. To model the non-linear effects of M2 on carbon emissions, the human capital index and share of manufacturing as a percentage of GDP were employed as the transition variables. The results indicated a nonlinear and positive relationship between M2 and carbon emissions. Furthermore, the impact of money supply on carbon emissions is weaker for countries with a higher human development index or a moderate share of manufacturing as a percentage of GDP.

Lau et al. (2024) evaluated the effectiveness of fiscal and monetary policies in enhancing environmental quality in BRICS countries from 1990 to 2018. They employed Pooled Mean Group-Autoregressive Distributed Lag (PMG-ARDL) estimations, Panel Fully Modified Ordinary Least Squares (FMOLS), and the Driscoll-Kraay estimation method. In the models, while CO_2 emissions were used as the dependent variable, government expenditures, money supply, population size, GDP per capita, and alternative energy consumption were used as independent variables. The findings demonstrated that, contrary to the majority in the literature, government spending and money supply have a negative impact on carbon dioxide emissions, thus benefiting the natural environment.

Bildirici et al. (2023) examined the effects of fiscal and monetary policy, energy consumption, and economic growth on CO_2 emissions in Türkiye for the period 1978-2021. They employed the nonlinear bootstrapping NBARDL and nonlinear NBVARDL for nonlinear causality testing. In the study, environmental pollution was proxied by CO_2 emissions. Government expenditures were used as an indicator of fiscal policy, and the average policy interest rate was included in the analysis as an indicator of monetary policy. The test results related to the impact of monetary policy indicated that a positive monetary policy shock could potentially reduce CO_2 emissions, while a negative shock led to an increase in CO_2 emissions.

Duc Tran et al. (2023) searched the impact of monetary policy on environmental pollution, focusing on Vietnam from 1992 to 2000. The authors generated an ARDL model by using CO_2 emissions per capita as the dependent variable, GDP per capita, total import and export to GDP ratio, electricity consumption per capita, real interest rate, exchange rate, money supply to GDP ratio and credit of the banking system to GDP ratio as the independent variables. The results of ARDL analyses demonstrated that monetary policy does not have a statistically significant impact on environmental pollution in either the short term or the long term. On the other hand, Granger causality analyses for causal relationships among the variables in the model revealed that there is a one-way causal effect of money supply expansion on increasing electricity consumption per capita, as well as a causal effect of electricity consumption per capita on environmental pollution.

The literature on the impact of monetary policy on environmental pollution reveals a complex relationship with varying results depending on the geographical and methodological contexts. Studies generally indicate that expansionary monetary policies tend to increase CO_2 emissions, while contractionary policies have a mitigating effect, as highlighted by Qingquan et al. (2020), Chishti et al. (2021), and Nguyen et al. (2022). Additionally, Attilio et al. (2023) and Wu et al. (2024) further elaborate on the nonlinear dynamics of monetary policy effects, suggesting that the impact is moderated by factors such as human development and economic structure. Reverse findings are also provided, as Lau et al. (2024) indicate that money supply may have a beneficial effect on CO_2 emissions. Moreover, although most studies in the literature employ panel data, a few focus on individual countries using time-series data. For instance, Duc Tran et al. (2023) and Bildirici et al. (2023) provide localised impacts and causal relationships, showing that monetary policy influences environmental pollution.

Overall, there is no consensus in the literature on the impact of monetary policy on environmental outcomes. Furthermore, while studies typically focus on either a group of countries or a single country, comparative analyses are lacking. Additionally, most of the studies use CO_2 emissions as the sole indicator of environmental degradation. This study aims to contribute to the literature by using an updated periods and two types of environmental indicators -CO_2 emissions and GHG emissions- providing a comparative analysis of advanced and emerging economies, and employing an efficient panel data estimation methodology, specifically the two-step system GMM, to examine the impact of monetary policy on environmental degradation.

4. Data, Empirical Model and Findings

4.1. Data

To investigate the impact of monetary policy on environmental degradation, this study utilises panel data from 1995 to 2021 for 58 countries, selected based on data availability. Additionally, a comparative analysis is conducted between advanced and emerging economies. Countries are categorised as advanced and emerging economies, based on International Monetary Fund (IMF) classifications.

Environmental degradation, the dependent variable in the model (equation 4), is represented by CO_2 emissions per capita (in tonnes) and GHG emissions per capita (in tonnes of CO_2 equivalents). These variables are sourced from Our World Data. The broad money to GDP ratio is selected as a monetary policy indicator based on existing literature and is obtained from World Bank Development Indicators (WDI). Additionally, GDP per capita, trade openness (defined as the sum of exports and imports as a percentage of GDP), and the share of renewable energy consumption in total are also used as independent variables, sourced from the WDI. Lastly, primary energy consumption per capita (in kWh) and the Financial Development Index are included as independent variables, sourced from Our World Data and the IMF, respectively. Table 1 provides a summary of the variables used in this study and their corresponding data sources.

Table: 1
Variables and Description

Variable	Description	Unit	Source
CO_2	CO_2 emissions per capita	Tonnes	Our World Data
GHG	GHG emissions per capita	Tonnes of CO_2 equivalents	Our World Data
Broad Money	Broad Money/GDP	%	WDI
GDP	GDP per capita	Constant 2015 prices	WDI
Trade Openness	Sum of exports and imports/GDP	%	WDI
Renewable Energy Consumption	Share of renewable energy consumption in total	%	WDI
Energy Consumption	Primary energy consumption per capita	kWh	Our World Data
Financial Development	Financial Development Index		IMF

4.2. Empirical Model

We employ the two-step system GMM for dynamic panel data analysis to investigate the impact of monetary policy on the environment. The general form of the model estimated in this study is as follows:

$$E_{it} = f(BRMONEY_{it}, GDP_{it}, OPN_{it}, RENENG_{it}, ENG_{it}, FD_{it}) \quad (5)$$

where E is environmental degradation indicators, BRMONEY indicates the broad money to GDP ratio, GDP denotes GDP per capita, OPN represents trade openness, RENENG refers to the share of renewable energy consumption in total energy, ENG stands for energy consumption per capita and FD is for financial development. Here, i indexes countries and t represents time. We use the logarithmic forms of the series in all subsequent analysis; therefore, we model environmental degradation as Equation (6):

$$ln(E_{it}) = \alpha_0 + \alpha_1 ln(BRMONEY_{it}) + \alpha_2 ln(GDP_{it}) + \alpha_3 ln(OPN_{it}) + \alpha_4 ln(RENENG_{it}) + \alpha_5 ln(ENG_{it}) + \alpha_6 ln(FD_{it}) + \varepsilon_{it} \quad (6)$$

In the literature, most studies on the relationship between monetary policy and environmental degradation focus on CO_2 emissions. On the other hand, GHG emissions are also significant sources of environmental degradation and global warming (Intergovernmental Panel on Climate Change, 2023). Therefore, to extend the existing literature and ensure robust results, we employ two different specifications of the model, using two distinct indicators of environmental degradation: CO_2 emissions per capita and GHG emissions per capita.

Model 1

$$ln(CO2_{it}) = \alpha_0 + \alpha_1 ln(BRMONEY_{it}) + \alpha_2 ln(GDP_{it}) + \alpha_3 ln(OPN_{it}) + \alpha_4 ln(RENENG_{it}) + \alpha_5 ln(ENG_{it}) + \alpha_6 ln(FD_{it}) + \varepsilon_{it} \quad (7)$$

Model 2

$$ln(GHG_{it}) = \alpha_0 + \alpha_1 ln(BRMONEY_{it}) + \alpha_2 ln(GDP_{it}) + \alpha_3 ln(OPN_{it}) + \alpha_4 ln(RENENG_{it}) + \alpha_5 ln(ENG_{it}) + \alpha_6 ln(FD_{it}) + \varepsilon_{it} \quad (8)$$

where CO_2 represents CO_2 emissions per capita and GHG is greenhouse gas emissions per capita.

Consequently, the dynamic panel models can be expressed in the following specific forms.

Model 1

$$ln(CO2_{it}) = \beta_0 + \beta_1 ln\,(C02_{it-1}) + \beta_2 ln(BRMONEY_{it}) + \beta_3 ln(GDP_{it}) + \beta_4 ln(OPN_{it}) + \beta_5 ln(RENENG_{it}) + \beta_6 ln(ENG_{it}) + \beta_7 ln(FD_{it}) + \eta_i + v_{it} \quad (9)$$

Model 2

$$ln(GHG_{it}) = \beta_0 + \beta_1 ln\,(GHG_{it-1}) + \beta_2 ln(BRMONEY_{it}) + \beta_3 ln(GDP_{it}) + \beta_4 ln(OPN_{it}) + \beta_5 ln(RENENG_{it}) + \beta_6 ln(ENG_{it}) + \beta_7 ln(FD_{it}) + \eta_i + v_{it} \quad (10)$$

The error term $\eta_i + v_{it}$ captures the decomposition of error components.

Table 2 provides the descriptive statistics of the variables. The dataset comprises 1,566 observations.

Table: 2
Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
CO_2	1566	1.242	0.939	-1.543	4.339
GHG	1566	1.878	0.809	-0.511	4.855
BRMONEY	1566	4.026	0.619	1.92	6.12
GDP	1566	8.962	1.126	6.427	11.5
OPN	1566	4.259	0.524	2.75	6.093
RENENG	1566	2.135	2.968	-23.026	4.418
ENG	1566	9.676	2.09	-23.026	12.622
FD	1566	-1.15	0.625	-3.603	-0.026

4.3. Empirical Findings

This study investigates the impact of monetary policy on environmental degradation. To examine the relationship between monetary policy and environmental degradation, two models (Model 1 and Model 2) are estimated using different environmental indicators. Both models are estimated for all economies, and then separately for advanced and emerging economies, to facilitate a comparative analysis. Before the model estimations, panel data analysis tests such as cross-sectional dependency, homogeneity, and stationarity are conducted.

Table 3 presents the results of the cross-sectional dependency test and slope homogeneity test for Models 1 and 2. The first three lines of the table present cross-sectional dependency tests, including the Breusch and Pagan (1980) LM test, the Pesaran et al. (2008) bias-adjusted LM test, and the Pesaran (2004) CD test, respectively. Following a cross-sectional dependency test, the results of two alternative slope homogeneity tests, such as the Delta test and the Adj. Delta test, both of which were developed by Pesaran and Yamagata (2008), are presented in Table 3.

Table: 3
Cross-Sectional Dependence & Slope Homogeneity Tests

	Model 1		Model 2	
Test	Statistic	p-value	Statistic	p-value
LM	2148	0.000	2186	0.000
LM adj	10.02	0.000	11.6	0.000
LM CD	5.639	0.000	5.385	0.000
Delta	34.223	0.000	31.156	0.000
Adj.Delta	40.797	0.000	37.140	0.000

According to the test results, cross-sectional dependency and slope heterogeneity are present in both models.

Since there is a cross-sectional dependency, we employ second-generation unit root tests proposed by Pesaran (2003). Test results are demonstrated in Table 4.

Table 4
Unit Root Tests

	Intercept Model		Intercept and Trend Model	
Variable	t-value	p-value	t-value	p-value
CO_2	-2.188	0.000	-2.188	0.841
GHG	-1.732	0.558	-2.452	0.122
BRMONEY	-2.064	0.007	-2.512	0.049
GDP	-2.140	0.001	-2.302	0.526
OPN	-1.995	0.027	-2.591	0.011
RENENG	-1.418	0.995	-1.987	0.996
ENG	-1.756	0.481	-2.306	0.513
FD	-2.647	0.000	-2.797	0.000

Unit root tests reveal that the series of CO2, GHG, BRMONEY, GDP, RENENG and ENG have unit roots and are nonstationary. To conduct the models with stationary series and obtain robust results, we take the first difference of these series and employ unit root tests. The results are shown in Table 5. D denotes the first differences of the series.

Table: 5
Unit Root Tests for the First Difference of the Nonstationary Series

	Intercept Model		Intercept and Trend Model	
Variable	t-value	p-value	t-value	p-value
DCO_2	-3.599	0.000	-3.783	0.000
DGHG	-3.604	0.000	-3.724	0.000
DBRMONEY	-3.250	0.000	-3.408	0.000
DGDP	-2.657	0.000	-2.815	0.000
DRENENG	-3.258	0.000	-3.508	0.000
DENG	-3.446	0.000	-3.541	0.000

According to unit root test results, taking first differences makes nonstationary series stationary. Therefore, we use the first difference of these series in the model estimations.

To examine the relationship between monetary policy and environmental degradation, we conduct dynamic panel estimations using the two-step system GMM methodology. The two-step system GMM approach effectively addresses endogeneity by using appropriate instrumental variables, exploiting a comprehensive set of moment conditions, and providing consistent estimates, making it a powerful tool for analysing dynamic panel data models (Blundell & Bond, 1998).

Arellano and Bond (1991) suggest using lagged values of the explanatory variables as instruments to avoid potential endogeneity issues in the two-step system GMM estimation process. Therefore, we select lagged values of the explanatory variables as instruments and conduct several diagnostic tests to validate them.

Firstly, the Hansen J-test (1982) is used to assess the validity of the instruments. According to the results of the Hansen J-tests for both model specifications across all groups of countries presented in Tables 6 and 7, the null hypothesis that all overidentifying restrictions are valid cannot be rejected. Thus, we confirm the validity of the instruments.

Additionally, Arellano and Bond's (1991) serial correlation tests are conducted. Both first-order (AR(1)) and second-order (AR(2)) autocorrelation tests are employed to ensure that sufficient lags have been included to address autocorrelation. The test results indicate that, while the null hypothesis of no first-order serial correlation in the first-differenced residuals is rejected, the null hypothesis of no second-order serial correlation in the first-differenced residuals is not rejected for all model specifications. Therefore, one lag of the dependent variable is included as an independent variable in the models (Table 6 and Table 7).

Table 6 presents the coefficients of the system GMM estimations, along with the results of the serial correlation test and Hansen J-tests statistics for Model 1. The comparative results are also presented in tables for all economies, as well as for advanced and emerging economies.

Table: 6
The Two-Step System GMM Estimation Results of Model 1

Variable	All Economies	Advanced Economies	Emerging Economies
Lag.DCO$_2$	-0.111 (0.024)***	-0.231 (0.083)**	-0.104 (0.011)***
DBRMONEY	0.014 (0.007)**	0.008 (0.051)	0.013 (0.005)**
DGDP	0.589 (0.033)***	-0.428 (0.133)***	0.816 (0.021)***
OPN	0.025 (0.011)**	-0.048 (0.066)	0.016 (0.006)**
DRENENG	-0.002 (0)***	-.028 (0.014)*	-0.002 (0)***
DENG	0.002 (.001)***	2.028 (0.813)**	0.001 (0)***
FD	-0.012 (.008)	0.032 (0.117)	0.018 (0.004)***
Constant	-0.125(0.052)**	0.208 (0.265)	-0.053 (0.027)*
N	1450	300	1150
AR (1)	-3.38***	-1.97**	-3.18***
AR (2)	0	-0.35	0.28
Hansen J stat	0.139	1.70	42.90

*Note: The standard errors are in the parentheses. *** p<0.01, ** p<0.05, * p<0.1.*

According to the estimation results of Model 1, expansionary monetary policy increases CO_2 emissions. On the other hand, when we break down the analysis by countries' development level, the results differ. For emerging economies, the positive relationship between monetary policy and CO_2 emissions per capita is still statistically significant. In contrast, no statistically significant relationship is observed for advanced economies.

The impacts of other dependent variables on CO_2 emissions also vary across country groups. There is a statistically significant negative relationship between GDP and CO_2 emissions in advanced economies; however, this relationship is positive for emerging economies. This finding aligns with the EKC literature, which suggests that environmental degradation initially increases with GDP per capita at low levels of national income and then decreases at high levels of income (Grossman & Krueger, 1991).

Furthermore, while an increase in trade openness raises CO_2 emissions in emerging economies, no statistically significant relationship is found in advanced economies. A similar pattern is observed regarding the impact of financial development on CO_2 emissions. Lastly, while increasing renewable energy usage reduces CO_2 emissions, an increase in primary energy consumption raises CO_2 emissions in both advanced and emerging economies.

To obtain robust results regarding the relationship between monetary policy and environmental degradation, we use GHG emissions per capita as the environmental indicator in Model 2. The estimation results of Model 2 are given in Table 7. Similar to Model 1, the results indicate a statistically significant positive relationship between monetary policy and GHG emissions for emerging economies. However, no statistically significant relationship is found for advanced economies. The estimation results for all other variables exhibit the same pattern as observed in Model 1. Therefore, it confirms the robustness of the estimation results.

Table: 7
The Two-Step System GMM Estimation Results of Model 2

Variable	All Economies	Advanced Economies	Emerging Economies
L.DGHG	-0.127 (0.008)***	-0.176 (0.46)***	-0.158 (0.005)***
DBRMONEY	0.017 (0.006)***	0.123 (-0.20)	0.012 (0.005)**
DGDP	0.478 (0.033)***	-0.24 (0.096)**	0.641 (0.031)***
OPN	0.033 (0.011)***	-0.008 (0.023)	0.017 (0.009)*
DRENENG	-0.002 (0)***	-0.011 (0.003)***	-0.002 (0)***
DENG	0.003 (0)***	0.373 (3.53)***	0.0003 (0)***
FD	-0.006 (.007)	-0.037 (0.118)	0.015 (0.004)***
Constant	-0.165 (0.052)***	0.051 (0.23)	-0.074 (0.038)*
N	1450	300	1150
AR (1)	-2.92***	-2.03**	-2.71***
AR (2)	-1.04	-0.93	-1.15
Hansen J stat	48.71	3.13	42.97

*Note: The standard errors are in the parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.*

5. Conclusion

This study aims to investigate the impact of monetary policy on environmental degradation. We employ dynamic panel data analysis for 58 countries spanning the period from 1995 to 2021. Additionally, the study examines the effects of GDP per capita, trade openness, renewable energy consumption, primary energy consumption per capita, and financial development on environmental degradation. A comparative analysis is also conducted to determine whether monetary policy affects environmental degradation differently in advanced and emerging economies.

We apply the two-step system GMM methodology to two different model specifications, utilising two distinct indicators of environmental degradation, such as CO_2 emissions per capita and GHG emissions per capita. The two-step system GMM methodology addresses possible endogeneity issues in the models.

The findings suggest that expansionary monetary policy increases CO_2 emissions. The comparative analysis reveals that, while the positive relationship between monetary policy and CO_2 emissions per capita remains statistically significant for emerging economies, no statistically significant relationship is observed for advanced economies. Additionally, a statistically significant negative relationship exists between GDP and CO_2

emissions per capita in advanced economies, whereas the relationship is positive for emerging economies. These differences between advanced and emerging economies may stem from several reasons. First, the industrial structure might differ between the two groups. Emerging economies typically rely more on energy-intensive sectors, such as manufacturing and the mining industry, whereas in advanced economies, a larger share of GDP is generated by less energy-intensive sectors, including services and technology. Consequently, when economic activity in emerging countries is boosted by expansionary monetary policy, it may lead to higher energy consumption, which is more likely to result in greater CO_2 emissions. Second, the energy mix in these two groups of countries also contributes to the different outcomes. Emerging countries may rely more heavily on fossil fuels, whereas advanced countries are more likely to have transitioned toward clean energy sources, such as renewables and more efficient energy systems. Any increase in production driven by monetary expansion might result in greater CO_2 emissions in emerging countries, while economic growth in advanced countries can be decoupled from environmental degradation. EKC provides further insight into this disparity. According to the EKC framework, emerging economies may be in the upward phase of EKC, where economic growth leads to higher emissions. In contrast, advanced economies, having passed the peak of the EKC, may now experience decoupling of economic growth from environmental degradation. Third, the regulatory framework might diverge between the emerging and advanced economies. Advanced economies may be implementing more stringent environmental policies than emerging economies. These policies might mitigate the adverse effects of expansionary monetary policy on environmental degradation. All factors, such as a favourable industrial structure, a cleaner energy mix, and a stricter regulatory framework, may explain why there is no statistically significant relationship between monetary policy and emissions in advanced economies, unlike in emerging economies.

The impacts of other dependent variables on CO_2 emissions per capita also vary across country groups. While an increase in trade openness raises CO_2 emissions per capita in emerging economies, no statistically significant relationship is found in advanced economies. Similar to the findings of Grossman and Krueger (1995), this result implies that trade and economic growth tend to increase pollution. This finding is also consistent with the Pollution Haven Hypothesis (PHH) (Copeland & Taylor, 1994; Frankel & Rose, 2005). According to the PHH, developing countries become "pollution havens" for advanced countries through increased openness to international markets. This occurs because developing countries are likely to have comparatively weaker environmental regulations. As a result, industries that face stringent environmental standards in advanced countries may relocate to developing countries, where they can operate under more lenient rules. This leads to higher emissions in the host countries. Although the PPH offers a plausible explanation for the observed relationship between trade openness and environmental degradation in both emerging and advanced countries, it remains a controversial topic in the literature, as some studies have found either conflicting or inconclusive evidence regarding the hypothesis (Antweiler et al., 2001; Cole, 2004).

A similar pattern emerges when examining the impact of financial development on CO_2 emissions per capita. The literature suggests a connection between financial development and economic growth (Araç & Kutalmış-Özcan, 2014). For instance, the Supply Leading Hypothesis (SLH), initially proposed by Schumpeter (1911) and later popularised by Patrick (1966), suggests that financial institutions, such as banks, play a crucial role in promoting economic development by facilitating technological innovations. This aligns with endogenous growth models, which argue that financial development fosters economic growth by promoting technological progress (Greenwood & Jovanovic, 1990; Greenwood & Smith, 1997). Patrick (1966) further posits that SLH is valid for the earlier stages of a country’s development, where the financial system actively drives economic growth. Considering this, it is reasonable to infer that financial development might accompany industrial expansion, especially in emerging countries. This expansion increases energy demand and contributes to CO_2 emissions, particularly in emerging countries that rely heavily on energy-intensive sectors. In contrast, in advanced economies, where financial resources are more likely to support cleaner technologies and sustainable investments, the adverse effect of financial development on emissions might be offset.

Finally, an increase in renewable energy use leads to a reduction in CO_2 emissions per capita, while a rise in primary energy consumption results in higher CO_2 emissions in both advanced and emerging economies, which aligns with several studies in the literature (Majeed & Luni, 2019; Magazzino et al., 2022; Gulistan et. al., 2020; Uddin, 2021).

Estimating the model specification, where GHG emissions per capita are used as an indicator of environmental degradation, yields similar results. The findings reveal a statistically significant positive correlation between monetary policy and GHG emissions in emerging economies. However, no statistically significant relationship is observed for advanced economies. The estimation results for all other variables show the same pattern, confirming the robustness of the findings.

The findings of this study highlight a significant concern: expansionary monetary policy can have the unintended consequence of increasing environmental pollution, particularly in emerging economies. This underscores the necessity for a more integrated approach to economic and environmental governance. To mitigate these adverse environmental effects, it is essential to incorporate sustainability criteria into monetary policy frameworks. It would be beneficial for central banks to assess the environmental impacts of their activities, revise their strategies in terms of climate change, conduct scenario analyses of climate change risks, and perform climate-related stress tests. Furthermore, central banks can explore ways to prioritise green investments, such as by creating green-targeted lending facilities that provide low-cost loans to financial institutions for financing green projects and promoting green financial instruments like green bonds. Additionally, central banks can integrate sustainability criteria into their asset purchase programs. By adopting such measures, central banks can help mitigate the negative environmental consequences of expansionary monetary policy and contribute to sustainable growth.

In recent years, many central banks in various countries have implemented macro-prudential policies to mitigate systemic risks associated with climate change and environmental degradation. For instance, the ECB has begun to conduct climate stress tests on banks to assess the resilience of the financial sector under various climate scenarios. China's central bank has adopted green lending requirements, encouraging banks to prioritise loans to environmentally friendly projects. Furthermore, the Swiss National Bank has started to consider climate-related risks in its asset management, including investments in green bonds as part of its foreign exchange reserves. Such measures steer banks' lending preferences in favour of green projects. With an increased money supply, these policies enable more environmentally sustainable projects, which leads to a reallocation of credit from carbon-intensive to low-carbon sectors. The study has several limitations that should be acknowledged. First, the analysis is constrained by the limited period and number of countries, both of which are a result of data availability. Additionally, only the money supply is used as an indicator of monetary policy in the empirical analysis, again due to data limitations. We can suggest that future studies could explore the relationship between monetary policy and environmental degradation using different monetary policy tools to provide a more comprehensive understanding.

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