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Çukurova Üniversitesi Sosyal Bilimler Enstitüsü Dergisi
Yıl: 2026 Sayfa: 1-10
https://dergipark.org.tr/tr/pub/cusosbil

DOI: 10.35379/cusosbil.1639189

Geliş Received: **13.02.2025**
Kabul Accepted **05.11.2025**

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Keywords:
Business cycle,
Greenhouse gas emissions,
Markov-switching autoregressive,
Asymmetry

Anahtar Kelimeler:
İş döngüsü,
Sera gazı emisyonları,
Markov-switching otoregresif,
Asimetri

ABSTRACT

This study aims to reveal the responses of carbon emissions to economic business cycles in the Turkish economy by using the Markov-Switching Autoregressive (MSAR) model.. It is frequently emphasized in the literature that carbon emissions exhibit a nonlinear relationship with economic growth and respond asymmetrically to periods of expansion and contraction. In this context, the study analyzes the cyclical components of annual total and per capita carbon emissions and gross domestic product (GDP) for the period 1970-2023. The findings show that carbon emissions increase during periods of economic expansion but do not decrease at the same rate during recessions. The results reveal that the response of emissions to business cycles is asymmetric and that emission growth is positive but less than one during expansion periods. On the other hand, the sensitivity of emissions is negative during economic recession periods and emissions show a more limited decrease compared to the contraction in GDP. These results have important policy implications for Turkiye's transition to a low-carbon growth strategy. In particular, stricter regulations should be introduced during periods of economic growth and spesific reduction target should be maintained even during periods of economic recession.

ÖZ

Bu çalışma, karbon emisyonlarının ekonomik iş döngülerine verdiği tepkileri incelemek amacıyla Türkiye ekonomisi için Markov-Switching Otoregresif (MSAR) modelini kullanmaktadır. Karbon emisyonlarının ekonomik büyüme ile doğrusal olmayan bir ilişki sergilediği ve genişleme ile daralma dönemlerine asimetrik tepkiler verdiği literatürde sıkça vurgulanmaktadır. Bu bağlamda, çalışmada 1970-2023 dönemi yıllık toplam ve kişi başına düşen karbon emisyonları ile gayri safi yurtiçi hasılanın (GSYİH) döngüsel bileşenleri analiz edilmiştir. Elde edilen bulgular, karbon emisyonlarının ekonomik genişleme dönemlerinde arttığını ancak durgunluk dönemlerinde aynı hızda azalmadığını göstermektedir. Sonuçlar, emisyonların iş döngülerine yönelik tepkisinin asimetrik olduğunu ve genişleme dönemlerinde emisyon büyümesinin pozitif ancak 1'den küçük olduğunu ortaya koymaktadır. Buna karşılık, ekonomik durgunluk dönemlerinde emisyonların duyarlılığı negatif olup, emisyonlar GSYİH'deki daralmaya kıyasla daha sınırlı bir azalış göstermektedir. Bu sonuçlar, Türkiye'nin düşük karbonlu büyüme stratejisine geçişi açısından önemli politika çıkarımları taşımaktadır. Özellikle, ekonomik büyüme dönemlerinde daha sıkı düzenlemeler getirilmesi ve ekonomik durgunluk dönemlerinde de belirli bir azaltım hedefinin korunması gerekmektedir.

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Alıntılamak için/Cite as: Kaymaz V.. (2026). The Cyclical Dynamics Of Carbon Emissions: A Markov-Switching Approach For Turkiye, Çukurova Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, s. 1-10

INTRODUCTION

Global warming and extreme weather events caused by carbon emissions, ecosystem degradation, food sustainability damage, water resource depletion, and other negative impacts not only lead to environmental but also economic and social problems. In order to overcome these problems, countries are evaluating environmental policies that will not harm economic growth. The process of reducing carbon emissions and transitioning to a sustainable economy, on the other hand, harms producers and indirectly household economies due to investment costs and increasing unit costs. Therefore, monitoring the development of carbon emissions and analyzing their relationship with economic growth is becoming increasingly important.

Academic studies attempt to explain the relationship between carbon emissions and economic growth and environmental quality, to understand the economic effects of carbon-intensive industries moving to countries with lax environmental policies due to strict environmental policies, to analyze the effects of policies implemented to reduce emissions, and to determine the impacts of productivity shocks on both the economy and the environment. In recent years, the number of academic studies analyzing the effects of business cycles on carbon emissions has increased. Just as the impact of business cycles on carbon emissions varies according to regimes, sectoral carbon emissions may respond differently according to business cycles.

According to Climate Transparency (2020), Turkiye lags behind G20 countries in terms of per capita emissions; however, between 2012 and 2017, G20 countries' emissions decreased by 2.3%, while Turkiye's increased by 5.6%. According to the 2024 report, Turkiye's share in global greenhouse gas emissions is 1.1% and it ranks 13th in the world in terms of emissions. Turkiye has submitted a National Contribution Declaration aiming to reduce its total emissions by 21% by 2030. However, according to the analysis by Climate Action Tracker (2024), Turkiye's current efforts and policies are not in line with the Paris Agreement's target of limiting global temperature increase to 1.5°C by 2050. Although a carbon tax, emissions trading system, or emissions intensity policies have not yet been implemented in Turkiye to reduce emissions, preliminary preparations have been initiated for the transition to an emissions trading system. Turkiye's goal is to establish its own carbon trading system within a few years, tracking carbon emissions and making producers pay for their carbon emissions.

It is important to understand the relationship between emissions and business cycles in order to combat climate change, design policies to reduce carbon emissions, and predict the course of emissions (York, 2012). Most studies examining the responses of carbon emissions to business cycles analyze groups of countries or the United States; however, the responses of emissions and changes over the years differ depending on the characteristics of the countries. The unique situations of the countries such as population, income, production structure, natural resources, and technology can differentiate the effects of GDP changes on emissions. Therefore, the analysis of a single country is more accurate in terms of showing the relationship between emissions and business cycles and produces different results than other countries.

There are limited studies analyzing the relationship between business cycles and carbon emissions in Turkiye. The existing literature generally focuses on country groups or developed economies. However, it is expected that the response of emissions to growth in developing economies such as Turkiye will differ from other countries due to different macroeconomic dynamics. This study makes two important contributions to the existing literature by examining the responses of total and per capita carbon emissions to business cycles in Turkiye. First, it analyzes which one is more volatile by determining the cyclicality of carbon emissions and economic growth. Second, it analyzes the responses of carbon emissions to business cycles in expansion and recession periods using the Markov Switching Autoregressive Model (MSAR).

The following section summarizes and discusses the literature analyzing the effects of business cycles on emissions. Section 3 explains the data used in the analysis and the selected econometric method. Section 4 presents the MSAR findings, and Section 5 discusses the results and compares them with the literature. Section 6 concludes the study.

LITERATURE REVIEW

In the literature, many studies do not take business cycles into account in emission forecast modeling and assume that emissions change at the average growth rate in parallel with changes in GDP (Sheldon, 2017). However, in recent years, the effects of business cycles on carbon emissions have been examined in more detail.

Although there is an asymmetric relationship between economic growth and environmental pollution in the long term (Dinda, 2004), cyclical fluctuations can reduce or increase carbon emissions. For this reason, many researchers argue that environmental policies should be pro-cyclical (Heutel, 2012; Annicchiarico and Di Dio, 2015). However, since the duration, economic and sectoral effects of business cycles vary, the responses of carbon emissions also differ. For this reason, countries design their emission reduction policies by taking business cycles into account and may differ from each other in terms of policy tools.

Heutel (2012) shows in his calibrated DSGE model for the United States that emissions increase in periods of economic growth and decrease in periods of recession. In his study, he emphasizes that tax policies should be cyclical in order to reduce carbon emissions and that taxes should be increased during expansion periods. Doda (2014) examined the cyclicity and volatility of emissions and found that emission elasticity according to output varies among countries. According to the results of his study, which analyzed carbon emission and GDP data of 122 countries for the period 1950-2011, emissions are cyclical and this cyclicity is positively related to GDP per capita. In addition, emission volatility is higher than GDP volatility.

Narayan and Narayan (2010) estimated the emission-income elasticity in developing countries using an error correction model and revealed geographical differences. According to their findings, the emission elasticity is significantly lower in Middle Eastern countries compared to South Asian, East Asian and Latin American countries. Burke et al. (2015) examines the effects of economic growth on emissions from fossil fuel and cement production using data from 189 countries for the period 1961-2010. The study results show that there is an asymmetry in the emission-income elasticity during economic expansion and recession periods. Emission elasticity decreases during prolonged economic contraction periods.

Huang and Jorgenson (2018) examine the relationship between consumption and production-based carbon emissions and economic development using data from 118 countries for the period 1990-2014. According to their findings, unlike other studies, there is no asymmetry between GDP and emissions due to expansion and contraction periods. The results differ in countries with a population of more than 10 million. Consumption-based emissions decrease rapidly during economic downturns, but do not increase at the same rate during economic recovery periods. Klarl (2020) examines the sensitivity of CO_2 emissions to business cycles using monthly data from the United States for the period 1973-2015 using the rolling regression method. According to the results, the sensitivity of emissions to GDP is not constant and emissions become more flexible during recession periods, and emissions change more rapidly during recession periods compared to economic recovery periods.

York (2012) examines the responses of emissions to business cycles using the least squares panel model using data from countries with a population over 500,000 for the period 1960-2008. According to the estimation results, the responses of emissions differ during economic recovery and recession periods. While a 1% increase in GDP per capita increases emissions by 0.7%, a 1% decrease in GDP reduces emissions by only 0.43%. According to the researcher, this asymmetric relationship is due to the fact that infrastructure investments (e.g. manufacturing facilities) made during the economic growth process continue to produce emissions during contraction periods. Shahiduzzaman and Layton (2015) perform a decomposition analysis with US monthly per capita emissions data for the period 1970-2013, showing that emissions decrease faster in contraction periods than in expansion periods.

Sheldon (2017), one of the few studies that conducts country-based analysis instead of panel data, uses the US energy-related carbon emissions and real GDP data for the period 1950-2011 and finds that the emission elasticity is 0.7 in economic growth periods and 1.3 in contraction periods. This shows that emissions decrease rapidly in economic recession periods and increase more slowly in expansion periods. Cohen et al. (2019) calculated the Kuznets elasticity for China with data for the period 1990-2012 and found that the response of the cyclical component of emissions to the cyclical component of GDP varies between 0.35 and 0.65. This shows that emission changes are higher in economic expansion periods than in contraction periods. Finally, Azami and Angazbani (2020) examined the response of emissions of the six countries with the highest carbon emissions in Asia and the Middle East to business cycles with the Markov Switching Autoregressive (MSAR) model. The results vary by country, with emission sensitivity increasing during expansion periods, particularly in Japan and South Korea, while emission flexibility is higher during recession periods in China, Iran and Saudi Arabia compared to expansion periods.

As a result, studies in the literature reveal that carbon emissions are related to business cycles. However, these studies, which are largely based on panel data analyses, may ignore heterogeneous structures across countries. Therefore, increasing country-based analyses will contribute to more effective design of environmental policies by revealing the response of emissions to business cycles more clearly.

EMPRICAL METHODOLOGY AND DATA SOURCES DATA AND VARIABLES

In this study, Turkiye's annual total greenhouse gas emissions (GHG), greenhouse gas emissions per capita, gross domestic product (GDP constant 2015) and gross domestic product per capita (constant 2015) data for the period 1970-2023 are selected to analyze the cyclicality in economic growth and carbon emissions. GDP data is accessed from the World Bank's dataset. GHG data is accessed from Our World in Data.

Figure 1 shows the normalized values of GHG and GDP based on 1970. GDP has been in a constant increasing trend since the beginning of the series. Economic growth has accelerated especially in the period after 2000. GDP has reached 10 times the initial value in the 50-year period. Carbon emissions have also been increasing since the beginning of the series; however, this increase is slower compared to GDP and has increased approximately 4 times during the period. The difference between GDP and emissions has started to widen especially in the period after 2000. In these years when the negative effects of carbon emissions are being voiced more and global steps are being taken for green transformation, energy efficiency and technological developments also have a possible impact. The weakening of the link between GDP and GHG over the years is a development that can be considered positive for achieving sustainable development goals; however, emissions continue to increase over the period.

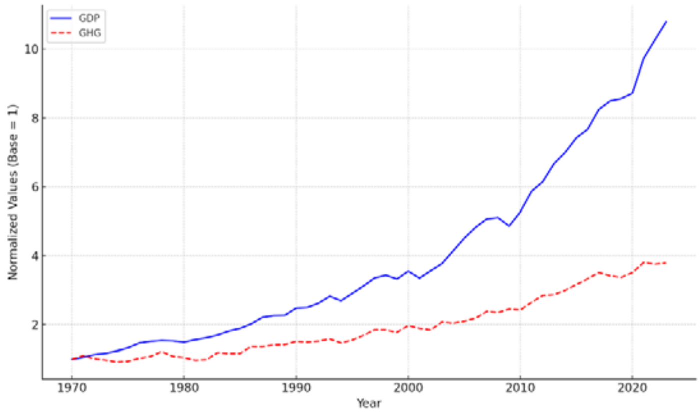

Fig. 1. Seasonally adjusted GDP and Greenhouse Gas Emissions

The determinants of carbon emissions are fossil fuel use and economic growth (Rosa and Dietz, 2012); however, economic growth does not follow a linear process and fluctuates within the trend due to factors causing business cycles. Just like economic fluctuations, carbon emissions also fluctuate periodically; however, academic studies show that there is no symmetrical relationship between changes in emissions and economic growth, emissions differ according to business cycles and respond to expansion-contraction periods at different rates.

The Hodrick-Prescott (HP) filter, which is frequently used in macroeconomic time series, is useful in examining trend and cyclical movements. The HP filter allows the analysis of short-term fluctuations by extracting the long-term trend, and also helps the series to become stationary by separating the trend in non-stationary data. Although the

HP filter is generally used for annual data, different filtering methods are preferred in series with sudden fluctuations such as financial time series. As a result of the separation of the trend, econometric models are applied on cyclical components. This study uses the cyclical fluctuations in gross domestic product and carbon emissions to understand periods of expansion and contraction.

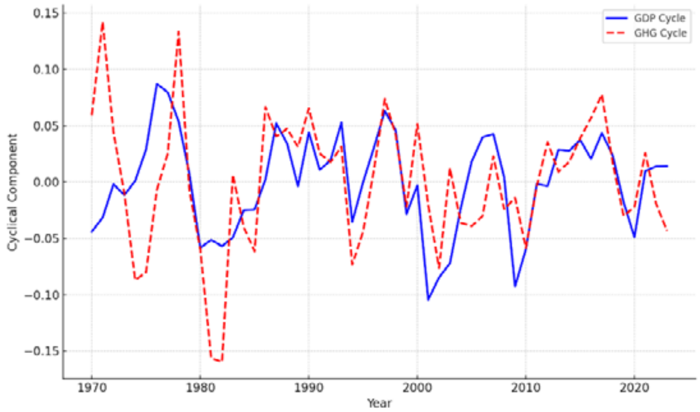

Fig. 2. Cyclical Components of GDP and Greenhouse Gas Emissions

The cyclical components of the detrended data are shown in Figure 2. The cyclical components of the two series also fluctuate over time depending on the business cycle and move parallel to each other. Generally, emissions increase in economic boom periods and decrease in recession periods; however, the correlation between them varies from period to period. Both series are highly volatile in the 1970-1980 period. Due to the decreasing effect of the 2008 Global Recession on emissions, there is a rapid decrease in emissions; however, volatility generally decreases over the years. Many factors such as the spread of low-carbon technologies, the growth of the services sector by decreasing the share of the industrial sector, the increase in the effectiveness of environmental policies, and the increase in environmental awareness may play a role in the decrease in volatility over the years.

MODEL SPECIFICATION AND ESTIMATION METHOD

Markov Switching models provide a powerful framework for analyzing regime changes in nonlinear time series. These models allow us to identify transitions between different regimes in time series and to examine the characteristics of these regimes. Markov Switching models are divided into two main types: Markov Switching Autoregressive (MSAR) and Markov Switching Dynamic Regression (MSDR). Both models are used to model regime changes; however, MSAR models are more suitable for analyzing macroeconomic business cycles, especially when the time series is affected by past values.

MSAR models, introduced by Hamilton (1989), are widely used to analyze business cycles and to examine the characteristics of transitions between regimes. These models allow for the analysis of nonlinear dynamic behaviors and allow for the simultaneous selection of the number of regimes and the autoregressive order. Each of the regime-specific parameters provides a separate framework for examining different dynamics under changing economic and environmental conditions. MSAR models are generally applied to quarterly or annual data and are a suitable tool for the analysis of macroeconomic processes.

In this study, a two-regime Markov Switching Autoregressive (MSAR) model was developed in order to analyze the cyclical relationship between carbon emissions and economic growth in accordance with the data set. The model assumes that carbon emissions exhibit different dynamics depending on the regimes and are dependent on their past values. Specifically, it is expressed as follows:

$$GHG_t = \mu_s + X_t\alpha + GDP_t\beta_{s_t} + \varphi_{1,s_t}\left(GHG_{t-1} - \mu_{S_{t-1}} - X_{t-1}\alpha - GDP_{t-1}\beta_{s_{t-1}}\right) + \varphi_{2,s_t}\left(GHG_{t-2} - \mu_{S_{t-2}} - X_{t-2}\alpha - GDP_{t-2}\beta_{s_{t-2}}\right) + \varepsilon_{s_t} \quad (1)$$

GHG_t and GDP_t are the cyclical components of emissions and economic volume. μ_{S_t} is the regime-specific constant term and shows the base level of carbon emissions in each regime. X_t as a set of covariates whose coefficients are fixed across regimes. $\varphi_{1,st}$ and $\varphi_{2,st}$ represent the first and second autoregressive (AR) terms in state s_t . ε_s is the regime-specific zero-mean error term.

In the model, regime changes are described by a first-order Markov Chain. High transition probabilities indicate that the regime is permanent; low transition probabilities indicate that regimes change frequently. Regime transition probabilities are expressed as follows.

$$P(S_t = | S_{t-1} = i) = p_{ij} \quad i,j \epsilon \{1,2\} \tag{2}$$

p_{ij} is the transition probability from regime i to regime j. The transition probability matrix is a matrix showing the probabilities of the system transitioning from one regime to another in models using Markov Chain. In the Markov Switching Autoregressive (MSAR) model, the time series transitions between certain regimes and these transitions are modeled with a first-order Markov process. Equation 3 shows the transition probability matrix showing the probabilities of the regimes transitioning to another regime in a certain period.

$$P = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix}, and \sum_{j=1}^{2} p_{ij} = 1 \tag{3}$$

ESTIMATION RESULTS

Series containing unit roots lead to incorrect estimates. Therefore, in this study, a Kwiatkowski-Phillips-Schmidt-Shin (KPSS) root test is performed to examine the stationarity of time series. In traditional unit root tests, incorrect results may occur if there are structural breaks in the series. In the KPSS test, the null hypothesis is that the series is stationary, and this difference provides an advantage compared to traditional tests.

Table 1. The results of KPSS unit root test

GDP	GHG	GDP Per Capita	GHG Per Capita
0.0426	0.0469	0.0465	0.0501
KPSS Critical Values: %1 - 0.216, %5 - 0.146, %10 - 0.119			

According to Table 1, all test results are smaller than the critical values. Accordingly, the null hypothesis cannot be rejected and the series is considered stationary. Comparing the standard deviations of the variables with each other provides information about the volatility of the variables relative to each other. According to Table 2, the standard deviation of the cyclical component of GHG is higher than the standard deviation of the cyclical component of GDP. Similarly, the standard deviation of the cyclical component of GHG Per Capita is higher than the standard deviation of the cyclical component of GDP Per Capita. The results show that emissions are more volatile, and economic fluctuations have greater effects on emissions than GDP.

Table 2. Standard deviation of cyclical components of GHG and GDP

GDP	GHG	GDP Per Capita	GHG Per Capita
0.0435	0.0586	0.0429	0.0574

Table 3 shows the correlation coefficients between cyclical components of GHG and GDP. The p-values in parentheses indicate that the results are significant. The results show that both GDP-GHG and GDP Per Capita- GHG Per Capita coefficients are positive, indicating that emissions are positively affected by economic growth. The correlation of cyclical components between GHG and GDP is higher than the per capita values.

Table 3. Coefficient of correlation cyclical components between GHG and GDP

GDP & GHG	GDP Per Capita & GHG Per Capita
0.4510 (0.0006)	0.4349 (0.0010)

Table 4 shows the results of non-linear and linear estimation. μ_{res} and μ_{exp} are the constant term in recession and expansion periods, respectively, β_{res} and β_{exp} are the elasticity of emissions to economic size in recession and expansion periods, respectively. ρ_{rr} is the probability of remaining in recession, and ρ_{er} is the probability of transitioning to economic expansion in the year after recession. ERD and EED are the expected durations of recession and expansion periods, $\mu_{res} - \mu_{exp} = 0$ erm controls whether the average values of emissions are equal in recession and expansion periods, similarly $\beta_{res} - \beta_{exp} = 0$ shows whether the elasticity of emissions to GDP differs according to recession and expansion periods.

For model estimation, 2 regime numbers are determined as stagnation and expansion. Akaike Information Criterion (AIC) is used to determine the degree of the Autoregressive (AR) model used to understand the effects of past values in the series and the lowest AIC is preferred. Therefore, AR is determined as 1 for both models.

Table 4. Non-linear and linear estimation results of GHG response to business cycles

	GHG-GDP		Per GHG-Per GDP	
	Non-linear regression	Linear regression	Non-linear regression	Linear regression
μ_{res}	0.01644** (0.01133)	-	0.01067** (0.00379)	-
μ_{exp}	-0.01526* (0.02577)	-	0.00290** (0.01307)	-
μ	-	0.0001** (0.00719)		-0.0001*** (0.00531)
β_{res}	-0.29028 (0.34978)	-	-0.28961*** (0.02930)	-
β_{exp}	0.66274** (0.22712)	-	0.60581** (0.15259)	-
β	-	0.60718** (0.16661)	-	0.32340*** (0.09329)
ρ_{rr}	0.66152 (0.45665)	-	0.10233 (0.15752)	-
ρ_{er}	0.25979 (0.19088)	-	0.22688 (0.08950)	-
AIC	-3.0773	-	-3.2329	-
LL	90.5496	-	94.6716	-
N	53	54	53	54
AR	1	-	1	-
R^2	-	0.2035	-	0.1877
ERD	2.95 (3.9859)	-	1.11 (0.1954)	-
ERD	3.85 (2.8283)	-	4.40 (1.7387)	-
$\mu_{res} - \mu_{exp} = 0$	10.05 0.0015	-	0.57 0.568	-
$\beta_{res} - \beta_{exp} = 0$	5.71 0.0168	-	-5.76 0.001	-

The results show that the sensitivity of emissions to GDP differs in recession and expansion periods, and business cycles are an important factor in explaining environmental quality. In the economic recession period, the elasticity of emissions to GDP is estimated to be less than 1 (-0.29028). In the economic recovery period, the same value is estimated as 0.66274. The transition probability results indicate that the probability of staying in recession is high; however, this result is not statistically significant. The transition from the recession period to the economic expansion period is quite slow. The recession and economic expansion periods are estimated as 2.95 and 3.85.

Per capita GHG estimates show that the elasticity values differ. The level of emission per capita decreases in the recession period, and the negative elasticity value also supports the results. The coefficient of 0.60581 estimated in the economic expansion period indicates that the elasticity increases in the economic expansion period; however, there is no direct relationship between them. The probability of remaining in a recession is underestimated compared to the total emissions results, reflecting its low persistence, while the transition from recession to expansion is similar in both estimates. The two estimates differ in the expected duration of the recession and expansion periods. The expected duration of the recession is 1.11 years, while the expected duration of the economic expansion is 4.41 years.

The linear model estimates show that the effect of GDP on total carbon emissions is positive and significant (0.0001), but the model cannot explain the differences between economic cycles.

DISCUSSION

The empirical findings of this study reveal the regime-dependent responses of total and per capita carbon emissions to business cycles. The results show that the responses of emissions to economic expansion and recession periods are asymmetric. This finding is consistent with the results of studies such as Heutel (2012) and Doda (2014), as both studies have shown that emissions increase faster in expansion periods but do not decrease at the same rate in contraction periods. This situation can be explained by the fact that energy demand does not completely disappear during economic contraction periods and infrastructure investments (e.g. industrial facilities) continue to maintain a certain level of emissions (York, 2012).

According to the findings of this study, the sensitivity of carbon emissions during economic expansion periods is positive but less than 1. In other words, emissions increase during growth periods, but at a lower rate compared to the GDP growth rate. Similar results were reached by Sheldon (2017) and in his study with US data, he estimated the emission elasticity as 0.7 during economic expansion periods. However, the sensitivity of emissions is negative and lower during economic recession periods. This shows that emissions do not decrease proportionally during economic contraction periods. Studies conducted by Cohen et al. (2019) on the Chinese economy have reached a similar conclusion and have shown that economic recessions keep the emission elasticity at lower levels.

The estimated transition probabilities reveal that recession periods tend to be permanent, but the transition from recession to expansion period is relatively slow. This finding is consistent with the research conducted by Klarl (2020) with US data, as it has been found that the sensitivity of emissions to business cycles varies over time and becomes more pronounced during recession periods. This analysis conducted for Turkiye suggests that similar mechanisms may also apply in developing economies.

In addition, linear model estimates show that the effect of economic growth on emissions is positive and significant. However, this model cannot explain the differences between economic cycles. Markov-Switching models developed by Hamilton (1989) confirm that the economic growth-emission relationship changes depending on different economic conditions when regime shifts are taken into account. In this context, unlike studies such as Sheldon (2017) and Burke et al. (2015), this analysis, which is specific to Turkiye, reveals the regime transitions of expansion and recession periods in more detail.

CONCLUSION

According to the findings of this study, total and per capita emissions in Turkiye respond asymmetrically to business cycles. Emissions increase during expansion periods but do not decrease proportionally during recession periods. These results carry important policy implications for Turkiye's transition to a low-carbon growth strategy. In particular, stricter regulations should be introduced during economic growth periods and a certain reduction target should be maintained during economic recession periods (Heutel, 2012; Annicchiarico & Di Dio, 2015).

For countries like Turkiye that are in the process of transitioning to an emissions trading system, designing mechanisms that take into account the impact of business cycles will be critical in preventing excessive price volatility and ensuring long-term policy credibility. The results facilitate the formulation of optimal climate policies and the estimation of emissions. In addition, the MSAR results will help determine the parameters to be used in the calibration of models analyzing the cycle-emission relationship. In this context, it will provide an important reference in the selection of appropriate parameters within the DSGE model.

Turkiye needs a well-defined medium and long-term roadmap in line with its 2053 Net Zero carbon target (Aşıcı, 2021). The choice of policy instruments should limit emission growth in expansion periods by taking into account the dynamics of business cycles and encourage the use of energy efficiency and green technologies. Green economy policies should be designed to reduce emissions while not hindering economic growth. The primary goal of carbon regulations is to encourage firms to adopt cleaner technologies and ensure their transition to sustainable production methods. However, these regulations should not create excessive economic burdens, otherwise they may cause economic contraction.

Future research can conduct more detailed analyses on a sectoral basis and examine how emissions respond to business cycles differ across the industry, energy, and services sectors. In addition, how the relationship between business cycles and emissions interacts with financial fluctuations will be useful for policy makers to design more effective environmental regulations.

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