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Impact of International Environmental Agreements on Procyclicality of Carbon Dioxide Emissions and Business Cycles

Uluslararası Çevresel Anlaşmaların İş Çevrimleri ve Karbondioksit Emilinin Döngüsel Bileşenleri Üzerindeki Etkisi

Bige KÜÇÜKEFE[1], Nilüfer Kaya KANLI[2]

Abstract

The relationship between cyclic components of carbon dioxide (CO_2) emissions and gross domestic product (GDP) growth is procyclical for a typical economy. Potential effects of a policy decision on the environment require policymakers to consider the impact of GDP growth on CO_2 emissions for a country. This paper investigates the changing dynamics of procyclicality of CO_2 emissions with respect to GDP growth following the Kyoto protocol which represents a strong commitment for a green economy by the industrialized countries. We compare two time periods (1970-2005 and 2006-2017) before and after the Kyoto Protocol by calculating the Pearson correlation coefficients and using linear regression models for 48 countries which produced 79% of the world total CO_2 emissions in 2017. Our study finds that the procyclicality of the CO_2 emissions and GDP growth decreased in 29 countries and increased in 19 countries in the period 2006-2017 following the Kyoto Protocol. We extract the cyclical components by Hodrick-Prescot filter. We also build VAR models and compute impulse response functions, which agree with the statistical findings.

Jel Codes: E32, F64, Q13, Q15, Q19
Anahtar Kelimeler: *Kyoto Protocol, Green economy, Business Cycle, CO_2 emissions, Climate change.*

[1] Tekirdağ Namık Kemal University, bkucukefe@nku.edu.tr, ORCID: 0000-0003-1945-3037
[2] Independent Researcher, nilukaya@gmail.com, ORCID: 0000 0001 9049 3862

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Öz

Tipik bir ekonomideki Karbondioksit emisyonunun (CO_2) ve Gayri safi yurtiçi hasıladaki (GSYIH) büyümenin döngüsel bileşenleri aynı yöndedir. Politika karar alıcıları, bir ekonomi politikası kararının çevre üzerindeki olası etkilerini hesaplarken, ülkedeki GSYIH'daki büyümenin CO_2 emisyonu üzerindeki etkilerini dikkate alması gerekir. Bu makale, sanayileşmiş ülkeler tarafından yeşil bir ekonomi için güçlü bir taahhüdü temsil eden Kyoto protokolünü takiben GSYİH büyümesine göre CO_2 emisyonlarının döngüselliğinin değişen dinamiklerini incelemektedir. Bu çalışmada 2017 yılında dünya toplam CO2 emisyonlarının %79'unu üreten 48 ülke için Pearson korelasyon katsayılarını hesaplayarak ve lineer regresyon modellerini kullanarak Kyoto Protokolü öncesi ve sonrası iki zaman dönemini (1970-2005 ve 2006-2017) karşılaştırılmaktadır. Çalışmamızda, Kyoto Protokolü sonrası 2006-2017 döneminde CO2 emisyonlarının ve GSYİH büyümesinin döngüselliğinin 29 ülkede azaldığını ve 19 ülkede arttığını ortaya koymaktadır. Döngüsel bileşenlerin ortaya çıkarılması için Hodrick-Prescot filtresi kullanılmıştır. Ayrıca, bu sonuçları elde edebilmek için istatistiksel bulgularla uyumlu olan VAR modelleri oluşturulmuş ve tepki fonksiyonları hesaplanmıştır.

Jel Kodları: *E32, F64, Q13, Q15, Q19*

Anahtar Kelimeler: *Kyoto Protokolü, Yeşil ekonomi, Konjonktür dalgalanmaları, CO2 emisyonu, İklim değişikliği*

1. Introduction

High concentration of greenhouse gases (GHG) in the atmosphere causes climate change by trapping heat and poses serious threat on sustainable growth and biodiversity. United Nations Framework Convention on Climate Change (UNFCCC) was adapted in 1992 with an objective of stabilizing GHG concentrations. The Kyoto Protocol which entered into force in 2005 implemented the objective of UNFCCC in a binding legal framework to reduce GHG emissions (Villoria-Sáez et al., 2016). The protocol was intended to limit and cut the GHG emissions by industrialized countries on average of 5% compared to 1990 levels over the five-year period of 2008-2012. The second phase of the protocol, Doha Amendment, was planned for 2013-2020 but it was not ratified due to insufficient support from member countries. Signed by 195 countries in 2016, the Paris Agreement set out a new global framework including the US and China to reduce GHG that contribute global warming.

Cyclical components of GDP and anthropogenic emissions of GHG among which CO_2 is the primary greenhouse gas have a strong correlation in a typical economy. CO_2 emissions are mainly produced by fossil fuel combustion for the purpose of electricity generation, heating, and transportation for which demand depends on economic activity. As the atmospheric concentration of CO_2 reaches historically high levels, procyclicality of CO_2 emissions poses a difficult dilemma that forces the policymakers to choose between economic growth and environment in a high-carbon economy. To tackle this, the green growth policies focus on sustainable development without degrading the environment by achieving resource efficiency, low or zero carbon footprint, and waste reduction.

Our study compares the procyclicality of CO_2 emissions and GDP before (1970-2005) and after (2006-2017) the international environmental action that came into effect the first time with Kyoto Protocol for 48 countries which emitted 79% of the world's CO_2 emissions in 2017. We used the Hodrick-Prescott filter to extract the cyclical components. There are two points that make our study significant. Firstly, we used the Pearson correlation coefficients and linear regression models to compare the procyclicality of CO_2 emissions and GDP for periods before and after the Kyoto Protocol. 2006-2017 period has only 12 data points which is insufficient for the purpose of obtaining a useful model. To overcome this problem, we obtained and compared the model parameters for longer periods (1970-2005 and 1970-2017) with 36 and 48 data points, respectively. Our practical contribution enabled us to obtain the model parameters for comparing two periods even though one of them has limited number of data points. Secondly, our study includes 48 countries which emitted 79% of the world's CO_2 emissions in 2017 whereas most of the existing literature focused on the CO_2 emissions and their procyclicality in the US (Wang & Wang, 2019; Khan et al., 2019) and EU countries (Pilatowska, Geise, & Wlodarczyk, 2018) only.

This paper is organized as follows. Section 2 presents a literature review and Section 3 describes data and methodology used in this study. We break Section 4 into three parts to present the results for the correlation calculation, linear regression model and VAR analysis for the cyclical components. Impulse response functions are also provided for the selected countries in this section. The findings are discussed in Section V, and Section VI concludes.

2. Literature Review

Implementation of the international environmental agreements under a legally binding framework started in 2005 with the Kyoto Protocol. During the past decade, several studies investigated the outcome and effectiveness of these agreements. Most of the researchers showed that ratification of the Kyoto protocol has significantly reduced CO_2 emissions (Grunewald & Martínez-Zarzoso, 2011; Kumazawa & Callaghan, 2012; Aichele & Felbermayr, 2013; Grunewald & Martinez-Zarzoso, 2016; Maamoun, 2019; Kim et al., 2020). On the other hand, Almer & Winkler (2017) found little evidence for the reduction of the emissions for the major emitter countries with the binding targets. Aakvik & Tjøtta (2011), Kim et al. (2012), Levy (1993), Bratberg, Tjøtta & Øines (2005) and Vollenweider (2013) researched the effect of international environmental agreements on air polluting emissions other than CO_2. There is limited research on the environmental and economic impacts of Kyoto Protocol. For example, Kim, Tanaka & Matsuka (2020) investigated economic impacts on the Kyoto protocol implying difference in difference method with CO_2 emissions, GDP, and socioeconomic dataset. They found that participating Kyoto Protocol as an Annex 1 party has significant positive effect on CO_2 emission reductions but a negative impact on the GDP. To evaluate economic impact of Kyoto protocol, our study aims to investigate cyclical components of GDP and CO_2 emissions before and after Kyoto Protocol.

Grunewald & Martínez-Zarzoso (2011) indicated that the Kyoto Protocol's obligations significantly reduced CO_2 emissions in a panel of 213 countries for the period of 1960 to 2009 to analyze the driving factors of CO_2 emissions within the setting of environmental regulations.

Similarly, Kumazawa & Callaghan (2012) used an unbalanced panel dataset consisting of 177 countries from 1980 to 2006 to form Environmental Kuznets Curve (EKC) models and showed that CO_2 emissions declined for industrialized countries. Over the period of their study, the industrial production also declined for both industrialized and developing countries. The fixed effects panel model estimates of Aichele & Felbermayr (2013) calculated that Kyoto Protocol has contributed to a 10 percent reduction on CO_2 emissions. Grunewald & Martinez-Zarzoso (2016) used a dataset of 170 countries over the period 1992–2009 to investigate the impact of the Kyoto Protocol on CO_2 emissions. By implementing a difference in differences methodology, they found that Kyoto Protocol commitments have a significant effect in reducing CO_2 emissions. Maamoun (2019) used the generalized synthetic control method (GSCM) to assess the Kyoto protocol's effectiveness and compared the actual situation with a scenario that assumes the protocol has not been implemented. According to his results, the emissions of the ratifying countries are approximately reduced by 7% below the assumed scenario. Kim et al. (2020) combined propensity score matching and the difference-in-difference method to investigate the environmental and economic impacts of the Kyoto Protocol's Annex I countries. Their results indicated that the CO_2 emissions decreased significantly under a negative long-run impact of the GDP. Using an environmental dynamic stochastic general equilibrium (E-DSGE) model, Chan (2020) estimated that pre-announcing a tightening carbon intensity target could reduce CO2 emissions using. On other hand, Almer & Winkler (2017) used country-level and US state-level panel data to implement the synthetic control method to show that the protocol has not significantly reduced the emissions in the Annex B countries of the protocol.

In the real business cycle (RBC) literature (Kydland & Prescott, 1982) a variable (x) is said to be procyclical if the correlation (ρ) between x and GDP is positive, i.e. $\rho(x,\text{GDP})>0$. Doda (2014) reported a strong procyclicality for CO_2 emissions in a typical country as a fact upon studying the topic in a comprehensive panel of countries. Using a basic RBC framework with pollution in an E-DSGE model, Heutel (2012) found that a price effect from costlier abatement during economic expansions outweighs an income effect of higher demand for clean air because of increased productivity, thereby failing to achieve low level emissions. Khan et al. (2019) calculated the contemporaneous correlation between the cyclical components of CO_2 emissions and real GDP as 0.64 for the period 1975-2015 in the United States. Azami & Angazbani (2020) investigated procyclicality for six large CO_2 emitting countries by using a Markov-switching autoregressive models and found that emissions are procyclical in China, Japan, Iran, Saudi Arabia, and South Korea, but the elasticity of the emission with respect to GDP significantly depends on regimes. Furthermore, contradictory findings on the existence of an inverse-U shaped relationship in the context of Kuznets curve between CO_2 emissions and GDP were reported by various authors (Holtz-Eakin & Selden, 2019; Schmalensee, Stoker & Judson, 1998; Aldy, 2006; Wagner, 2008). On the other hand, Sheldon (2015) questioned the business cycle effects on the CO_2 emissions forecasts and indicated that the elasticity of emissions was not constant. For example, emissions fall more sharply when GDP declines than they rise when GDP increases in the US. She also predicted that accounting for the business cycle would result in 5% lower cumulative emissions through 2050 relative to the baseline forecast. Pilatowska, Geise & Wlodarczyk (2018) computed the asymmetric response of CO_2

emissions to changes in GDP by employing a VAR model for the EU countries. Germany, Ireland, and the UK showed decoupling of economic growth from emissions since 1990. The United States has achieved economic growth compatible with carbon reduction since 2007. Wang & Wang (2019) assessed the effectiveness of research and development in the decoupling economic growth from carbon emissions. In their research, they found a strong decoupling in the US and research and development intensity and efficiency contributed decoupling.

Since the 1970s, various international environmental agreements have been signed to tackle negative externalities and international environmental problems. Previous studies mostly focused on the effects of international environmental agreements on air pollution (Grunewald & Martínez-Zarzoso, 2011; Kumazawa & Callaghan, 2012; Grunewald & Martinez-Zarzoso, 2016; Maamoun, 2019; Almer & Winkler, 2017; Aakvik & Tjøtta, 2011; Kim et al., 2012; Levy, 1993; Vollenweider, 2013; Bratberg, Tjøtta & Øines, 2005) as presented in the literature review.

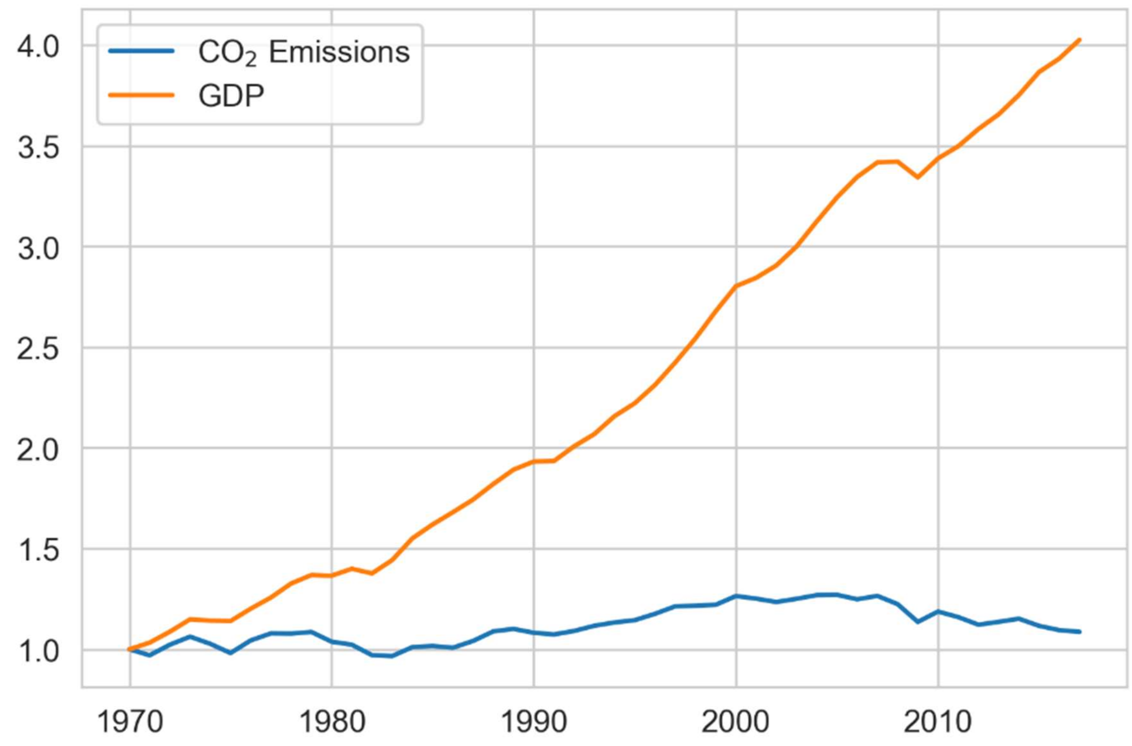
There remains a literature gap on the impact of the international environmental agreements on the procyclicality of CO_2 emissions. Changes in CO_2 emission levels with respect to GDP were investigated by many authors (Grunewald & Martinez-Zarzoso, 2016; Kumazawa & Callaghan, 2012) but the relation between cyclical components of GDP and CO_2 emissions and its comparison for the periods before and after the Kyoto Protocol have not been studied. This paper aims to fill this gap.

3. Data and Methodology

Two key variables in our study are CO_2 emissions and GDP. The dataset includes annual data from 1970 to 2017. Yearly data eliminates the need for seasonal adjustments that would normally be required for quarterly and monthly data. We use data from the Emissions Database for Global Atmospheric Research (EDGAR) of the European Commission and the Netherlands Environmental Agency (Crippa et al. 2020) for CO_2 emissions. GDP data are provided from the April 2019 version of the Conference Board (2019). Even though there are 98 countries in our balanced panel, these countries emitted 96% of the world total CO_2 emissions in 2017 excluding international aviation and shipping. Hence, the panel data in our study includes major CO_2 emitting countries in the world.

For each country in the panel, both CO_2 emissions and GDP series are normalized to their respective 1970 levels so that the starting value is 1 for both series. Fig. 1 plots the normalized series for the US to illustrate that GDP and CO_2 emissions appear to move together at different levels until 2000. From 2000 on in the US, the historic pattern between the two series weakened and reversed after 2010.

Figure 1: CO_2 Emissions and GDP, US 1970-2017



Both Series are normalized to their 1970 levels.

We use the Hodrick-Prescott decomposition method (HP filter) (Hodrick & Prescott (1997)), to obtain the cyclical components on the normalized series. Despite its drawbacks, the HP filter is a standard method for removing trend movements and identifying cycles in the RBC literature (Rayn & Uhlig (2002)). Alternatives to HP filter are Baxter-King (BK) bandpass moving average filter, the Christiano-Fitzgerald (CF) random walk filter, and the Butterworth (BW) rational square wave filter (Christiano & Fitzgerald (1999)).

The HP filter solves the following optimization problem for y_t series with t = 1, 2, ..., T, which is made up of a trend component τ_t and a cyclical component c_t:

$$min_\tau\left(\sum_{t=1}^{T} {c_t}^2 - \lambda \sum_{t=2}^{T-1} [(\tau_{t+1} - \tau_t)(\tau_t - \tau_{t-1})]^2\right) \quad (1)$$
$$subject\ to\ y_t = \tau_t + c_t$$

where λ is the penalty parameter with a value of 6.25 following the recommendation by Ravn & Uhlig (2002) for yearly data set.

The strength of association between two variables can be represented by the Pearson correlation coefficient (Freedman, Pisani & Purves, 2007). Given a pair of variables (X, Y), the Pearson correlation coefficient (ρ) is defined as

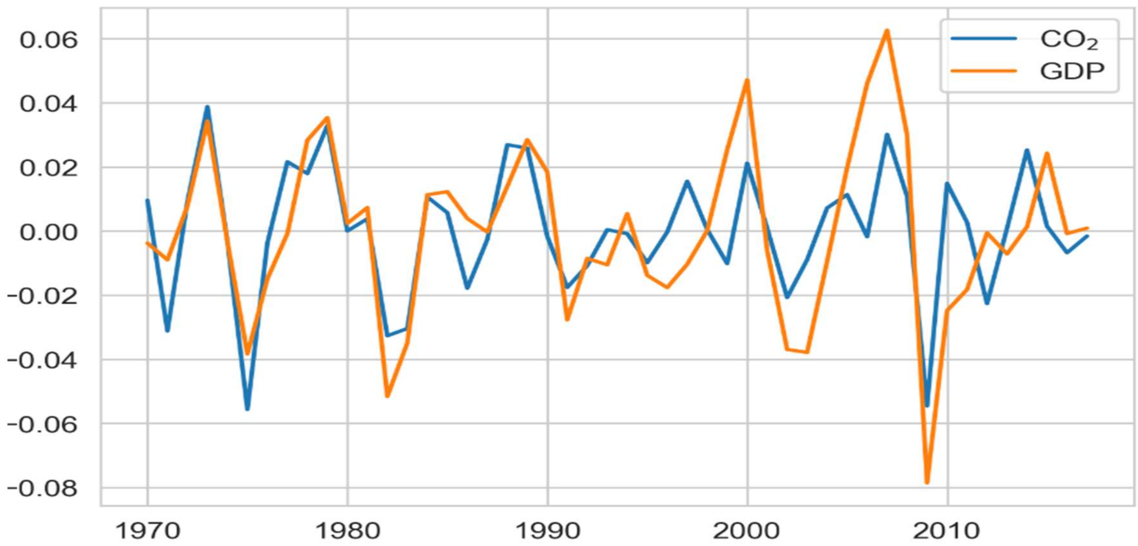
$$\rho_{X,Y} = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sigma_X \sigma_Y} \quad (2)$$

where σ_X and σ_Y are standard deviations of X and Y, $\bar{x}$ and $\bar{y}$ are means of X and Y, respectively.

Let X_A and Y_A be two vectors (X_A = [x_1, x_2, …, x_k], Y_A= [y_1, y_2, …, y_k]) with the correlation coefficient ρ_{XY}. By adding the value pair of x_{k+1} and y_{k+1}, X_A and Y_A vectors become [x_1, x_2, …, x_k, x_{k+1}] and [y_1, y_2, …, y_k, y_{k+1}], respectively. The correlation coefficient, ρ_{XY}, can increase, decrease, or remain unchanged after including (x_{k+1}, y_{k+1}). A larger (smaller) ρ_{XY} indicates an increase (decrease) in the strength of association between X_A and Y_A due to the newly added x and y values. Similarly, adding new value vectors X_B= [x_{k+1}, x_{k+2}, …, x_n], Y_B= [y_{k+1}, y_{k+2}, …, y_n] to initial X_A and Y_A will change the correlation coefficient ρ_{XY} in a way that is determined by only X_B and Y_B. In our calculations, X_A and Y_A represent the cyclical components of the CO_2 emissions and GDP for the period 1970-2005, respectively. With this approach, we evaluate the impact of the 2005-2017 period (i.e., post Kyoto protocol) by comparing the correlation coefficients of X_A, Y_A (1970-2005) with [X_A+X_B], [Y_A+Y_B] (1970-2017). If ρ_{XY} for the first period (1970-2005) is greater (smaller) than the complete period (1970-2017), the strength of association between the cyclical components decreased (increases) in the second period (2005-2017).

We obtain the cyclical components of the CO_2 emissions and GDP for each country in the panel by applying the HP filter to the normalized series. We use the US as an example and present the cyclical components in Fig. 2. The strong positive correlation between two components is evident but it seems slightly decreased after 2010. After checking that both series are stationary with the Augmented Dickey-Fuller test (ADF), the Pearson correlation coefficient is calculated as 0.722 with a p-value of near zero (<0.01), thereby confirming that the correlation coefficient is statistically significant. Note that this value is for the complete period (1970-2017). We also calculate the correlation coefficient for the period 1970-2005 and it is 0.762 which indicates that the correlation was comparatively higher for this period. This comparison allows us to evaluate the impact of international environmental agreements on procyclicality of CO_2 emissions. A decrease (increase) in the correlation coefficient from its first period value (1970-2005) shows that CO_2 emissions become less (more) procyclical after 2005.

Figure 2: Cyclical Components of CO_2 Emissions and GDP, US 1970-2017.



Note: The cyclical values are obtained by applying the HP filter to the normalized series.

We also build a linear regression model for the cyclical components of GDP and CO2 emissions and evaluate the change in the regression coefficient of the linear model for two periods as we performed with correlation coefficients. The linear relationship between X and Y vectors can be written as

$$y = \alpha_0 + \beta x + \epsilon \quad (3)$$

where x, y are n-dimensional vectors, β is the regression coefficient, α_0 is a constant, and ϵ is the error term. The regression coefficients (α_0 and β) are estimated by using the ordinary least squares (OLS) approach such that the sum of squared residuals (RSS) is minimum.

Let β be the regression coefficient of two vectors $X_A = [x_1, x_2, \ldots, x_k]$ and $Y_A = [y_1, y_2, \ldots, y_k]$. The change in the regression coefficient β for the linear model of X_A and Y_A vectors after adding x_{k+1} and y_{k+1} shows the impact of x_{k+1} and y_{k+1} on the model. A higher (lower) β reveals increased (decreased) dependence of Y_A to X_A due to x_{k+1} and y_{k+1}. Extending the analysis to add value vectors $X_B = [x_{k+1}, x_{k+2}, \ldots, x_n]$, $Y_B = [y_{k+1}, y_{k+2}, \ldots, y_n]$ to initial X_A and Y_A gives a new regression coefficient different from the original β for X_A and Y_A. The difference in the regression coefficient solely depends on X_B and Y_B. Thereby indicating the directional impact, they create. If β for the first period (1970-2005) is smaller (greater) than the complete period (1970-2017) than the post Kyoto period (2005-2017) saw a decreased (increased) dependence of the cyclical components of the CO_2 emissions on GDP cyclical components for a country.

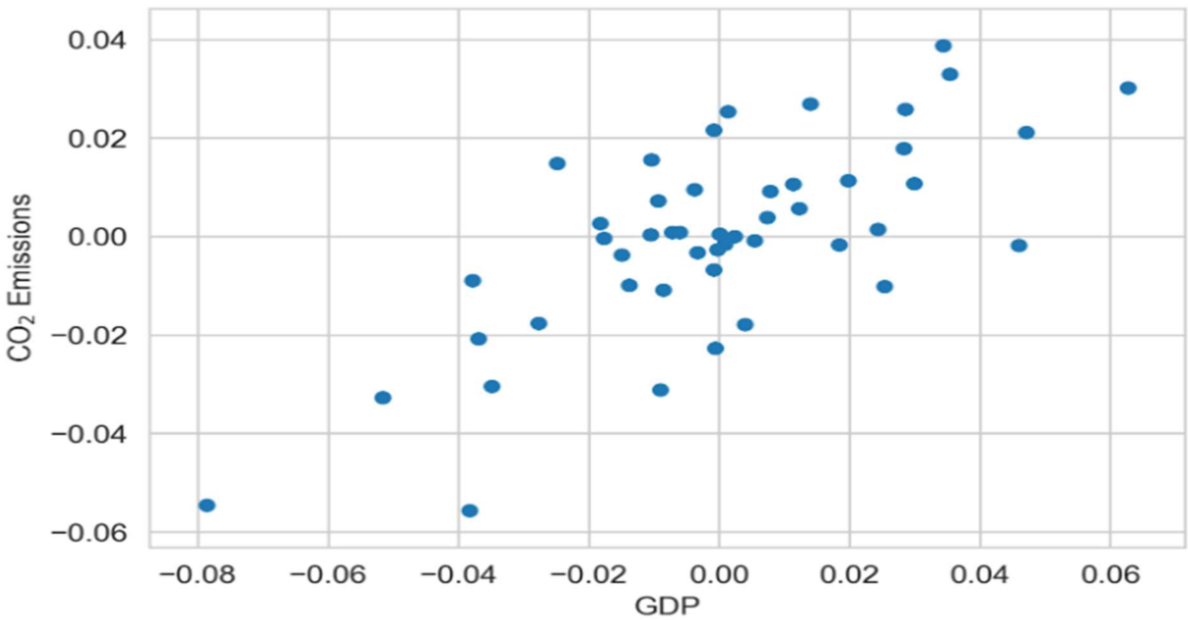
The linear relationship between two variables for the US is depicted in Fig. 3. A higher regression coefficient for the first period reveals transformation towards decreasing procyclicality of CO_2 emissions and vice versa. We calculate the regression coefficients for the US as 0.547 (1970-2017) and 0.654 (1970-2005) with p-values of near zero which suggests a decrease in positive correlation between cyclical components of the CO_2 emissions and GDP from 2005 for the US.

We repeat this process for each country in our panel. Correlation coefficients and linear regression models with p-values greater than 0.05 are excluded from the evaluation. To investigate the autoregressive behavior of the cyclical components, Vector Autoregression (VAR) models are constructed to compare Impulse Response Functions (IRF) for two periods qualitatively. Generalizing the univariate autoregressive model to allow for multiple variables, VAR models capture relationships between variables and their past values and were made popular in economics by Sims (1980). Let $CO2E_t$ and GDP_t denote the cyclical components of CO2 emissions and GDP, respectively. Bivariate VAR model with lag 2 for $CO2E_t$ and GDP_t variables is

$$\begin{bmatrix}\Delta CO2E_t\\ \Delta GDP_t\end{bmatrix} = \begin{bmatrix}\alpha_1\\ \alpha_2\end{bmatrix} + \begin{bmatrix}\beta_{11} & \beta_{12}\\ \beta_{21} & \beta_{22}\end{bmatrix}\begin{bmatrix}\Delta CO2E_{t-1}\\ \Delta GDP_{t-1}\end{bmatrix} + \begin{bmatrix}\phi_{11} & \phi_{12}\\ \phi_{21} & \phi_{22}\end{bmatrix}\begin{bmatrix}\Delta CO2E_{t-2}\\ \Delta GDP_{t-2}\end{bmatrix} + \begin{bmatrix}\varepsilon_{1t}\\ \varepsilon_{2t}\end{bmatrix} \quad (4)$$

where ε_{1t} and ε_{2t} are error terms satisfying that $E(\varepsilon_t) = 0$, $E(\varepsilon_t \varepsilon_t') = \Omega$ and $E\left(\varepsilon_t \varepsilon_{t-k}'\right) = 0$. Both $CO2E_t$ and GDP are required to be stationary (i.e., without unit root) for use in a VAR model. The IRF response of $CO2E$ to a sudden and temporary change in GDP lets us qualitatively analyze the procyclicality of CO_2 emissions for two periods. A drop (increase) in the peak value of IRF suggests a decrease (increase) in positive correlation between CO2 emissions and GDP for the country. Optimal lag values for country specific VAR models are computed by Schwarz Criterion.

Figure 3: Cyclical Components of CO_2 Emissions vs GDP, US 1970-2017.



Note: The cyclical values obtained from applying the HP filter to the normalized series.

4. Results

Correlations coefficients of the cyclical components of CO_2 emissions and GDP (normalized values) are calculated for two time periods: 1970-2005 and 1970-2017. There are 100 countries in the panel originally but 2 of them (Cameroon and Qatar) are excluded due to high p-values (>0.05) of their corresponding cyclical components. Correlation coefficients are calculated by Pearson's method. After excluding the countries with high p-values for the correlation coefficients, 48 countries remained in the panel. Even after almost half of the countries are excluded from the original panel, the remaining 48 countries were responsible for 79% of the world total CO_2 emissions in 2017 excluding international shipping and aviation. Table 1 shows the summary statistics. The average of correlation coefficients (ρ_{avg}) decreased from 0.536 to 0.529. This slight drop suggests that the procyclicality of CO2 emissions decreased from 2005 to 2017 on average but the strong positive correlation remained except Hong Kong (China) which has countercyclical emissions. Similarly, standard deviation (σ) of the correlation coefficient across countries dropped to from 0.2 to 0.188 suggesting that differences between the panel countries decreased after 2005.

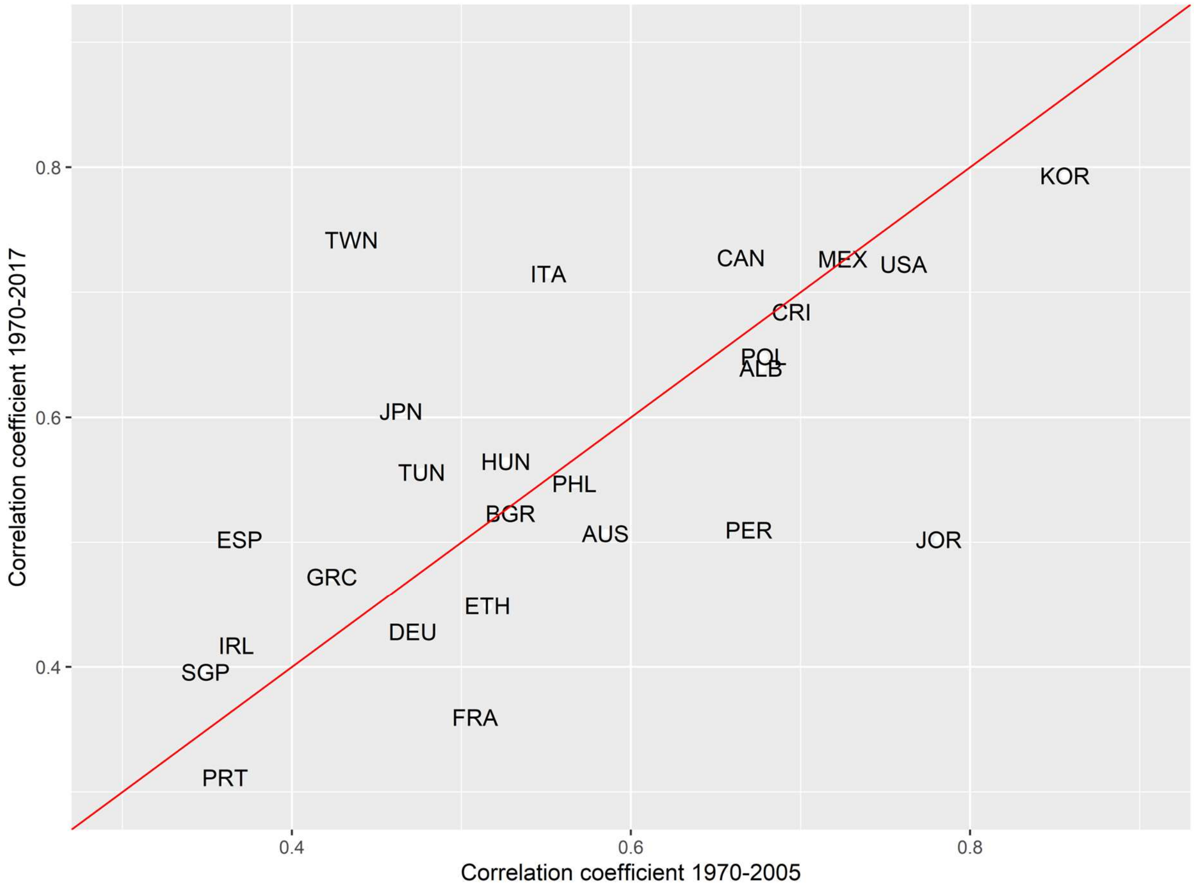
Table 1: Procyclicality of CO_2 Emissions

Countries (ISO Codes)	1970-2005	1970-2017
ALB, ARG, AUS, BEL, BGR, BRA, CAN, CHL, CHN, COD, COL, CRI, CZE, DEU, DOM, DZA, ECU, ESP, ETH, FRA, GBR, GRC, GTM, HKG, HUN, IRL, IRN, IRQ, ITA, JAM, JPN, KOR, KWT, MEX, MYS, PER, PHL, POL, PRT, ROU, RUS, SGP, THA, TUN, TUR, TWN, USA, ZAF	ρ_{avg}=0.536 σ_ρ=0.200 *LR model:* β_{avg}=0.890	ρ_{avg}=0.529 σ_ρ=0.188 β_{avg}=0.867

The linear regression models we built for the purpose of comparison produce similar results about the procyclicality as shown in Table 1. The mean of regression coefficients (β) value declined to 0.867 from 0.890. This result agrees with our finding by using the correlation coefficients that the procyclicality of CO_2 emissions slightly decreased in the period following the Kyoto Protocol.

The change in the correlation at country levels deserves a closer look. Figure 4 illustrates the variation in the correlation coefficients between two periods for each country in the panel. 29 countries shifted towards less procyclical CO_2 emissions, and 19 countries moved in opposite direction. Among large economies, only France recorded a notable shift from 0.507 down to 0.366 while majority of negative movements (i.e., procyclicality decreases) were marginal. The United States just managed a 0.04 drop from 0.762 to 0.722. The shift is more notable for large economies if the direction is positive (i.e., increased procyclicality). For example, China's correlation coefficient increased to 0.61 from 0.395 and Italy has reached to 0.722 with an increase of 0.170. Note that even though some countries increased their procyclicality dramatically (e.g., China, Italy, and Spain) with respect to their first period value, these countries have CO_2 emissions less procyclical than the United States. Thailand has the highest procyclicality with 0.861 and Portugal has the lowest value with 0.312 among the group with positive procyclicality.

Figure 4: Correlation Coefficients for Two Periods (Selected Countries).



Countries below the diagonal line decreased the procyclicality of CO_2 emissions after 2005.

Table 2 gives the complete list of the countries in the panel and their respective Pearson correlation and regression coefficients. All the calculations reported in Table 2 have a p-value of less than 0.05. Regression coefficients are obtained from linear models that use normalized values. Hence, comparing the regression coefficient values across countries is not possible. In parallel to relationship between GDP and CO_2 emissions reported in the literature, cyclical components see a reduced procyclicality after the Kyoto Protocol.

To obtain the variation of a country's procyclicality in both directions (increase or decrease), we build a simple bivariate VAR model with optimal lag values for each country by using the cyclical components and obtain IRFs for two time periods under consideration. The simulations run in 10 periods after applying an impulse to GDP. Since our aim is to compare the direction and magnitude of cyclical responses, we are concerned only with the first period values of the CO_2 emissions on the IRFs. Employing the same comparison method with the correlation coefficients, a lower (higher) value of the CO_2 emission for the overall period

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(1970-2017) in comparison to the first period (1970-2005) indicates change in autoregressive behavior of procyclicality for a country after the first period.

Table 2: Correlation (ρ) and Regression (β) Coefficients

COUNTRY	ρ^+	ρ^*	β^+	β^*
Albania	0.661	0.685	0.795	0.828
Algeria	0.418	0.404	1.791	1.533
Argentina	0.652	0.695	0.478	0.548
Australia	0.541	0.608	0.682	0.772
Belgium	0.343	0.414	0.515	0.747
Brazil	0.742	0.674	1.137	0.646
Bulgaria	0.522	0.529	0.645	0.606
Canada	0.712	0.664	0.677	0.681
Chile	0.530	0.505	0.694	0.678
China	0.610	0.395	0.760	0.500
Colombia	0.553	0.611	0.548	0.726
Costa Rica	0.690	0.697	1.783	2.050
Czechia	0.446	0.414	0.222	0.258
Dom. Rep.	0.596	0.698	1.270	1.864
DR Congo	0.336	0.373	1.924	1.605
Ecuador	0.456	0.645	1.580	2.649
Ethiopia	0.287	0.504	1.139	1.274
France	0.366	0.507	0.468	0.824
Germany	0.435	0.471	0.347	0.517
Greece	0.458	0.425	0.552	0.684
Guatemala	0.320	0.410	2.517	1.916
Hong Kong (China)	-0.346	-0.449	-0.487	-0.777
Hungary	0.551	0.518	0.498	0.509
Iran	0.522	0.632	0.564	0.743
Iraq	0.529	0.547	1.460	1.426
Ireland	0.428	0.371	0.212	0.358
Italy	0.722	0.551	0.902	0.732
Jamaica	0.673	0.665	2.864	2.089
Japan	0.575	0.465	0.519	0.478
Kuwait	0.395	0.479	0.620	0.808
Malaysia	0.662	0.671	1.292	0.721
Mexico	0.690	0.725	0.765	0.764

Peru	0.500	0.659	0.514	0.605
Philippines	0.537	0.565	0.936	1.010
Poland	0.640	0.678	0.690	0.762
Portugal	0.312	0.361	0.811	1.060
Romania	0.686	0.786	0.730	0.974
Russia Fed.	0.572	0.637	0.587	0.855
Singapore	0.392	0.351	0.294	0.446
South Africa	0.449	0.355	0.806	0.621
South Korea	0.801	0.856	1.039	1.129
Spain	0.509	0.368	0.768	0.680
Taiwan (China)	0.750	0.438	0.454	0.322
Thailand	0.861	0.851	1.787	1.927
Tunisia	0.539	0.440	0.854	0.661
Turkey	0.537	0.595	0.662	0.759
United Kingdom	0.491	0.505	0.390	0.495
United States	0.722	0.762	0.546	0.654

Note: (+): Period 1970-2017, (*): Period 1970-2005. All the calculations have a p-value of less than 0.05. Countries are in alphabetic order.

The IRF functions are shown in the Appendix. China's correlation coefficient increased to 0.610 from 0.395*. This suggests a shift towards more procyclical CO_2 emissions. The first period values are 0.019459 and 0.005952* for CO_2 emissions. Note that significantly higher value of the overall period is in line with the magnitude of change for correlation coefficients.

The first period values for the US CO_2 emissions are 0.001949 and 0.003071*. This drop confirms the finding by the correlation coefficients (0.722<0.762*) that the US slightly shifted toward less procyclical carbon emissions in the period 2005-2017 even though it remained among the countries with relatively higher procyclicality.

With its negative correlation and regression coefficient values for both periods Hong Kong (China) is the only exception in the panel. These values suggest a countercyclical relation between the cyclical components of the CO_2 emissions and GDP for Hong Kong (China). IRFs indicate that countercyclicality decreased and emissions dropped to near zero (-0.006166) from -0.071432* following a temporary GDP shock. The negative response of the CO_2 emissions is in contrast with the other countries in the panel and is caused by countercyclicality.

The IRFs qualitatively reveal the change in autoregressive behavior of procyclicality of cyclical components of GDP and CO_2 emissions for the countries in the panel before and after 2005.

5. Discussion

This study finds that significant reduction in CO_2 emission levels with respect to GDP following the international environmental agreements is not observed in the cyclical components in which the reduction was gradual on average. The Pearson correlation coefficient between the cyclical components of CO_2 emissions and GDP slightly decreased from 0.536 to 0.529 on average in the countries included in this study. Majority of the countries including the US, France, Russia, South Korea managed to reduce the procyclicality. On the other hand, the procyclicality increased in some counties (e.g.,Canada, China, Japan, Spain, Brazil, and Italy).

The notable downward trend in CO_2 emission levels is the result of more efficient environmental policies in line with the rising awareness and demand for a better environment. Price effect was dominant over the income effect in Heutel's E-DSGE model (2012) thereby failing to meet the demand for clean air due to increased productivity. With the transformation taking place led by international environmental agreements, it is possible that the income effect may overcome the price effect in the future. Our study reveals that cyclical components of CO_2 emissions and GDP do not follow this pattern and they have decreased gradually. This indicates a stronger link between business cycles and CO_2 emissions. The procyclicality has modestly dropped in the period following the Kyoto Protocol in contrast with the significant reduction in CO_2 levels with respect to GDP.

6. Conclusion

Climate change poses a huge risk to the world and reducing GHG is crucial for the planet's future. During the economic development period after World War II, significant growth in world economies led to the over-concentration of GHGs in the atmosphere. Sustaining environmental quality without sacrificing economic growth is the goal of sustainable development policies today.

Global response to climate change started in 1994 when the UNFCCC took effect to limit GHGs. The first global action to address the emission problem was UNFCCC's Kyoto Protocol. Since 2005, various international environmental agreements have been in effect to limit emissions. As explained in the literature review part, several studies showed that these agreements led to reduction in emissions, but they also cause an output loss in the long-term. As the atmospheric concentration of CO_2 reaches historically high levels, procyclicality of CO_2 emissions poses a dilemma that forces the policymakers to limit economic growth to stabilize the emissions.

In this study, we investigated the impact of international environmental agreements on the link between CO_2 emissions and business cycles. Our main finding is that the historically strong correlation between CO_2 emissions and business cycles has started to weaken following the Kyoto protocol which required the industrialized countries to commit reductions in their CO_2 emissions. Empirical and analytical methods we employ to identify the trend of procyclicality of CO_2 emissions with respect to GDP indicate a gradual decrease from historical values for many countries.

The main finding of this study is that gradual decrease in the procyclicality of CO_2 emissions showed a different pattern in comparison to the levels which saw notable reductions following the international environmental agreements.

As future work, the underlying reasons for the different dynamics of cyclical components of the CO_2 emissions should be investigated.

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Etik Beyanı: Bu çalışmanın tüm hazırlanma süreçlerinde etik kurallara uyulduğunu yazarlar beyan eder. Aksi bir durumun tespiti halinde Fiscaoeconomia Dergisinin hiçbir sorumluluğu olmayıp, tüm sorumluluk çalışmanın yazarlarına aittir.

Yazar Katkıları: Bige KÜÇÜKEFE, çalışmada Giriş, Veri Seti, Ekonometrik Metodoloji ve Bulgular, Sonuç bölümlerinde ve veri toplama ile analiz aşamalarında katkı sağlamıştır. Nilüfer KAYA KANLI, çalışmada Giriş, Kuramsal Çerçeve ve Ampirik Literatür bölümlerinde ve veri toplama aşamalarında katkı sağlamıştır. 1. yazarın katkı oranı: %50, 2. yazarın katkı oranı: %50.

Çıkar Beyanı: Yazarlar arasında çıkar çatışması yoktur.

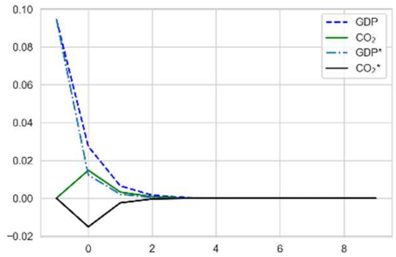
Ethics Statement: The authors declare that ethical rules are followed in all preparation processes of this study. In case of detection of a contrary situation, Fiscaoeconomia has no responsibility, and all responsibility belongs to the authors of the study.

Author Contributions: Bige KÜÇÜKEFE contributed to the study in the Introduction, Data Set, Econometric Methodology and Results, Conclusion sections, in the data collection and analysis stages. Nilüfer KAYA KANLI contributed to the study in Introduction, Theoretical Framework and Empirical Literature sections and data collection stages. 1st author's contribution rate: 50%, 2nd author's contribution rate: 50%.

Conflict of Interest: There is no conflict of interest between the authors.

APPENDIX

Appendix 1: Impulse Response Functions with Selected VAR Lags of the Countries



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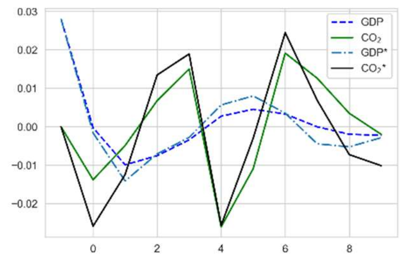

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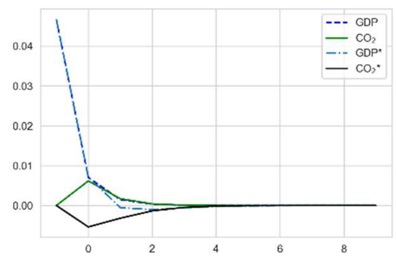

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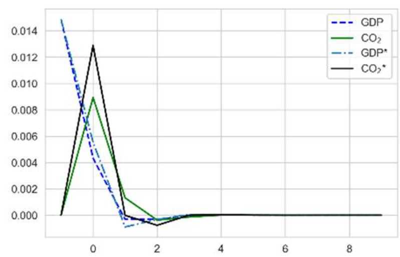

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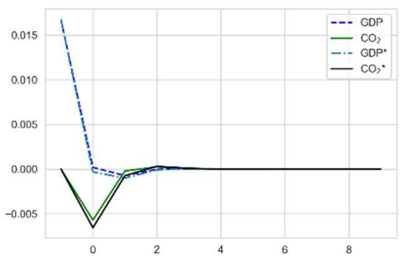
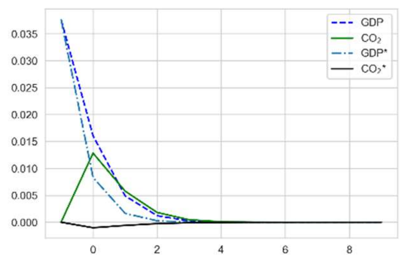
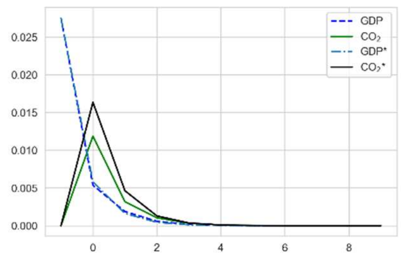
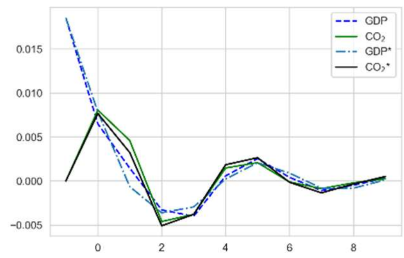


Belgium (lag=1)



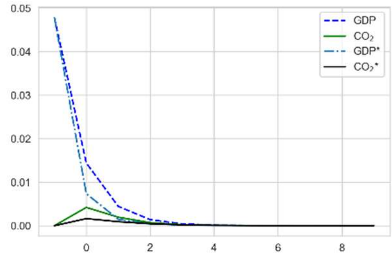
Brazil (lag=1)

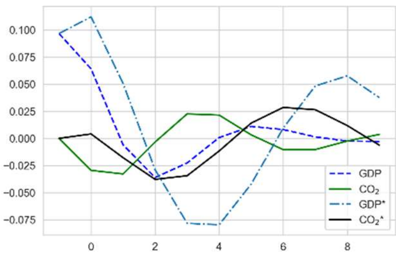




Bulgaria (lag=1)

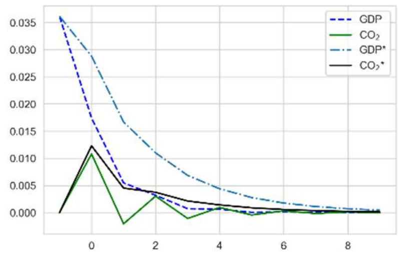
Canada (lag=2)

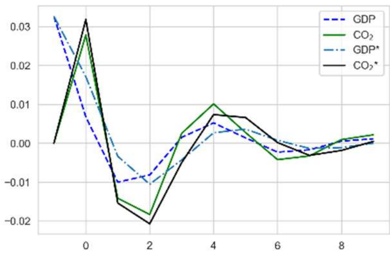




Chile (lag=1)

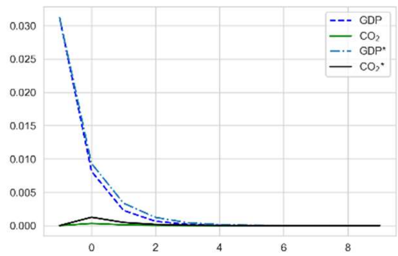
China (lag=2)

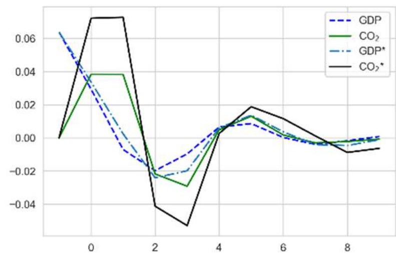




Colombia (lag=1)

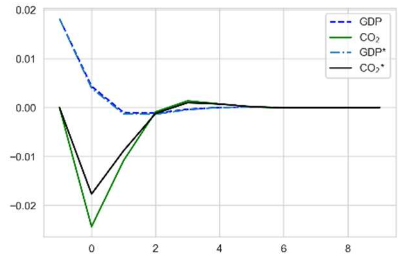
Costa Rica (lag=2)

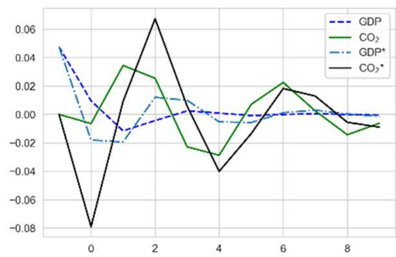




Czech Republic (lag= 1)

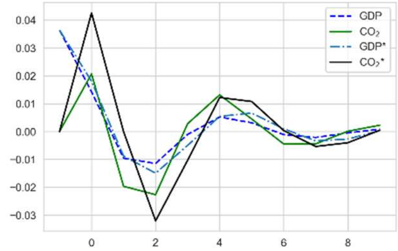
Dominican Republic (lag= 2)



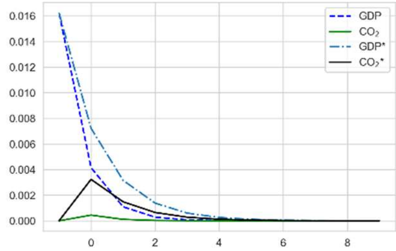


DR Congo (lag=1)

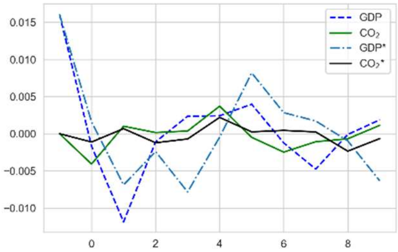
Ecuador (lag 2)



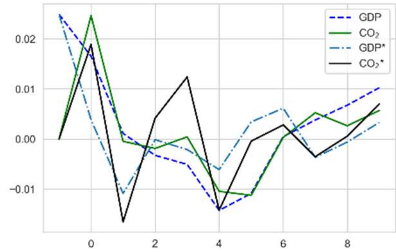
Ethiopia (lag=2)



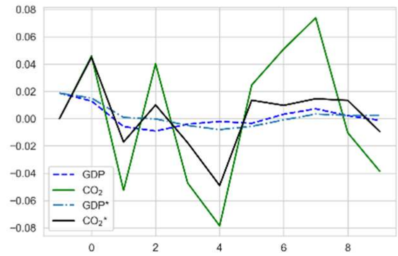
France (lag=1)



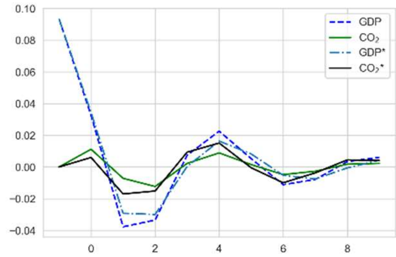
Germany (lag=4)



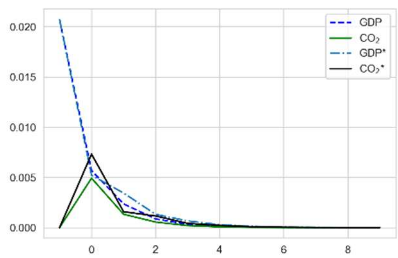
Greece (lag=4)



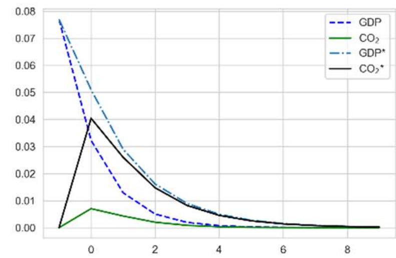
Guatemala (lag=4)



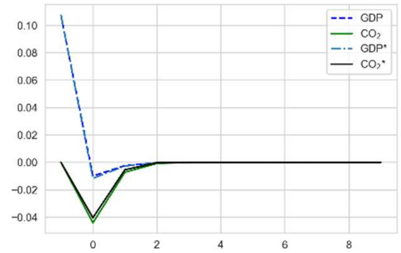
Hong Kong (China) (lag2)



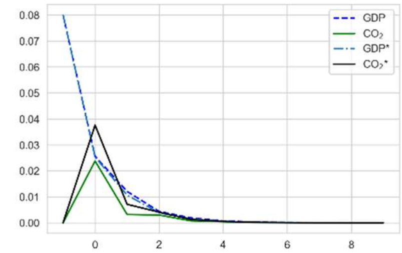
Hungary (lag=1)



Iran (lag=1)



Iraq (lag= 1)



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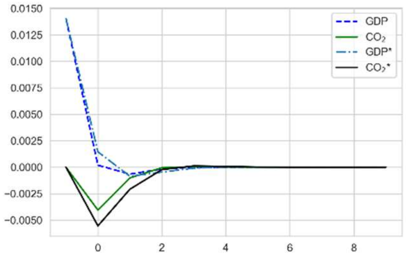
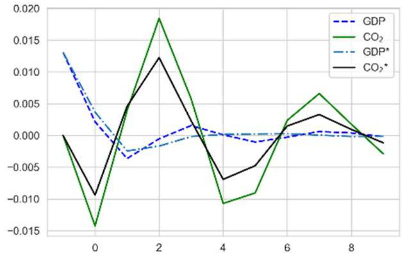
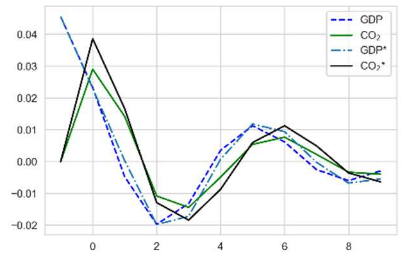


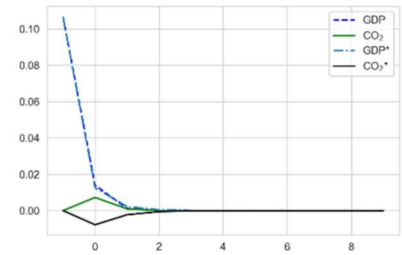
Italy (lag=1)



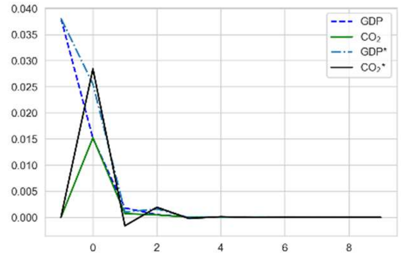
Jamaica (lag=2)



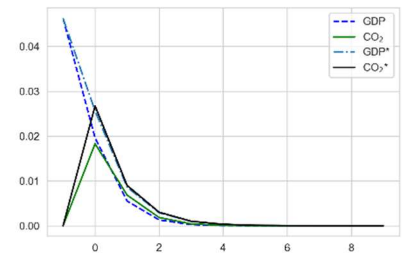
Kuwait (lag=2)



Malaysia (lag=1)



Mexico (lag=1)



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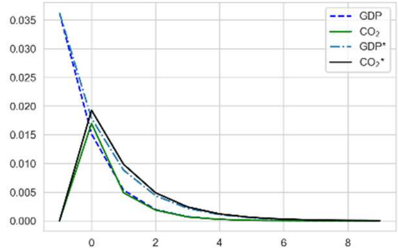
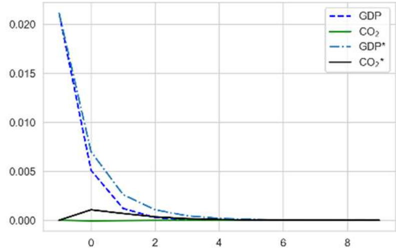
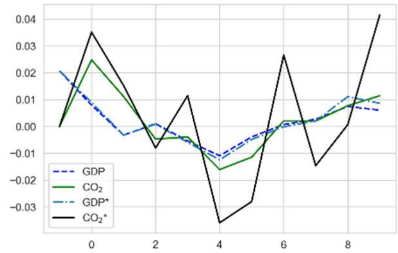


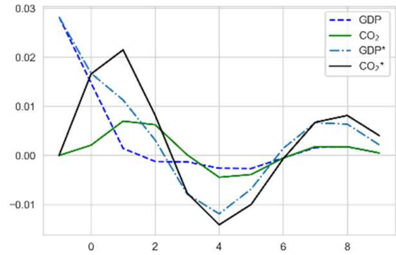
Philippines (lag=1)



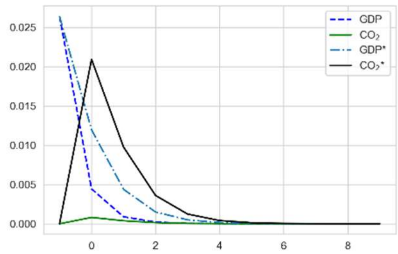
Poland (lag=1)



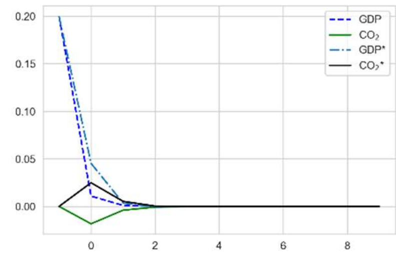
Portugal (lag=4)



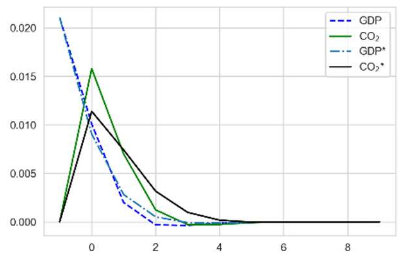
Romania (lag=2)



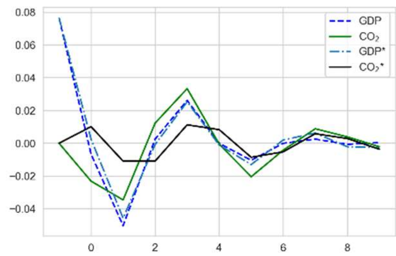
Russian Federation (lag= 1)



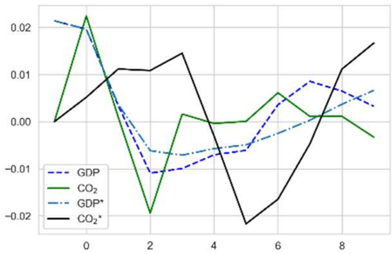
Singapore (lag =1)



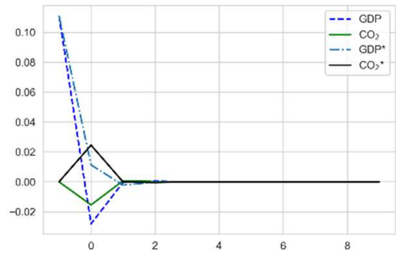
South Africa (lag= 1)



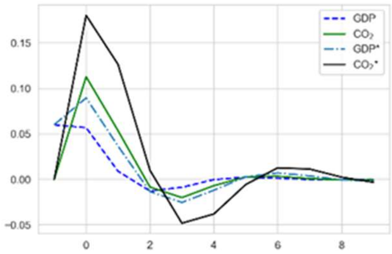
South Korea (lag=1)



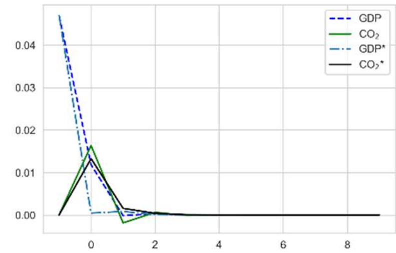
Spain (lag=4)



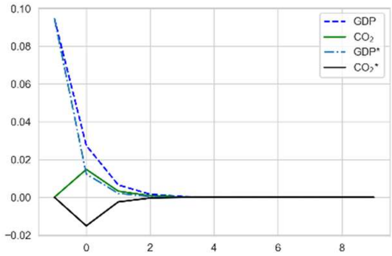
Taiwan (China) (lag=1)



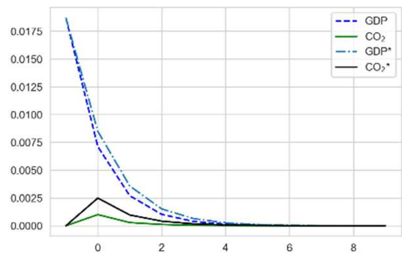
Thailand (lag=1)



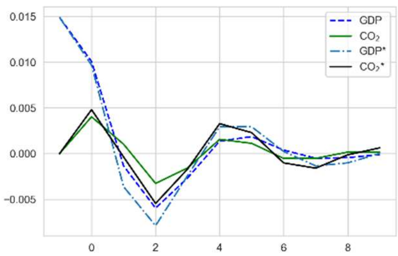
Tunisia (lag=1)



Turkey (lag=1)



United Kingdom (lag=1)



United States (lag=2)