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Climate Change-Trade Openness- Financial Depth Index-Economic Growth Nexus: A Study of G-20[1]

Burçin ÇAKIR GÜNDOĞDU*, Hakan KAHYAOĞLU**

ABSTRACT

This study examines the impact of climate change, which is seen as an environmental problem but has the power to affect the economic and financial structure, of trade openness, economic growth, and depth of financial markets in G-20 countries between 1980 and 2020. It has been concluded that the variables can be used as a policy tool in this context, where the development of trade openness and financial depth in the G-20 countries, which account for 80% of global trade, has the effect of reducing climate change by creating environmentally friendly economic growth. Panel Var and Holtz-Eakin, Newey, and Rosen GMM Estimator method were used in the study. In addition, it has been determined that action-response functions have an effect on the variables in the face of a shock to the carbon dioxide emission variable.

Keywords: Climate Change, Trade and Environment, Financial Depth Index, Panel-data Models, Economic Growth

JEL Classification: Q54, F18, P34

İklim Değişikliği-Ticari Açıklık-Finansal Derinlik-Ekonomik Büyüme İlişkisi: G-20 Üzerine Bir Çalışma

ÖZ

Bu çalışmada, bir çevre sorunu olarak görülen ancak ekonomik ve finansal yapıyı etkileme gücüne sahip olan iklim değişikliğinin, 1980-2020 yılları arasında G-20 ülkelerinde ticari açıklık, ekonomik büyüme ve finansal piyasaların derinliği üzerindeki etkisi incelenmiştir. Küresel ticaretin %80'ini gerçekleştiren G-20 ülkelerinde ticari açıklık ve finansal derinliğin geliştirilmesinin, çevre dostu ekonomik büyüme yaratarak iklim değişikliğini azaltıcı etkiye sahip olduğu bu bağlamda değişkenlerin bir politika aracı olarak kullanılabileceği sonucuna varılmıştır. Çalışmada Panel Var ve Holtz-Eakin, Newey ve Rosen GMM Tahmincisi yöntemi kullanılmıştır. Ayrıca karbondioksit emisyonu değişkenine gelen bir şok karşısında etki-tepki fonksiyonlarının değişkenler üzerinde etkili olduğu tespit edilmiştir.

Anahtar Kelimeler: İklim Değişikliği, Ticaret ve Çevre, Finansal Derinlik Endeksi, Panel Veri Modelleri, Ekonomik Büyüme

JEL Sınıflandırması: Q54, F18, P34

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* Res. Assist., İstanbul Gelisim University, Faculty of Economic, Administrative and Social Sciences, Department of Economics and Finance, bucakir@gelisim.edu.tr, ORCID ID: 0000-0002-8578-4929

** Prof. Dr., Dokuz Eylul University, Faculty of Economic and Administrative Sciences, Department of Economics, hakan.kahyaoglu@deu.edu.tr, ORCID ID:0000-0002-6031-7494

1. INTRODUCTION

The biggest dilemma of human beings is that, while continuing to exist, they consciously or unconsciously destroy the nature that ensures their existence. As a proverb of the Native Americans puts it: "When the Last Tree Is Cut Down, the Last Fish Eaten, and the Last Stream Poisoned, You Will Realize That You Cannot Eat Money”**.** So what is the relationship between "money" and "nature" mentioned in the Native Americans proverb? What is the role of economics, an interdisciplinary science, in making nature sustainable? These two questions form the starting point of the study's roadmap.

As a social science, economics cannot be considered in isolation from the other branches of science. An economist must be a psychologist in the study of consumer behaviour, a mathematician in the use of numbers, and a good artist in the drawing of graphs. In this context, researchers in the field of economics, with its multifaceted structure, attempt to explain the relationship between environmental problems and the economy through the inclusion of nature in their fields of study. They are aware that economic development and prosperity are linked to preserving natural resources. However, there are very few studies explaining the importance of the relationship between nature and the economy, and those which have been conducted tend to focus on a single issue, such as how global warming affects labour productivity. However, looking at the effects of global warming, which is one of the greatest problems of our time and which, if left unaddressed, will threaten biodiversity and human life, from a single perspective will not be sufficient to understand and solve the problem. Observing this gap in the literature, Pestel and Oswald (2021) wrote: "Why are there relatively few economists working on climate change? A Survey" In their study, they set out to investigate why few economists are working on climate change. In this context, this study aims to contribute to the literature. Unlike other studies, it examines the changing structure of the economy, finance and climate together.

The global risks caused by climate change cause human deaths and many people to become homeless. The cost of repairing the damages caused by homelessness of individuals, inability to pay their existing debts or risks arising from climate risks affects many financial institutions and the economies of many countries. Therefore, taking climate risks into account not only prevents individuals from becoming economically and socially vulnerable, but also enables economies to gain strength against climate risks by minimising the risks they create on economy and finance. In this context, the adoption of an environmentally friendly approach by financial instruments, the green instruments created for this purpose, the practices not to support enterprises that pollute the environment gain importance and increase the importance of financial markets that function to transfer money to the sectors. Another variable in the study is the openness to internationalisation. International trade has an impact on the economic growth rates of countries. However, the export and import of environmentally sensitive products, the measures applied on the trade of products that cause environmental pollution, the transport of commercial products, the use of transport vehicles that do not cause air pollution during the shipping phase reveal the importance of international trade. To summarise, trade and the sophistication of the financial structure may have a polluting effect on economic growth or may support a green economic growth through practices that prevent environmental pollution. Therefore, the rate of trade openness and the depth of financial markets can be used as an economic policy tool. This idea is supported by many studies (Hua,2023; Goswami,2023; Chhabra,2023; Karedla et.al.,2021; Allan et.al., 2019; Tamazian et. al.,2009; Linnenluecke et.al.,2016)

The aim of the study is to analysed the interaction between climate change, trade openness, financial depth index and economic growth. In this context, selected countries from the G-20 (Turkey, Italy, France, Canada, Germany, Mexico, China, Japan, Russia, Brazil, Argentina, South Africa, Australia, UK, India, USA, Indonesia, China, Saudi Arabia and Korea) are used. Panel VAR method is implemented using data from 1980-2020.

In the econometric analysis section, descriptive statistics are first included. Cross-sectional dependence and heterogeneous/homogeneous structure of the series are determined using the Pesaran (2008) test. In the second stage, the CADF and CIPS tests, which are second-generation unit root tests, are applied to the heterogeneous data with cross-sectional dependence, and the stationarity of the series are tested. In the third stage, Panel variance analysis is applied. PVAR models are a useful forecasting tool for macroeconomic applications that can account for additional data from the cross-sectional dimension (Camehl, 2023). Panel VAR models also help examine various transmission problems between individual panel units (members) that cannot be addressed in simple VAR models. However, the optimal lag length must first be determined to apply the panel var model. Braun and Mittnik (1993) found in their study that determining the lag length is important for the panel var model and that an incorrect determination of the lag length will lead to biased results in the analyses. In addition, if the lag values are set longer than they are, the variables take on higher values than they are (Seddighi, Lawler &, Katos 2000). In this context, the lag length is set to "1" and the application is calculated according to this lag value. The results of the applied Holtz-Eakin, Newey and Rosen GMM estimator indicate that carbon dioxide emissions are a significant variable in explaining the financial depth index, GDP per capita and trade openness.

The fourth stage of the study is to carry out impact response analyses. Impulse Response Functions are used to examine the effects of shocks in the VAR system. In line with this information, the result of the impulse-response functions obtained from the data set of the study is that, in the face of a shock on the carbon dioxide emission variable, the depth index of financial markets first increases and then decreases on the trade openness variable, while the effect of the shock disappears within 4-5 years has been observed. On the variable of gross domestic product per capita, it showed a structure that decreased and then became stable and has been observed that the effect of the shock disappears within 4-5 years.

Compared to studies in the literature, it has been observed that there are numerous studies examining the relationship between financial depth index and climate change. These studies only address the relationship between climate change and financial depth, or only the relationship between climate change and openness, and do not address what effect the economic growth, trade openness and financial depth triangle has on carbon dioxide. In this respect, the study fills the gap in the literature. Moreover, the methodology of the study differs from the Granger, Panel ARDL and Panel Var and Holtz-Eakin, Newey and Rosen GMM Estimator models in the literature by including the impulse response function. Since the study is a new subject, it has limitations in terms of data. At this point, researchers will have the opportunity to update the study in a more comprehensive range of years in the coming years. In addition, the development of green bonds, the widespread use of green financial instruments and the more comprehensive data obtained will enable the study to be elaborated and investigated in a wider scope.

2. LITERATURE REVIEW

Studies on the relationship between financial development, trade openness, economic growth and the environment have accelerated in recent years. The majority of these studies only investigate the relationship between financial development and environmental quality or trade openness and environmental quality. The majority of studies examining the relationship between financial development, trade openness and the environment together have included the renewable energy consumption variable and examined the relationship between the variables within the framework of causality. While providing summary information of the studies in the literature section, the studies were selected taking into account the years 2014-2024 in order to include current studies. A brief summary of the studies is as follows:

Shuaibu et al. (2020), examined the effects of climate change on agricultural productivity in Nigeria during the period between 1960 and 2017 using the ARDL method. The researcher concluded that global climate change, which is considered an alarming concept in many countries, creates high rainfall rates in Nigeria, increases food production, and therefore contributes positively to the economy by reducing commercial dependence on the food sector.

Can et al. (2022), examined the trade-environment link using Granger causality tests in a sample study covering 31 OECD countries over the period 2007-2017. According to the results of the study using ecological footprint, per capita income, per capita energy consumption, and green trade openness index, there is a causal relationship between the presence of green products in the trade basket of countries and the ecological footprint. In this context, countries play an important role in reducing environmental pollution and therefore reducing the effects of climate change by taking measures that take the environment into account in their commercial relations.

Afesorgbor and Demena (2022), base their study on two basic hypotheses. These; "An increase in trade openness leads to a significant change (i.e. increase or decrease) in environmental emissions" and "Trade emission elasticity differs qualitatively and quantitatively for developed and developing countries." The main reason for determining these hypotheses is the studies done in the literature. The results of the studies are not based on definitive judgment. The researcher found that a 1% increase in a country's trade openness leads to an increase in emissions of between 0.02% and 0.06%, using a bivariate FAT-PET analysis.

Ansari et al. (2020) looking at data from 1971-2013 for countries with the highest carbon dioxide emissions, time series, and Granger causality tests to try to answer the question of how the trade openness of these countries affects carbon dioxide emissions. The results obtained are based on the USA, Canada, and Iran. They show that trade openness is a determinant of the carbon dioxide emissions variable in Saudi Arabia, but the Kuznets curve hypothesis is only valid for the USA.

Hakimi (2019), highlights the impact of trade openness on environmental quality within the framework of the role of institutions. In the study covering 143 countries, first all countries were analyzed and then the study was repeated by grouping them as developed countries and developing countries. In the section where all countries are analyzed, it is concluded that trade does not have a significant effect on environmental quality, while grouped studies reveal how trade harms environmental quality and the role of institutions in protecting the environment. In this context, it can be concluded that the development levels of the countries are an important factor. Thi et.al. (2023), similar to Hakimi (2019)'s study, examined the relationship between trade openness and carbon dioxide emissions in 53 countries. According to the results of the study covering the years 1990-2019, trade openness is an important policy tool to improve environmental quality. Sana et. al. (2021), produced a more comprehensive study by adding the financial development variable in addition to these studies. The findings of the study examined based on a panel sample of 92 countries for the period 1990 - 2018 are that carbon emissions have an impact on the level of financial development and trade openness. The author argues that it is still possible to reduce carbon emissions and achieve sustainable development goals. This is possible by abandoning fossil fuels and strengthening green energy sources.

Jamel and Maktouf (2017), aimed to explain the relationship between economic growth and environmental degradation, financial development, and trade openness in their study. In his research, they examined 40 European countries using the panel method, between 1985 and 2014. The findings confirm the existence of a bidirectional causality relationship between the variables.

Darwish, Khudari, and Othman (2023), explained the relationship between carbon dioxide emissions by taking into account the development level of the countries. It has been found that there is a strong relationship between financial development and environmental performance indices. However, study results vary according to the development levels of countries. Understanding the complex relationship between financial development and environmental performance is also important in terms of economic policies to be implemented.

Rajpurohit and Sharma (2020) aim to analyse the impact of financial development, energy consumption and foreign direct investment variables on carbon emissions. They focus on developing Asian countries. They conducted studies in India, Pakistan, Bangladesh, Sri Lanka and Malaysia between 1980 and 2014. As a result of the investigations, it was observed that a developed financial structure reduces carbon emissions, but carbon emissions increase in countries with a medium level of financial development.

Ren, Zhao, Yuan, and Li (2023) analyzed the short- and long-term effects of financial development on carbon emissions with the Pooled Average Group estimation method using a sample of 30 provinces in China from 2000-2019. The findings show that financial development significantly reduces carbon emissions in the long term, but no significant relationship is observed in the short term. The author makes three important findings in his study. First, the emission reduction effect of financial development is stronger in provinces with low poverty levels. Second, financial development reduces carbon emissions at the regional level. Third, the way to mitigate climate change suggests improving the financial system in China. Ayache, Barhoumi, and Hammas (2016) examined the relationship between economic growth, financial development, trade openness, and carbon emissions in European Countries between 1985 and 2014. According to the test results analyzed using the Panel-General Linear Model (GLM) method by considering 40 European countries, economic growth and financial development, economic growth and trade openness, economic growth and CO2 emissions, financial development and trade openness and There is a bidirectional causality relationship between trade openness and CO2 emissions. In addition, the study confirms the existence of the environmental Kuznets curve.

Nasir et al. (2019), looking at data from 1982-2014 for ASEAN-5 countries, examined the effects of foreign direct investments, financial development and economic growth on climate change, and the findings of the study showed that financial development, economic development and foreign direct investments are related to the environment in the long term. in the direction. The study also supports the Pollution Haven Hypothesis for ASEAN-5 countries.

Ehigiamusoe and Lean (2019) analyzed the impact of economic growth, energy consumption, financial development on carbon emissions and the causality link between them, through a sample of 122 countries. At the same time, the researcher divided the sample into different income groups and tested whether income status had any effect on the variables. The findings obtained in the study determined that income level has different results on carbon emissions. It was concluded that economic growth and financial development reduce carbon emissions in the high income group and increase them in the low and middle income groups.

Usman et. al.(2022) investigated the impact of financial development, economic growth, trade openness, non-renewable and renewable energy use on carbon dioxide (CO 2) emissions in Pakistan between 1990 and 2017. The findings of the study observed that financial development and the widespread use of renewable energy significantly improve environmental quality, while economic growth, non-renewable energy consumption and openness to trade trigger the deterioration of environmental quality.

Li et. al. (2022) investigated the relationship between financial deepening and environmental quality using data from BRICS countries covering the years 1990-2019. While conducting this research, the Panel ARDL method was used. It has been found that financial deepening has a positive effect on improving environmental quality in the long term.

Yang et. al. (2022) investigated how urbanization, financial development, and trade openness impact carbon emissions in China. The author argues that trade openness makes it easier for countries to purchase and use new clean technologies from other countries that reduce carbon emission levels in investor countries. It has been determined that financial development has a negative and significant effect on carbon emissions.

Zhang, Liu and Bea (2017) examined the existence of the environmental Kuznets Curve and investigated how trade openness, economic growth, and energy consumption impact carbon emissions. In the light of the findings, the study emphasizes that supporting and encouraging trade openness not only improves environmental quality but also supports economic growth.

Table 1: Literature

Authors	Country/Region	Data	Methods	Results
Thi et.al. (2023)	53 Countries	1990-2019	FMOLS, DOLS, GMM System	Trade openness improves environmental quality.
Ren, Zhao, Yuan ve Li (2023)	30 provinces of China	2000-2019	Pooled Average Group estimation method	Financial development significantly reduces carbon emissions in the long run.
Can et. al. (2022)	31-OECD	2007–2017	Granger Coentegration Test	Green products reduce carbon emissions via trade openness
Usman et. al.(2022)	Pakistan	1990-2017	Bound *F*-test and Johansen cointegration tests	Financial development and renewable energy consumption significantly increase environmental quality.
Li et al. (2022)	BRICS	1990–2019	Nonlinear autoregressive distributed lag (ARDL)	Financial deepening improves environmental quality.
Yang et. al. (2022)	China	1969–2019	Toda-Yamamoto Granger causality test	Financial development has a negative and significant effect on carbon emissions.
Sana et.al.(2021)	92 Countries	1990 – 2018	Pooled ordinary least squares, the fixed effects model and the system generalized method of moments with panel	The impact of trade on environmental quality is related to the development level of the country.
Ansari et.al. (2020)	Selected 10 Countries	1971-2013	Granger Coentegration Test	Trade increases carbon emissions.
Rajpurohit and Sharma (2020)	Developing Asian countries	1980-2014	Pooled mean group	The relationship between financial development and carbon emissions depends on the development level of countries.
Hakimi and Hamdi (2019)	143 Countries	2006–2015	Panel data analysis	The impact of trade on environmental quality is related to the development level of the country.

Nasir et al. (2019),	ASEAN-5	1982-2014	Dynamic Ordinary Least Squares (DOLS) and Fully Modified OLS (FMOLS)	Economic growth, financial development and FDI leads to an increase in environmental degradation.
Ehigiamusoe and Lean (2019)	122 countries	1990–2014	First-generation and second-generation cointegration	Economic growth and financial development reduce carbon emissions in the high income group and increase them in the low and middle income groups.
Zhang, Liu and Bea (2017)	Newly industrialized countries (NICs-10)	1971 to 2013.	Granger Coentegration Test	Trade increases carbon emissions
Jamel and Maktouf (2017)	40 European Countries	1985-2014	Panel data analysis	There is a bidirectional causal relationship between environmental degradation, financial development and trade openness.
Ayache, Barhoumi ve Hammas (2016)	40 European Countries	1985-2014	Panel GLM Model	There is a bidirectional causal relationship between economic growth, financial development, trade openness and carbon emissions.

Resource: Authors

Unlike the studies in the literature, our study examined the effect of the relationship between financial depth index, economic growth and trade openness on climate change by including the financial depth index model. In addition, causality analysis and pooled panel data method were generally used in the studies, but the Panel Var and Holtz-Eakin, Newey and Rosen GMM method was not used. In this respect, the study differs from other studies with its research method.

Following the above literature survey, this study intends to explore the following hypotheses:

H_1: Climate change, which is seen as an environmental problem, has become an internal variable of the economy by affecting international trade, economic growth, and financial depth index.

H_2: There is an interaction between climate change, financial depth index, economic growth, and trade openness in G-20 countries, representing approximately 85 percent of GDP, 80 percent of global trade, and 60 percent of the world's population.

H_3: Trade openness and financial depth index can be used as policy tools to reduce the effects of climate change.

3. DATA AND METHODOLOGY

To investigate the impact of climate change on global trade and financial markets, the G20 countries (UNDP, 2019), which represent approximately 85 percent of GDP, 80 percent of global trade, and 60 percent of the world's population, were examined. G-20 countries include 19 member countries and the European Union (EU). To avoid double-counting some countries, the European Union is excluded from our analysis. Therefore, only 19 member countries within the G-20 were included in the study. These countries are: Turkey, Italy, France, Canada, Germany, Mexico, China, Japan, Russia, Brazil, Argentina, South Africa, Australia, Australia, United Kingdom, India, USA, Indonesia, Saudi Arabia, and Korea.

To be examined in the econometric analysis of the study, annual carbon dioxide emissions(co2) were considered as the dependent variable, and gross national product per capita (GDP), openness rate (open), and financial markets depth index (fdept) were considered as independent variables between 1980 and 2020. The data were taken from the official website of the World Bank (data.worldbank.org) and Stata 17 and Eviews 10 package programs were used. Unlike other data, openness data was obtained by the author by dividing the sum of imports and exports, in other words, foreign trade volume, by GDP.

The following model was created to explain that climate change, defined as an environmental problem, also affects the economic and financial structure. The first version of the model of the study is as follows;

$$Co_{2i,t} = f\ (GDP_{i\ t},\ OPEN_{\ i,\ t},\ GDP_{\ i,\ t},\ FDEPT_{i,\ t}) \quad (1)$$

The variables are transformed into their natural logarithms, which are shown in the following:

The panel model can be defined as in the following equation:

$$LNCO_{2it} = \alpha_{it} + \beta_{it}LNGDP_{it} + \beta_{2\ it}LNOPEN_{it} + \beta_{3\ it}LNFDEPT_{it} + \varepsilon_{it} \quad (2)$$

Here, i indicates the country, t indicates the year, α indicates the constant variable and ε_{it} indicates the error term of the model.

Panel var analysis will be applied in the study. The Var model, which we encounter in time series, could be applied to panel data through Holtz-Eakin, Newey, and Rosen (1988). Holtz-Eakin, Newey, and Rosen (1987), in their study using wage and hour data, stated that until the day the study was conducted, the var technique was mostly used for macroeconomic time series (Taylor, 1980), but this technique was used in dynamic relationships such as individuals' working hours and wages. The panel var model is also a dynamic model by its nature. For this reason, Holtz-Eakin, Newey, and Rosen predicted the application of the var model in panel series. Holtz-Eakin, Newey, and Rosen GMM Estimator (Forward Orthogonal Deviations Method) will be applied in the study. Using the first difference method in panel var methods created with the GMM model causes data loss. Therefore, in the study, the panel var model will be calculated with the forward orthogonal deviations method of Arellano and Bover (1995), which does not cause data loss. In this context, the articles of Abrigo and Love (2016) and Love and Zicchino (2006) were used in the analysis phase of the study.

4. EMPIRICAL ANALYSIS

In this section, the first cross-sectional dependency and homogeneity tests will be performed on the data. The second stage is to analyze the stationarity of the series. Then, the Panel var method, impulse response function, and prediction error variance decomposition will be performed. Finally, panel causality tests will be included.

4.1. Homogeneity Test

The homogeneity test of Pesaran and Yamagata (2008) provides the advantage of observing that the slope coefficients have homogeneous/heterogeneous characteristics for each country. According to the test, if the probability value of the delta and corrected delta test statistics of the model is greater than the 0.05 significance level, the slope coefficients are homogeneous, and if it is less than the 0.05 significance level, the slope coefficients are heterogeneous. Considering the results in the table 2, the value of the delta tilde and corrected delta tilde test statistics added to the model is less than 0.05. Therefore, it was determined that all slope coefficients of the variables in the model did not have the same value, in other words, they were heterogeneous.

Table 2: Pesaran and Yamagata (2008) Homogeneity Test

	Delta	*P-value*
Delta tilde	*47.099*	*0.000****
Adjusted delta tilde	*50.263*	*0.000****

Resource: Authors

Notes: ∗, ∗ ∗ and ∗ ∗ ∗ indicate significance at the 10%, 5%, and 1% level, respectively.

4.2. Cross-Section Independence Test

Many tests are investigating cross-sectional dependency in the literature. However, the sample taken in the study becomes important when deciding which test to apply. For example, when the N value is 10 or less, the Pasaran (2004) CD test is used (Pesaran, 2004). Cross-section dependence can arise for various reasons, usually due to spatial correlations, economic distance, and shocks that are not commonly observed (Anselin, 1988). In this context, Pesaran stated that the CD test is used for heterogeneous dynamic models with multiple breaks and small/large N and T. has shown that it can be applied to a wide variety of models, including non-stationary dynamic models (Sarafidis, Yamagata, and Robertson, 2009:3).

Pesaran (2004) proposed two approaches to test cross-section dependence. One of these is Breusch and Pagan's (1980) LM test. The other test is the CD test. Paseran (2004) considered the symbol CD as an abbreviation for cross-sectional dependence.

In a series where cross-sectional dependence occurs, erroneous and deviant evaluations occur. In this context, Breusch-Pagan's (1980) LM test, Pesaran, Ullah, and Yagamata's (2008) LM adj test, and Pesaran's (2004) CDlm tests were used in the study to investigate the cross-sectional correlation. There are 19 countries (N = 19) within the scope of the research and time was determined between 1980-2020 (T = 41). Therefore, the time dimension (T) is larger than the horizontal section dimension (N) (T>N). The results of the Breusch-Pagan (1980) LM test, Pesaran, Ullah, and Yagamata (2008) LM adj test, and Pesaran (2004) CDlm tests, which are three basic tests used to investigate the cross-sectional correlation under a condition where the time dimension is greater than the cross-sectional dimension, are given in the table 3. The hypotheses created for these tests are as follows;

H_0: There is no cross-section dependence

$H_{1:}$ There is a cross-sectional dependence

Table 3: Cross-Section Dependency Test Results

Test	**Statistic**	**p-value**
LM	751	0.0000***
LM adj*	113.3	0.0000***
LM CD*	6.886	0.0000***

Resource: Authors

Determining cross-sectional dependence is important to draw the road map of econometric analysis. If the H_0 hypothesis is accepted, in other words, in a situation where there is no cross-sectional dependence, first-generation unit root tests will be applied. In case the H_0 hypothesis is rejected, the application will be carried out with second-generation unit root tests (Baltagi, 2008: 284). According to the findings, the probability values of all test results are less than 0.05. Therefore, the existence of a cross-sectional correlation between the variables was accepted.

4.3. Pesaran (2007) CADF Unit Root Test

Cross-sectional dependence can cause serious problems when testing the null hypothesis of the unit root. Therefore, great efforts have been devoted to the development of "second-generation" testing applications that are resistant to such dependencies (Breitung and Pesaran, 2008). The two most commonly used tests to obtain more accurate results to eliminate inconsistency, cross-section dependence, and heterogeneity problems are CADF and CIPS tests (Westerlund, Hosseinkouchacck, and Solberger:2013,2).

The advantage of the CADF test is that it allows for obtaining accurate results in both conditions, N<T and T<N (Pesaran, 2007:269). The arithmetic mean of the calculated CADF tests provides information about the CIPS test statistics. While CADF investigates stationarity at the unit level, CIPS is used to investigate the stationarity of the panel in the general framework (Pesaran, 2007).

CADF (Crosssectional Augmented Dickey-Fuller) unit root test gains importance as it has the advantage of being able to examine the stationarity of the series under both conditions, N<T and N>T. The hypotheses of the test are established as follows:

H_o *= There is a unit root in the series.*

H_1*: = There is no unit root in the series.*

The obtained values are compared with the critical values in the article "A Simple Panel Unit Root Test In The Presence Of Cross-Section Dependence" by Pesaran (2007). In the case of calculated CADF ist> table value, the null hypothesis is rejected. Therefore, the alternative hypothesis "there is no unit root in the series" is accepted.

In light of this information, Model A and Model B CADF test results, with and without trends, are given in the table. In the CADF test critical table values with a trendless structure, the critical values are -2.360 for 1%, -2.200 for 5%, and -2.110 for 10%, and in Model A with Trend, the critical values are -2.850 for 1%, -2.710 for 5% and -2.630 for 10%. The values were taken according to the critical table values of Pesaran (2007). The number of lags is taken as 1. While Model A contains the CADF second generation panel unit root test results, in Model B, the results obtained by taking the first difference of the series are shown in the table.

According to the probability values (P value) of the CADF second generation panel unit root test trendless Model A, the LNCO2 variable has a value greater than 0.05 (0.692), while the LNGDP (0.014), LNOPEN (0.043), LNFDEPT (0.000) variables have a value of 0.05. It has a lower value than. In line with these results, LNCO2 has a unit root structure, and LNGDP, LNOPEN, and LNFDEPT variables have a stationary structure. Compared to Model A, which has a trendy structure, only the FDEPT variable is observed to have a stationary structure. Unlike Model A, in Model B, the first difference of all variables in the series is taken. According to the results of Model B with and without trend, it was observed that all variables had a stationary structure.

Table 4: CADF Test Results (Model A)

Model A				**Critical Value**		
Variables	**t-bar**	**Z(t-bar)**	**P değeri**	**%1**	**%5**	**%10**
LNCO2	-1.659	0.501	0.692	-2.360	-2.200	-2.110
LNGDP	-2.260	-2.210	**0.014**	-2.360	-2.200	-2.110
LNOPEN	-2.151	-1.719	**0.043**	-2.360	-2.200	-2.110
LNFDEPT	-2.733	-4.345	**0.000**	-2.360	-2.200	-2.110
Model A (model with trend)				**Critical Value**		
LNCO2	-2.181	0.768	0.779	-2.850	-2.710	-2.630
LNGDP	-2.262	0.376	0.646	-2.850	-2.710	-2.630
LNOPEN	-2.437	-0.466	0.321	-2.850	-2.710	-2.630
LNFDEPT	-2.983	-3.099	**0.001**	-2.850	-2.710	-2.630

Table 5: CADF Test Results (Model B)

	Model B ((model with trend)					
	t-bar	Z(t-bar)	**P değeri**	**Critical Value**		
				%1	**%5**	**%10**
LNCO2	-4.124	-10.625	0.000	-2.360	-2.200	-2.110
LNGDP	-3.971	-9.935	0.000	-2.360	-2.200	-2.110
LNOPEN	-4.151	-10.748	0.000	-2.360	-2.200	-2.110
LNFDEPT	-4.810	-13.723	0.000	-2.360	-2.200	-2.110
Model B (model with trend)						
LNCO2	-4.147	-8.712	0.000	-2.850	-2.710	-2.630
LNGDP	-4.227	-9.096	0.000	-2.850	-2.710	-2.630
LNOPEN	-4.307	-9.483	0.000	-2.850	-2.710	-2.630
LNFDEPT	-4.812	-11.919	0.000	-2.850	-2.710	-2.630

Note: Pesaran's (2007) CADF test was calculated by taking the number of lags as 1 in Model B. The model includes both constant and trend values. Critical values in the model were taken from Pesaran's (2007) article "A Simple Panel Unit Root Test In The Presence Of Cross-Section Dependence".

4.4. CIPS Unit Root Test

After calculating the CADF test, the CIPS test statistic is calculated by taking the arithmetic mean of this test. The purpose of using the CIPS test in the study is that while the CADF test performs unit root testing for country data separately, the CIPS test provides information about the general stationarity structure of the panel. Another advantage is that it gives consistent results in series with small cross-section (N) and time (T) dimensions (Arestis, Chortareas, & Magkonis, 2014).

CIPS (Cross Sectionally Augmented IPS) test statistics results are obtained by taking the arithmetic average of CADF second-generation panel unit root tests. CIPS test statistics provide information about the stationary/unit-rooted structure of the overall panel. The table below includes CIPS test results for Model A and Model B and critical value information for 1%, 5%, and 10%. The structure of the series is determined by comparing CIPS values with the critical value table of Pesaran (2007). The fact that the CIPS values are higher than the table critical values is interpreted as the series being stationary (Pesaran, 2007). In light of this information, it was concluded that while only the LNFDEPT variable had a stationary structure in Model Ave B in the fixed model, all variables had a stationary structure in the trending model.

Table 6: CIPS Unit Root Test Results

Variables	Model A	Model B
LNCO2	-1.806	-2.283
LNGDP	-2.109	-2.148
LNOPEN	-2.002	-2.156
LNFDEPT	-2.760***	-3.007***
CIPS Critical Value		
%1	-2.36	-2.85
%5	-2.2	-2.71
%10	-2.11	-2.63

Note: For critical values, the critical value table of Pesaran (2007) was used. The stationarity for the 1% critical value is shown as "***", the stationarity for the 5% critical value is shown as "**", and the stationarity for the 10% critical value is shown as "*". In the study, the lag value was determined as 1.

Table 7: CIPS unit root test (model with trend)

Model with trend		
Variables	**Model A**	**Model B**
LNCO2	**-5.515*** **	**-5.552*** **
LNGDP	**-5.122*** **	**-5.350*** **
LNOPEN	**-5.015*** **	**-5.140*** **
LNFDEPT	**-5.751*** **	**-5.935*** **
CIPS Critical Value		
%1	**-2.36**	**-2.85**
%5	**-2.2**	**-2.71**
%10	**-2.11**	**-2.63**

Note: For critical values, the critical value table of Pesaran (2007) was used. The stationarity for the 1% critical value is shown as "***", the stationarity for the 5% critical value is shown as "**", and the stationarity for the 10% critical value is shown as "*". In the study, the lag value was determined as 1.

4.5. Panel Vector Autoregression (Pvar) Approach

Macroeconomic analyses and policy evaluations require greater attention to the existing interdependencies and national economic relationships between sectors, markets, and countries. PVAR models are a useful forecasting tool for macroeconomic applications with the ability to take into account additional data from the cross-sectional dimension (Camehl, 2023).

Panel VAR analysis is based on the selection of the optimal lag order and moment condition in the panel VAR specification (Traoré, 2018: 29). Braun and Mittnik (1993) found in their study that determining the lag length is important for the panel var model, and that incorrectly determining the lag length will cause deviated results in the analyses. Additionally, when lag values are set longer than they are, variables take higher values than they are (Katos, Lawler, & Seddighi, 2000). In this context, the lag length results are calculated below.

In the table 8, the Hansen J statistic is indicated as "J", and the J value is the probability value. According to this test, the lag value that has the highest J statistic but the lowest J test probability value, MBIC, MAIC, and MQIC critical values is selected (Andrews and Lu, 2001). The test result showed the values obtained up to 4 lags, and the lag value with the smallest critical value was determined as 1. The PVAR model for all countries discussed in this section of the study was determined as the appropriate model with a lagged panel, taking into account the selection criteria.

Table 8: Optimal lag length selection

Lag	CD	J	J value	MBIC	MAIC	MQIC
1	-1.823585	59.0673	.6511292	-343.5931	-68.9327	-176.3516
2	-5.815298	38.74016	.8275427	-263.2552	-57.25984	-137.8241
3	-17.4082	16.63634	.9884713	-184.6939	-47.36366	-101.0731
4	-248.9237	3.658039	.9993777	-97.00707	-28.34196	-55.1967

Note: *Calculated by the author. J in the table is Hansen J statistic; MBIC is modified Bayesian information criterion; MAIC is modified Akaike information criterion; MQIC stands for modified Hannan Quinn information criterion.*

4.6. Holtz-Eakin, Newey, and Rosen GMM Estimator (Forward Orthogonal Deviations Method)

Panel Var test results were determined with the Holtz-Eakin, Newey, and Rosen GMM Estimator, with the lag length set to 1, and are shown in Annex-1. Considering this information, variables with probability values less than 0.05 significance level are indicated with the symbol "*". In light of this information, it is concluded that the explanatory power of values that are less than the critical value of 0.05 and marked with an asterisk is significant. Holtz-Eakin, Newey, and Rosen GMM Estimator (Forward Orthogonal Deviations Method)

According to the results,

- The lagged value of the variables of gross national product per capita, openness rate, and depth index of financial markets is meaningful in explaining the carbon dioxide emission variable.
- The one-lagged value of the variables of gross national product per capita, openness rate, and depth index of financial markets is meaningful in explaining the variable of gross national product per capita.
- The lagged value of the carbon dioxide emission variable and the depth index of financial markets is significant in explaining the openness ratio.

4.7. Impulse Response Functions

Impulse response functions are used to examine the effects of shocks in the VAR system. It traces the effect of a shock of one unit or one standard deviation to an endogenous variable on all endogenous variables in the VAR model. All other variables and shocks are held constant. (Rehal,2022).

The results of the impulse response functions are shown in the figure. In the first line, the financial depth index of the markets, the openness rate in the second line, the gross national product per capita in the third line, and the effects of any shock in the carbon dioxide emission variable are shown in the last line. At the same time, the relationships between these variables and themselves are also discussed.

A shock occurring in the depth index of financial markets reacts with the openness ratio first increasing and then decreasing, and the effect of this shock lasts for approximately 5-6 years and then disappears. Likewise, the effect of a shock occurring in the depth index of financial markets on the gross national product per capita lasts approximately 5-6 years.

- In the face of a shock on the carbon dioxide emission variable, the depth index of financial markets first followed an increasing and then decreasing trend. It has been observed that the effect of the shock disappears within 4-5 years.
- In the face of a shock on the carbon dioxide emission variable, the openness rate first followed an increasing and then decreasing trend. It has been observed that the effect of the shock disappears within 4-5 years.
- In the face of a shock on the carbon dioxide emission variable, gross national product per capita showed a structure that decreased and then stabilized. It has been observed that the effect of the shock disappears within 4-5 years.

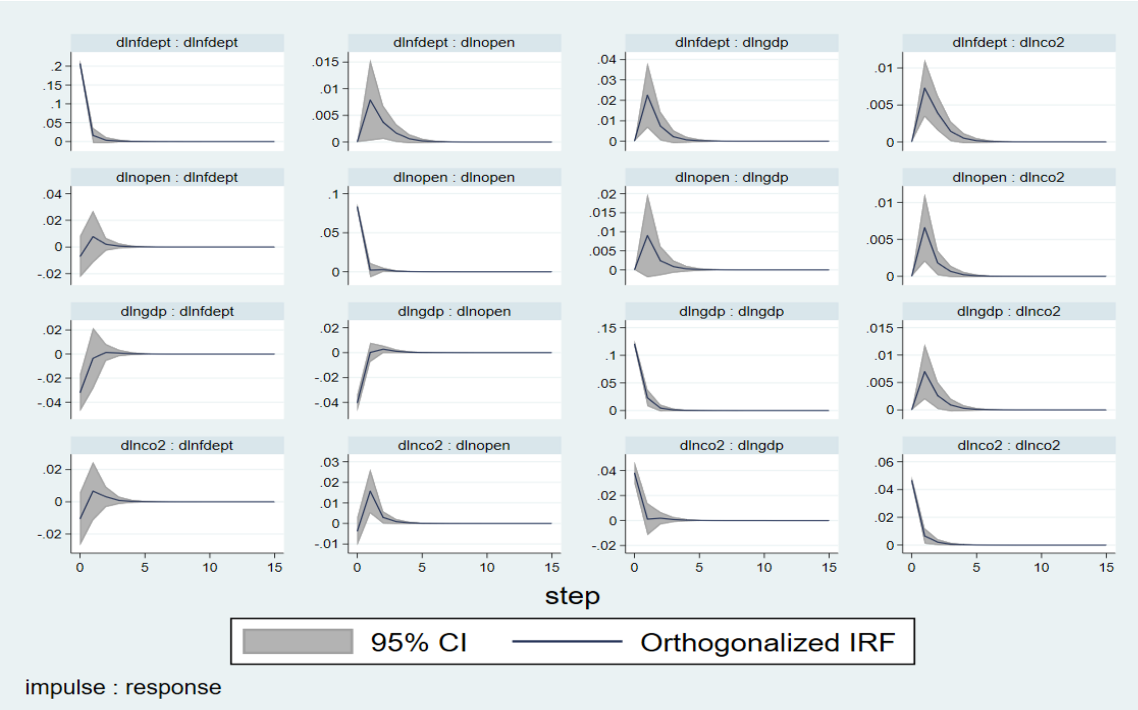

Figure 1: Impulse Response Functions

4.8. Forecast Error Variance Decomposition

The values in the table (Annex-2) show the results of variance decomposition. According to the results obtained, all of the variables that may occur in the variance of carbon dioxide emissions are explained by themselves in one lag, and 93% of it is explained by themselves in the second lag. It has been observed that as the lag rate increases, this value gradually decreases. According to the results of the decomposition of the variance of the gross national product per capita variable, a change in the variance of the gross national product per capita variable is explained by itself at a rate of 90% in the first lag, and 9% is explained by the carbon dioxide emission variable. A lag in the variance of the openness index is explained by 79% by itself and 20% by the gross national product per capita variable.

It was concluded that the first leg of a change in the depth index variance of financial markets was explained by itself at a rate of 97%, and 2% was explained by the gross national product per capita variable.

4.9. Stability Condition

A stability condition test will be applied to test the reliability of the findings obtained from the PVAR model applied in the study. As a result of this test, it is understood that if all modules are less than one, the model satisfies the stability condition (Abrigo and Love, 2016:794).

Table 9: Stability Condition

Eigenvalue		
Real	**Imaginary**	**Modulus**
.3472721	0	.3472721
.0842919	-.0579357	.1022823
.0842919	.0579357	.1022823
-.0727644	0	.0727644

Resource: Authors

A graph of the stability test can be created by adding the graph option with the Stata 17 program. The eigenvalues and unit circle position in the figure below show that the results obtained in the study are located within the unit circle, therefore they are consistent and meet the pVAR stability condition.

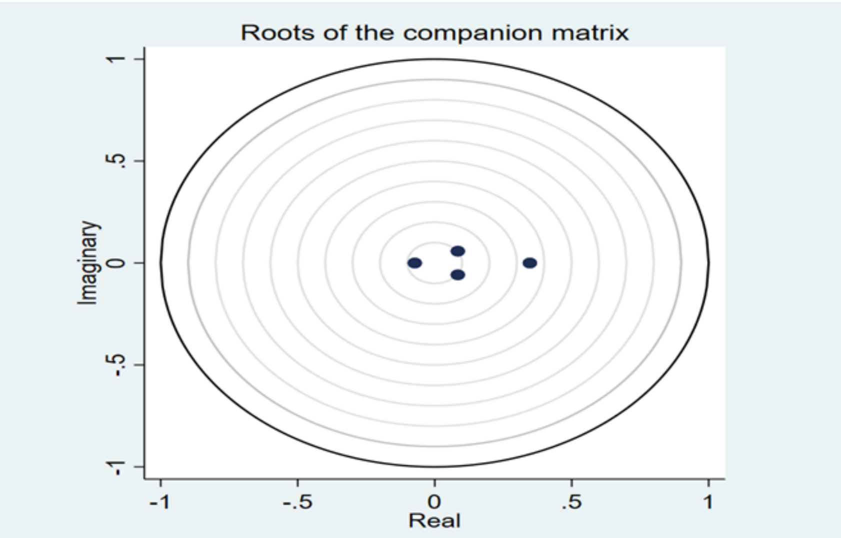

Figure 2: PVAR stability condition.

4.10. Dumitrescu and Hurlin (2012) Causality Tests

Dumitrescu and Hurlin's (2012) cointegration test is one of the new cointegration tests that is not used very often in the literature. The test appears as an important test because it is valid in cases where there is cross-sectional dependence and in cases where T>N and T<N conditions are

met, and it can provide effective results even in unbalanced panels (Dumitrescu and Hurlin, 2012: 1457). The test considers the null hypothesis that no Granger-causal relationship is assumed to exist for any member of the panel. Dumitrescu and Hurlin's (2012) test is based on the aggregate Wald statistic of individual Granger causality tests.

Table 10: Dumitrescu ve Hurlin (2012) Causality Test Results

	Wbar stat.	Zbar stat.	Probability
LNCO2 → LNGDP	18.7526	7.0125	0.0000***
LNGDP → LNCO2	18.1936	6.5069	0.0000***
LNCO2 → LNOPEN	20.0477	8.1840	0.0000***
LNOPEN → LNCO2	19.8785	8.0309	0.0000***
LNCO2 → LNFDEPT	18.6825	6.9491	0.0000***
LNFDEPT → LNCO2	14.8278	3.4624	0.0005***

Note: *Stationarity for 1% critical value is indicated as "***", stationarity for 5% critical value is indicated as "**", and stationarity for 10% critical value is indicated as "*".*

5. CONCLUSION

While climate change is seen as an environmental problem, the increasing effects of natural disasters such as floods and droughts and their reflections on the economy have led to the concept of climate change being investigated by economists and therefore a natural event being included within the scope of economics. Starting from the question of how an environmental problem is intertwined with economy and finance, this study aims to examine the interaction between climate change, trade openness rate, gross domestic product per capita rate and financial depth index in the period 1980-2020.

As a result of the homogeneity and cross-section dependence tests applied first in the econometric analysis section, it was determined that the series had a heterogeneous structure and cross-section dependence existed. After these properties of the series were determined, CADF and CIPS tests, which are second generation unit root tests, were applied. As a result of the applied unit root tests, it was determined that the series was stationary at the first difference.

With globalization, relations between countries, sectors and markets have increased and it has become important to take these relations into consideration. For this reason, panel VAR models provide advantages for macroeconomic applications. As noted by Canova and Ciccarelli (2013), its main advantages include the ability to examine both static and dynamic interrelationships, unrestricted consideration of connections between units, ease of incorporating time changes into coefficients and shock variances, and the ability to accommodate dynamics. For this reason, after the test to determine the optimal lag length of the variables in the study, the lag length was determined as 1 and the Panel Var model was applied with the Holtz-Eakin, Newey and Rosen GMM Estimator (Forward Orthogonal Deviation Method). It was found that the probability values obtained were less than the critical value of 0.05. In this context, it was concluded that the lagged values of the variables of gross national product per capita, trade openness rate and depth index of financial markets are significant in explaining the carbon dioxide emission variable.

Impulse Response Functions are used to examine the effects of shocks in the VAR system. In this context, according to the results of the impulse-response function applied to the variables, the depth index and trade openness rate of the financial markets first increased and then decreased in the face of a shock to the Carbon dioxide emission variable. It has been observed that the effect of the shock disappears within 4-5 years. In the face of the shock in the carbon dioxide emission variable, the gross national product per capita exhibited a structure that first decreased and then stabilized. It has been observed that the effect of the shock disappears within 4-5 years. The stability condition results of the model show that the model is consistent and meets the pVAR stability condition. Additionally, it was determined that there was a mutual causality relationship between the variables.

In light of all this information, the study concluded that trade openness, gross domestic product per capita and financial depth index are effective on carbon dioxide emissions in G-20 countries, based on the data obtained from the period 1980-2020. Considering the three basic hypotheses of the study in the literature section of the study the first hypothesis is that climate change, which is seen as an environmental problem, has become an internal variable of the economy by affecting international trade and financial depth index.

In this context, it is understood that the first hypothesis is valid. The second hypothesis of the study is that there is an interaction between climate change, financial depth index, economic growth and trade openness rate in G-20 countries. In this context, econometric results show that there is interaction between variables and data within G-20 countries. The third hypothesis is that trade openness rate and financial depth index are economic policy tools used to prevent the negative effects of climate change. Information obtained from econometric results shows that the variables are related. In this regard, a change in trade openness, financial depth and economic growth variables will affect carbon dioxide emissions, which is an indicator of climate change, by reducing or increasing them. Therefore, the policies implemented are important and these variables can be used as a policy tool.

While climate risks have the power to affect the entire economy by causing disruption of supply chains, disruption of production, food supply problems, changes in prices, increase in costs, and deterioration of budget balance, they also create systemic risks for the financial structure by affecting the balance sheets, asset prices and debt structures of financial institutions. poses a threat.

Climate risks turn into macroeconomic risks by directly affecting the balance sheets of financial institutions and spreading risks across markets and sectors. Therefore, climate change must be reduced primarily through financial institutions that provide money transfers to sectors. This requires the financial and economic structure to act in harmony with the environment. Many policies are implemented by the state, such as developing financial markets, ensuring the use of green tools, and not financing the production of businesses that harm the environment. In addition, sustainability needs to be supported in commercial relations through the export and import of environmentally friendly products. In line with all this information, a trade and financial structure that is not harmful to the environment become two important tools to reduce the effects of climate change by ensuring green economic growth.

Araştırma ve Yayın Etiği Beyanı

Bu çalışma bilimsel araştırma ve yayın etiği kurallarına uygun olarak hazırlanmıştır.

Yazarların Makaleye Katkı Oranları

Burçin Çakır Gündoğdu'nun makaleye katkısı %50, Hakan Kahyaoğlu'nun makaleye katkısı %50'dir.

Çıkar Beyanı

Yazarlar açısından ya da üçüncü taraflar açısından çalışmadan kaynaklı çıkar çatışması bulunmamaktadır.

Annex 1: Holtz-Eakin, Newey, and Rosen GMM Estimator Results

	Coefficient	**Std. Error**	**Z value**	**P>|z|**	**95% confidence interval**	
dlnco2						
dlnco2 L1.	.0781551	.0619769	1.26	0.207	-.0433174	.1996276
dlngdp L1.	.0946278	.0202311	4.68	0.000***	.0549756	.13428
dlnopen L1.	.0821778	.0276373	2.97	0.003***	.0280096	.1363459
dlnfdept L1.	.0350561	.0092224	3.80	0.000***	.0169805	.0531317
dlngdp						
dlnco2 L1.	-.1529001	.1400763	-1.09	0.275	-.4274446	.1216443
dlngdp L1.	.2587379	.061179	4.23	0.000***	.1388293	.3786464
dlnopen L1.	.1175782	.0674401	1.74	0.081*	-.014602	.2497584
dlnfdept | L1	.1085533	.0374346	2.90	0.004***	.0351828	.1819237
dlnopen						
dlnco2 L1.	.3291806	.1123583	2.93	0.003***	.1089623	.5493989
dlngdp L1.	.0211314	.0394883	0.54	0.593	-.0562643	.098527
dlnopen L1.	.0282956	.0576288	0.49	0.623	-.0846548	.1412459
dlnfdept | L1	.038002	.0189568	2.00	0.045**	.0008473	.0751568
dlnfdept |						
dlnco2 L1.	.1470805	.2390394	0.62	0.538	-.3214282	.6155892
dlngdp L1.	.0249672	.1158947	0.22	0.829	-.2021821	.2521166
dlnopen L1.	.0999865	.1138774	0.88	0.380	-.1232091	.3231822
dlnfdept | L1	.0779028	.0521029	1.50	0.135	-.0242169	.1800225

Note: *** indicates 1%, ** symbol indicates 5%, and * indicates significance at 10% level.

Annex-2: Forecast Error Variance Decomposition

dlnco2

Term	**dlnco2**	**dlngdp**	**dlnopen**	**dlnfdept**
0	0	0	0	0
1	1	0	0	0
2	.9394306	.0186394	.0160266	.0259035
3	.9011192	.017584	.0449455	.0363512
4	.8922243	.0193773	.0469982	.0414003
5	.8883759	.020222	.0481189	.0432833
6	.8869684	.020509	.0485683	.0439544
7	.8864597	.0206315	.0487067	.0442021
8	.8862743	.0206752	.0487595	.044291
9	.8862078	.020691	.0487784	.0443229
10	.8861837	.0206967	.0487851	.0443344
11	.8861752	.0206988	.0487875	.0443386
12	.886172	.0206995	.0487884	.04434
13	.8861709	.0206998	.0487887	.0443406
14	.8861706	.0206999	.0487888	.0443408
15	.8861703	.0206999	.0487889	.0443408

dlngdp

Term	**dlnco2**	**dlngdp**	**dlnopen**	**dlnfdept**
0	0	0	0	0
1	.092642	.907358	0	0
2	.0858943	.8677271	.0070169	.0393618
3	.086177	.8609415	.0112834	.0415981
4	.0868453	.8588011	.0118977	.042456
5	.086935	.8580813	.0120919	.0428918
6	.0869808	.8578079	.0121953	.043016
7	.0870005	.8577114	.0122266	.0430615
8	.0870067	.8576773	.0122378	.0430782
9	.087009	.8576649	.012242	.0430841
10	.0870099	.8576604	.0122434	.0430862
11	.0870102	.8576589	.012244	.043087
12	.0870103	.8576583	.0122442	.0430873
13	.0870103	.8576581	.0122442	.0430874
14	.0870103	.8576581	.0122443	.0430874
15	.0870103	.8576581	.0122443	.0430874

dlnopen

Term	**dlnco2**	**dlngdp**	**dlnopen**	**dlnfdept**
0	0	0	0	0
1	.0011772	.2019282	.7968946	0
2	.0307023	.1938505	.7650098	.0104374
3	.0305256	.1957607	.7606453	.0130684
4	.030977	.1953513	.7600935	.0135782
5	.031159	.1953664	.7596216	.0138531
6	.0311947	.1953682	.7594912	.0139459
7	.031213	.1953648	.7594447	.0139775
8	.0312192	.1953646	.7594268	.0139894
9	.0312213	.1953644	.7594206	.0139936
10	.0312221	.1953644	.7594184	.0139951
11	.0312224	.1953644	.7594177	.0139957
12	.0312225	.1953644	.7594174	.0139958
13	.0312226	.1953643	.7594172	.0139959
14	.0312226	.1953644	.7594172	.0139959
15	.0312226	.1953644	.7594172	.013996

dlnfdept

Term	**dlnco2**	**dlngdp**	**dlnopen**	**dlnfdept**
0	0	0	0	0
1	.0012744	.0239242	.0010534	.973748
2	.0012834	.02448	.0017444	.9724922

3	.0101255	.0334987	.0073403	.9490355
4	.0111169	.0351353	.0081055	.9456423
5	.011501	.0353542	.0087901	.9443548
6	.0117008	.035485	.0089839	.9438304
7	.0117579	.0355329	.0090461	.9436631
8	.0117793	.0355478	.0090718	.9436011
9	.0117873	.0355534	.0090806	.9435787
10	.0117901	.0355555	.0090837	.9435708
11	.0117911	.0355562	.0090849	.9435679
12	.0117914	.0355565	.0090853	.9435669
13	.0117916	.0355565	.0090854	.9435665
14	.0117916	.0355566	.0090855	.9435663
15	.0117916	.0355566	.0090855	.9435663

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