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# The Main Macroeconomic Determinants of Environmental Degradation in the Independent Turkic Republics and Türkiye: Panel Data Analysis*

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## Abstract

Precautions to prevent environmental degradation, which is important for the continuation of life, are among the most important issues to which all countries attach importance. For a sustainable environment, it is necessary to make both globally common and individual policy arrangements appropriate to the capabilities of each country. In the applied literature, there are very few studies on the main macroeconomic factors affecting environmental degradation in the independent Turkic Republics and Türkiye which have an ecological deficit despite their underground and aboveground natural resources. For this reason, panel data analyses were conducted for the independent Turkic Republics of Azerbaijan, Kazakhstan, Kyrgyzstan, Turkmenistan,

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Uzbekistan and Türkiye using annual data for the period 1996-2018, depending on data availability. In the analysis, ecological footprint, which represents environmental degradation, is considered as a dependent variable; GDP per capita, economic complexity index, non-renewable and renewable energy consumption, and trade openness are considered as independent variables. The results of the analyses show that the most important determinants of environmental footprint are GDP per capita, non-renewable energy consumption, and economic complexity index.

**Keywords**
Ecological deficit, ecological footprint, biocapacity, macroeconomic determinants, independent Turkic Republics, panel data analysis.

## Introduction

Environmental degradation is essential for the whole world, and almost every single country makes significant efforts to prevent environmental degradation. The degradation of the environment (ecosystem), which can be defined as the economic, social, and physical environment where humans and all other living and non-living beings are in a relationship and interact with each other, is usually caused by human-induced activities. Considering the natural balance between humans and the environment as links in a chain, disruptions in the links affect the entire chain and cause environmental degradation (T.R. Ministry of Environment and Urbanization 3). Hence, environmental problems emerge on the basis of individual countries, but the negative effects of this adversely affect not only the relevant countries but also the whole world.

Until the 1960s, it was assumed that scientific and technological progress and economic growth would make nature the servant of man, and that the impact of land and natural resources on the economic development of countries would diminish with technological progress. However, the energy crises in the 1970s, the liberalization of trade and financial markets in the 1980s, and the increasing environmental problems or awareness since the 1990s showed that production and consumption had numerous direct and/

or indirect negative impacts on the environment at the national, regional, and global levels (Yapraklı 6-7).

Nowadays, there is a need for international cooperation to identify the environmental problems of countries and the factors that cause these problems, and to find sustainable and stable solutions that are specific to each country. Therefore, international action plans for the environment, the common property and heritage of all mankind, are being prepared, various conventions and agreements are being adopted, and efforts are being made to ensure that the principles adopted are part of the national policy objectives of countries. Despite the global nature of the problem, the contribution of countries to the emergence of environmental problems is not the same at the local level and/or at the level of being affected by the problem or the dimensions and impacts of the actions they take.

The environment, which is the basis for the production and consumption activities carried out by people, is deteriorated as a result of the increase in these activities, leading to a reduction in economic activities in a cyclical process (Damirova and Yayla 108). Since there is a complementary relationship between natural resources and human-created capital, environmental degradation caused by economic activities eventually leads to a decline in economic output and wealth levels (Ockwell 4601). The continuation of economic activities without depleting available natural resources depends on the ecosystem being compatible with its limited carrying capacity (Cutler et al. 892). The ecological footprint is calculated to show whether said compatibility exists and whether the carrying capacity of the ecosystem is exceeded.

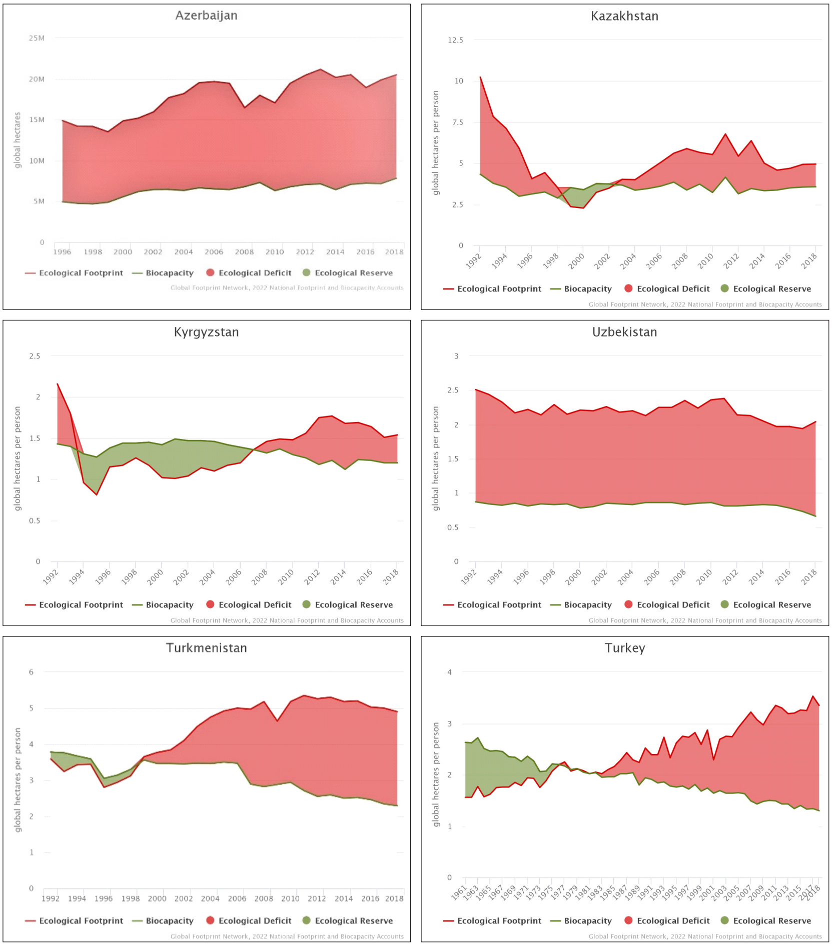
The ecological footprint, one of the most basic indicators of environmental degradation, shows the extent of natural resource use in each country and is expressed in global hectares per capita (production capacity of 1 hectare of land-gha). The ecological footprint is the amount of renewable natural resources (fertile soil, water, air, vegetation cover, etc.) required to produce the natural resources consumed in a country and globally, using data production technology, and dispose of the resulting waste. Biocapacity indicates the capacity to produce renewable natural resources and is calculated in global hectares (gha) per capita. The ecological footprint is compared to the amount of natural resources (biocapacity) that can be produced in the same period. In this way, ecological deficit (reserve) values (= biocapacity-ecological footprint) are determined and the extent of environmental degradation can be identified (WWF-Turkey 6, 30-35). An increasing ecological deficit means decreasing ecological reserves and increasing environmental degradation. In this case, the minimum requirement for a sustainable environment (biocapacity-ecological footprint = 0) cannot be provided, and natural resource demand and economic growth must be limited to return the ecological footprint to the equilibrium level. The ever-increasing ecological deficit may lead to the collapse of many critical ecosystems and the inability of the planet to regenerate itself, and even to the death of life (Ewing et al. 5).

The main objective of this study is to determine the main macroeconomic determinants of the increase in the ecological footprint of Türkiye and the five Turkic Republics that became independent in 1991. The independent Turkic Republics were chosen as the subject of research because they are constantly facing an ecological deficit, although they are generally in relatively good condition in terms of underground (oil, natural gas, and precious metals) and surface (fertile agricultural land, forests, grasslands, and water basins) natural resources (Tunay 178). Therefore, the objective of this study is to uncover the reasons for the ecological deficit in these countries, especially based on basic macroeconomic indicators, and to provide policy recommendations to reduce the ecological footprint.

Based on the explanations above, the introductory section of this study examines the impact of the main macroeconomic factors on the ecological footprint (EF) specifically for the independent Turkic Republics and Türkiye, followed by the examination of the change in the ecological deficit over time on a graphical basis for the countries and the literature review on the subject. After the implementation section, which provided explanations of the scope and dataset, methodology, and analysis results, the study concluded with the conclusions section, which evaluated the analysis results and made policy recommendations.

## Ecological Deficit in the Independent Turkic Republics and Türkiye

Since the early 1990s, environmental degradation has generally increased in Türkiye and the independent Turkic Republics (Azerbaijan, Kazakhstan, Kyrgyzstan, Turkmenistan, and Uzbekistan). The values of ecological footprint and biocapacity per capita obtained from the available data on the independent Turkic Republics are shown in Graph 1.




**Graph 1.** *Ecological Footprint and Biocapacity Values of Countries per Capita* (Global Footprint Network 2022)

As shown in the graphs for the independent Turkic Republics, the ecological deficit in Azerbaijan and Uzbekistan stabilised around a certain value [average (-1.5) gha], while in Kazakhstan [average (-2.75) gha] the decreasing ecological deficit in 1992-1998 turned into an ecological surplus in 1999-2002, showing a continuous upward trend after 2003, although it was lower than in 1992-1998 [average (-1.67 gha)]. In Turkmenistan, which had an ecological surplus (average 0.2 gha) in 1992-1999, the ecological deficit [average (-1.81) gha] has increased continuously since 1999, with the exception of 2009.

The ecological deficit in Kyrgyzstan, which followed a declining trend in 1992-1993, reached a value of 0.35 gha in 1994 and from that time until 2007 showed an ecological surplus (0.3 gha on average). During the period 2008-2018, the ecological deficit increased and amounted to [an average of (-0.35) gha]. Based on the graphs, it can be said that the ecological footprint is generally higher than the biocapacity. In other words, the biological resources have difficulty in eliminating the resulting environmental degradation in the independent Turkic Republics (Eren 47-48), which produce and export industrial goods based on valuable minerals such as oil, natural gas, and gold; agricultural products such as cotton, grain, and rice; and cattle, sheep, and goat breeding.

These countries (with the exception of Türkiye), which had adopted a closed and planned economic system in the period of USSR, began to implement new policies during the transition to a market economy (liberalisation of trade and finance), and thus achieved high export revenues. The Turkic Republics mainly export raw materials (especially oil and natural gas) and import capital and consumer goods. Higher prices for exported goods prevent these countries from getting into balance of payments problems. However, noncompetitive production and export based on nonrenewable energy resources such as oil and natural gas can lead to both pollution and a decline in income and foreign trade revenue, even "Dutch disease," in the medium and long term due to environmental concerns (Tunay 179-180). According to the Dutch Disease, investments in other industrial and service sectors, output and exports decrease in countries that heavily export raw materials based on natural resources. Despite the increased export of raw materials, this leads to a decrease in the share of total exports in GDP and a slowdown in economic growth (Gylfason and Zoega 1098-1099).

As seen in Graph 1, this value was zero in 1982 in Türkiye, which had an ecological surplus (0.43 gha on average), along with a decreasing trend during 1961-1981. During the period 1983-2018, Türkiye's ecological deficit [(-1.1) gha on average] increased continuously except for the years

1994 and 2001. During the period when Türkiye had an ecological surplus, the strategy of import-substituting industrialization was applied and labor-intensive goods were produced. Apart from the decreases in the years of economic and financial crisis, the ecological deficit increased in the years when Türkiye implemented the strategy of trade and financial liberalization and open industrialization since the 1980s. In particular, in the post-1980 period, the consumption of energy resources such as oil and natural gas and the production and export of energy-intensive goods and services were covered to a considerable extent by imports (Yapraklı 130-131).

**Literature Review**

Numerous applied studies have been conducted in the literature to determine the macroeconomic factors that affect EF, and most of these studies have focused on one and/or more factors and the relationships between them. According to the results of these studies, the impact of macroeconomic factors on the environment differs depending on numerous country-specific factors such as the countries' level of development, production and export structures, consumption patterns, degree of globalization, industrialization, and applied foreign trade strategies. It is possible to summarize the applied studies under review according to the obtained results as follows:

Studies by Grossman and Krueger (353-377), Ang (4772-4778), Hotunluoğlu and Tekeli (108-126), Soytaş et al. (482-489), Halıcıoğlu (1156-1164), Tamazian et al. (246-253), Wang et al. (4870-4875), Sharma (376-382), Özcan (1138-1147), Öztürk and Acaravcı (262-267), Artan et al. (308-325), Asane and Otoo (426-435), Salahuddin et al. (1226-1235), Doğan and Şeker (1074-1085), Balogh and Jambor (217-226), Nasreen et al. (1105-1122), Can and Gözgör (16364-16370), Khan et al. (22850-22860), Işık et al. (10846-10853), Çetin and Saygın (529-546), Destek and Sarkodie (2483-2489), Neagu (1-18), Kosifakis et al. (261-271), Doğan et al. (1-12), Destek and Sinha (118-137), Yeter et al. (405-432), Leitão et al. (1-15), and Aller et al. (105-154) examined the impact of economic growth on environmental degradation. These studies found that environmental degradation generally increases as income levels increase and pollution decreases above a certain threshold (Environmental Kuznets Curve), although this varies by country. Thus, as long as income levels are low, the priority is to increase production and meet basic needs. However, when a certain level of income is reached, environmental awareness increases, environmentally friendly technologies and energy resources are used, and thus environmental degradation begins to decrease.

The basic applied studies [Ang (4772-4778), Hotunluoğlu and Tekeli (108-126), Soytaş et al. (482-489), Halıcıoğlu (1156-1164), Soytaş and Sarı (1667-1675), Wang et al. (4870-4875), Sharma (376-382), Özcan (1138-1147), Asane and Otoo (426-435), Doğan and Şeker (1074-1085), Balogh and Jambor (217-226), Nasreen et al. (1105-1122), Can and Gözgör (16364-16370), Neagu and Teodoru (1-29), Işık et al. (10846-10853), Destek and Sarkodie (2483-2489), Neagu (1-18), Destek and Sinha (118-137), Pata (846-861), and Aller et al. (105-154)], which studied the impact of energy consumption on the environment, found that the increase in the use of nonrenewable energy (such as coal, oil, and natural gas), the basic input for consumption and production (especially in the manufacturing industry), increases environmental pollution. The studies by Doğan and Şeker (1074-1085), Balogh and Jambor (217-226), Işık et al. (10846-10853), Doğan et al. (1-12), Destek and Sinha (118-137), Pata (846-861), and Leitão et al. (1-15) found that the increasing use of environmentally friendly renewable energy (such as solar energy and wind energy) has reduced environmental degradation, increased environmental regeneration, and increased waste tolerance, but the use of renewable energy has been low in low-income countries due to the high cost of constructing and operating energy facilities based on renewable energy sources.

The basic studies that examine the relationship between economic complexity and environmental degradation [Can and Gözgör (16364-16370), Neagu and Teodoru (1-29), Doğan et al. (31900-31912), Neagu (1-18), Kosifakis et al. (261-271), Doğan et al. (1-12), Pata (846-861), Leitão et al. (1-15), Neagu and Neagu (78-99), and Bucak (1-16)] showed that economic complexity is now used as an indicator of development instead of economic growth in the global world order. Economic complexity indicates the amount of technical knowledge in the production structure, which is determined by the factors of production of a country. The fact that the production technology of the goods in a country's export basket, while other factors are fixed, is technical knowledge and know-how-intensive shows that the degree of complexity of these goods, and thus of the economy, is high.

The Economic Complexity Index (ECI) measures the diversity and prevalence of a country's competitive (differentiated/similar) export goods that require technical knowledge (the number of countries that can produce these goods). Countries that produce competitive export goods with high diversity and low diffusion make high profits, especially in intra-industry trade. Countries with a relatively high level of development may have more complex production structure. In other words, the degree of complexity of trade goods produced by countries can be designed according to their level of development (Can and Gözgör 16367; Yapraklı and Özden 54-55). Studies on the relationship between environmental degradation and economic complexity found that the level of pollution was relatively higher in countries with low economic complexity.

The main studies that examine the environmental impact of trade liberalization [Halıcıoğlu (1156-1164), Tamazian et al. (246-253), Sharma (376-382), Öztürk and Acaravcı (262-267), Artan et al. (308-325), Asane and Otoo (426-435), Doğan and Şeker (1074-1085), Balogh and Jambor (217-226), Çetin and Saygın (529-546), Destek and Sinha (118-137), and Aller et al. (105-154)] concluded that the increase in foreign trade, especially consumption and imports of energy-based inputs in developing countries, has both led to an export-based export structure and increased the environmental impact.

On the other hand, although there are numerous studies on this topic in the literature, very few studies have been conducted on the independent Turkic Republics and there is no common and clear opinion on these countries. The studies by Günel (151-164) and Yeter et al. (405-432) have shown that factors such as economic growth and consumption of non-renewable energy negatively affect the environment in the Turkic Republics.

Table 1 provides the basic information on the studies presented above.

**Table 1**
Summary of the Literature on the Macroeconomic Determinants of the Ecological Deficit

| Researcher/s | Period and Country/ies | Method | Result |
|---|---|---|---|
| Grossman and Krueger/1995 | 1989-1990/ 39 countries | Panel data analysis | GDP affects environmental pollution in an inverted U-shape |
| Ang/2007 | 1960-2000/ France | Co-integration, VEC | Economic growth increases energy consumption and carbon emissions. |
| Hotunluoğlu and Tekeli/2007 | 1995-2003/ 18 EU members | Panel data analysis | Environmental pollution is affected positively by fossil fuel consumption and negatively by taxes. |
| Soytaş et al./2007 | 1960-2004/ the US | VAR, causality | While energy consumption increases carbon emissions, income does not. |
| Halıcıoğlu/2009 | 1960-2005/ Türkiye | Co-integration, causality | Income is the variable that has the greatest negative impact on carbon emissions, followed by energy consumption and foreign trade. |
| Tamazian et al./2009 | 1992-2004/ BRIC | Panel data analysis | Economic development and trade openness reduce carbon emissions and improve environmental quality. |
| Soytaş and Sarı/2009 | 1960-2000/ Türkiye | Granger causality | There is a mutual causality between $CO_2$ emissions and energy consumption. |
| Wang et al./2011 | 1995-2007/28 provinces of China | Panel data analysis | There is a reciprocal relationship between $CO_2$ emissions, energy consumption, and economic growth. |

| | | | |
|---|---|---|---|
| Sharma/2011 | 1985-2005/ 69 developed countries and developing countries | Panel data analysis-GMM | While per capita income has an impact on carbon emissions, energy consumption and openness do not. |
| Özcan/2013 | 1980-2008/ 12 Middle Eastern countries | Co-Integration, FMOLS | There is an inverted U-shaped relationship between income and carbon emissions in 5 countries. Energy consumption has a positive effect on carbon emissions. |
| Öztürk and Acaravcı/2013 | 1960-2007/ Türkiye | Time series analysis | GDP affects carbon emissions in an inverted U-shape, and trade openness affects them positively. |
| Artan et al./2015 | 1981-2012/ Türkiye | Time series analysis | There is a long-term relationship between economic growth, trade openness, and environmental pollution. |
| Asane and Otoo/2015 | 1980-2009/ 45 African countries | Input-Output/ Panel data analysis | Per capita income and energy affect carbon emissions in low- and middle-income countries. Openness is meaningless in all income groups. |
| Salahuddin et al./2016 | 1991-2012/ OECD countries | Panel data analysis | Economic growth has a negative impact on CO2 emissions |
| Doğan and Şeker/2016 | 1985-2016/ 23 developed countries and developing countries | Panel data analysis/ FMOLS, DOLS | While renewable energy consumption and trade openness reduce carbon emissions, non-renewable energy consumption increases. |

| | | | |
|---|---|---|---|
| Balogh and Jambor/ 2017 | 1990-2013/ 168 countries | Panel data analysis-GMM | Renewable energy consumption has a negative impact on carbon emissions, while non-renewable energy and trade openness have a positive impact. |
| Nasreen et al./2017 | 1980-2012/5 South Asian countries | Time series analysis/ARDL, causality | GDP and energy consumption increase carbon emissions. |
| Can and Gözgör/2017 | 1964-2014/ France | Dynamic EKC | In the long run, ECI is the determinant of CO2, along with income and energy consumption. The ECI suppresses CO2 emissions. |
| Khan et al./2018 | 1990-2015/ emerging market economies | Panel data analysis | Economic growth increases $CO_2$ emissions. |
| Neagu and Teodoru/2019 | 1995-2016/25 EU member states | Panel co-integration, FMOLS, DOLS | Countries with high non-renewable energy intensity and low ECI levels have higher greenhouse gas(GHH) emissions. |
| Doğan et al./2019 | 1971-2014/55 countries | Panel data analysis | ECI increases carbon emissions in low- and middle-income countries while controlling them in high-income countries. |
| Işık et al./2019 | 1980-2015/10 US States | Panel regression | GDP and non-renewable energy consumption have a positive effect on pollution and renewable energy has a negative effect. |
| Günel/2019 | 1992-2014/6 Turkic Republics | Panel data analysis | There is a reciprocal relationship between environmental degradation and economic growth. |

| | | | |
|---|---|---|---|
| Çetin and Saygın/2019 | 1960-2014/ Türkiye | ARDL | Income and foreign trade have a positive effect on carbon emissions |
| Destek and Sarkodie/2019 | 1977-2013/ 11 newly industrialized countries | Panel data analysis-AGM | In 5 countries there is an inverted U-shaped relationship between economic growth and energy consumption, in 4 countries between economic growth and ecological footprint |
| Destek and Sinha/2020 | 1980-2014/ OECD member countries | Panel data analysis | GDP influences the ecological footprint U-shaped, the consumption of non-renewable energy positively, the consumption of renewable energy and trade openness negatively. |
| Doğan et al./2020 | 1990-2004/ 28 OECD countries | Panel data analysis- FMOLS, DOLS | PC income has a positive effect on carbon emissions, ECI and renewable energy consumption have a negative effect. |
| Kosifakis et al./2020 | 2016/126 countries | Spearman's correlation analysis | The relationship between ECI, PC income and ecological footprint varies from country to country. |
| Neagu/2020 | 1995-2014/ 48 countries | Panel data analysis- FMOLS, DOLS | Economic complexity, income and fossil fuel consumption have a positive long-term impact on the ecological footprint |
| Aller et al./2021 | 1995-2014/ 92 developed countries- developing countries | Machine learning | GDP PC affects fossil fuel consumption, and trade affects carbon emissions. |

| | | | |
|---|---|---|---|
| Leitão et al./2021 | 1990-2005/ BRICS countries | Panel data analysis-Co-integration FMOLS, DOLS | There is an inverted U-shaped relationship between PC income and carbon emissions, and there is a negative relationship between ECI and renewable energy consumption. |
| Pata/2021 | 1980-2016/ the US | Co-integration, VEC | ECI (above a certain threshold), globalization and renewable energy reduce pollution. |
| Damirova and Yayla/2021 | 10 developed countries and developing countries/ 1995-2016 | Panel data analysis | The impact of income on the environment varies from country to country |
| Yeter et al./2021 | 1992-2019/6 Turkic Republics | Panel data analysis | Per capita income and energy consumption increase carbon emissions. |
| Neagu and Neagu/2022 | 1995-2017/48 countries with a positive ECI level | Panel data analysis-Co-integration | There is an inverted U-shaped relationship between the ECI and ecological footprint. |
| Bucak/2022 | 1995-2017/G8 and Türkiye | Toda-Yamamoto causality analysis | The direction of the causal relationship between the ECI and EF varies from country to country. |

Note: PC denotes Per Capita, the ECI denotes the Economic Complexity Index, and EF denotes the Ecological Footprint.

The main applied studies in the literature on this topic have generally focused on the relationship between environmental degradation and one and/or two main macroeconomic variables, and other factors have mostly been included as control variables in the estimating equations. In the applied literature, there are very few studies (only the independent variables of economic growth and energy consumption are used) on the factors that influence this in the Independent Turkic Republics, which have an ecological deficit despite their below and above ground natural wealth. Unlike other studies, this study examined the effects of the main macroeconomic variables used extensively in the literature on the ecological footprint in Türkiye and the Independent Turkic Republics. In this way, it will be possible to comprehensively show the factors affecting the ecological footprint and the relative magnitudes of these factors, and to make appropriate policy recommendations. It is expected that the results of the study and the policy recommendations will guide future research.

## Macroeconomic Determinants of Ecological Deficit: Panel Data Analysis

The present study attempted to identify the main macroeconomic factors affecting the ecological footprint, one of the main indicators of environmental degradation using econometric analysis methods in Türkiye and the independent Turkic Republics, and to provide policy recommendations for reducing the ecological footprint.

## Data Set and Model

In the study, an econometric analysis was performed for Türkiye and the independent Turkic Republics (Azerbaijan, Kazakhstan, Kyrgyzstan, Turkmenistan, and Uzbekistan). The fact that very few applied studies have been conducted on the independent Turkic Republics and a limited number of variables have been used do not allow us to obtain a comprehensive and clear picture. Therefore, it was necessary to conduct such a study in order to contribute to the relevant literature and provide input to policy makers.

In the study, annual data for the period 1996-2018 were used to estimate the main macroeconomic factors affecting the ecological footprint, depending on data availability. The time dimension of the panel is larger than the cross-sectional dimension ($T=23 > N=6$). Great care must be taken in the selection of independent variables to avoid spurious results. Numerous economic factors affect the ecological footprint, while other factors are fixed. Therefore, macroeconomic variables that are both directly related and extensively used in the literature were preferred instead of examining the effect of each variable in this study. Table 2 provides information on the variables used in the analysis.

**Table 2**
Variables Used in Analysis

| Variables | Sources |
|---|---|
| Ecological footprint (EF) | Global Footprint Network (https://data.footprintnetwork.org) |
| GDP per capita (GDP) | World Bank (https://databank.worldbank.org/source/world-development-indicators) |
| Economic complexity index (ECI) | Atlas of Economic Complexity (https://atlas.cid.harvard.edu/) |
| Non-renewable energy consuption (NonRenew) | U.S Energy Information Administration (https://www.eia.gov) |
| Renewable energy consumption (Renew) | U.S Energy Information Administration (https://www.eia.gov/) |
| Trade openness (Trade) | World Bank (https://databank.worldbank.org/source/world-development-indicators) |

Note: Except for ECI, the logarithms of the series of variables are taken

The study used the following extended basis function based on the function used extensively in the literature, including applied studies on this topic

EF = f(GDP, ECI, NonRenew, Renew, Trade)

The representation of the basis function in the form of the estimating equation is given in equation (1).

$$lnEF_{it} = \alpha_{it} + \beta_1 lnGDP_{it} + \beta_2 ECI_{it} + \beta_3 lnNonRenew_{it} + \beta_4 lnRenew_{it} + \beta_5 lnTrade_{it} + \varepsilon_{it} \quad (1)$$

In equation (1), α represents the constant term, i represents land, t represents time, ε represents the error term, β represents the slope parameter, and ln represents the logarithm. Ecological footprint (EF) is a dependent variable in the model, while GDP per capita, economic complexity index (ECI), nonrenewable energy consumption (NonRenew), renewable energy consumption (Renew), and trade openness (Trade) are independent variables.

The coefficient $\beta_1$ is expected to be positive (Ang, 4772-4778; Asane and Oto, 426-435; Khan et al., 22850-22860). As an increase in GDP per capita increases production and consumption, the ecological footprint becomes larger. The $\beta_2$ coefficient is expected to be negative (Neagu and Teodoru, 1-29; Leitão et al., 1-15). The ecological footprint will decrease considering that an increase in the economic complexity index leads to a more environmentally friendly technological production. Moreover, the level of pollution is relatively higher in countries with low economic complexity. It is expected that $\beta_3$ will be positive (Hotunluoğlu and Tekeli, 108-126; Işık et al., 10846-10853; Aller et al., 105-154) and $\beta_4$ will be negative (Işık et al., 10846-10853; Destek and Sinha, 118-137; Leitão et al., 1-15; Pata, 846-861). While the increase in non-renewable energy consumption increases the ecological footprint, the increased renewable energy consumption decreases the ecological footprint. It is expected that the $\beta_5$ coefficient will be positive (Öztürk and Acaravcı, 262-267; Balogh and Jambor, 217-226; Çetin and Saygın, 529-546). Increasing trade openness of the country increases its environmental footprint.

## Method

To determine appropriate estimators in panel data models, we first test the homogeneity of the slope parameters. The delta (Δ) test of Pesaran and Yamagata is one of the methods used for this purpose. Two separate test statistics computed in the delta test are shown in equations (2) and (3) (Pesaran and Yamagata 57):

$$\tilde{\Delta}= \sqrt{N}\left(\frac{N^{-1}\,\tilde{S}-k}{\sqrt{2k}}\right) \tag{2}$$

$$\tilde{\Delta}_{adj}= \sqrt{N}\left(\frac{N^{-1}\,\tilde{S}-k}{\sqrt{Var(\tilde{z}_{iT})}}\right) \quad Var(\tilde{z}_{iT}) = \frac{2k(T-k-1)}{T+1} \tag{3}$$

In equations (2) and (3), N represents the cross-sectional dimension (number of countries), T represents the time dimension (number of years), $\tilde{S}$ represents the Swamy test statistic, k represents the number of independent variables, and Var represents the variance. The $\tilde{\Delta}$ test statistic is used for large samples and the $\tilde{\Delta}_{adj}$ test statistic is used for small samples. The null and alternative hypotheses of the delta test are as follows.

$H_0 : \beta_i = \beta$ *The slope parameters are homogeneous.*

$H_1 : \beta_i \neq \beta$ *The slope parameters are homogeneous.*

If the probability values (p-value) of the calculated test statistics are less than 0.05, the null hypothesis is rejected, and it is decided that the slope parameters are heterogeneous.

When analysing panel data, the problem of cross-sectional dependence must be resolved before performing the unit root test. When the time dimension (T) is larger than the cross-sectional dimension (N) (T > N), the CDLM1 developed by Breusch and Pagan (1980) and the bias-adjusted CD test developed by Pesaran et al. can be applied to the variables. The $CDLM_1$ test statistic shows a chi-square distribution with d degrees of freedom and is calculated as in equation (4) (Breusch and Pagan 240).

$$\lambda_{LM} = T \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}^2 \quad (4)$$

In $CDLM_1$ test statistics, $\hat{\rho}_{ij}^2$ represents the correlation coefficient between the residuals of units i and j. Pesaran et al. developed a bias-adjusted CD test by adding the mean and variance to the CDLM test statistic because erroneous results can occur in the CDLM test if there are deviations from the individual means and variance. The test statistic in question is shown in equation (5) (Pesaran et al. 108).

$$LM_{adj} = \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \frac{(T-k)\hat{\rho}_{ij}^2 - \mu_{Tij}}{\upsilon_{Tij}} \quad (5)$$

In equation (5), the mean is given by $\mu_{tij,}$ and the variance by $\mu_{tij}$. For both $CDLM_1$ and bias-adjusted CD tests, the null and alternative hypotheses are as follows.

$H_0$: There is no cross-sectional dependence.

$H_1$: There is cross-sectional dependence.

If the probability values of the calculated test statistics are less than 0.05, the null hypothesis is rejected and it is determined that cross-sectional dependence exists.

It is important to detect cross-sectional dependence for selecting the unit root test to be used in the analysis. If there is no cross-sectional dependence, first generation unit root tests are used. If cross-sectional dependence is present, second-generation unit root tests that account for this problem are used. The CADF test developed by Pesaran, one of the second generation unit root tests, was used in the study. The CADF test represents an extended version of the regression equation in the traditional ADF unit root test with cross-sectional means of the first differences and lagged values of the series. The regression equation of the CADF test is shown in equation (6) (Pesaran 269).

$$\Delta y_{it} = \alpha_i + b_i y_{i,t-1} + c_i \bar{y}_{t-1} + d_i \Delta \bar{y}_t + e_{it} \quad (6)$$

In the CADF regression equation, $\bar{y}_{t-1}$ refers to the cross-sectional mean of the lagged value of the series, and $\Delta \bar{y}_t$ refers to the cross-sectional mean of the first difference of the series. The regression equation is estimated for each cross section, and CADF test statistics are generated. The arithmetic mean of these test statistics is then calculated, and the CIPS statistics are computed for the entire panel. The CIPS statistics are shown in equation (7) (Pesaran 267).

$$CIPS = N^{-1} \sum_{i=1}^{N} CADF_i \quad (7)$$

In the CADF test, the null hypothesis is based on unit root, whereas the alternative hypothesis is based on stationarity. If the calculated test statistic is greater than the absolute value of the critical values formed by Pesaran, the null hypothesis is rejected and it is decided that the series is stationary.

In panel data analysis, model estimation is performed by determining the appropriate method depending on the stationarity of the variables, homogeneity/heterogeneity, and cross-sectional dependence. In this study, the augmented mean group (AMG) estimation method developed by Eberhardt & Bond and Eberhardt & Teal was used. An identification problem occurs when unobserved common factors in the empirical model are controlled for the evolution of both the dependent and independent variables. The AMG estimator can solve this identification problem by accounting for unobserved common factors through a Monte Carlo simulation. The empirical model used in the AMG method is shown in equations (8), (9), and (10) (Eberhardt and Bond 2).

$$y_{it} = \beta_i' x_{it} + u_{it} \quad u_{it} = \alpha_i + \lambda_i' f_t + \varepsilon_{it} \quad (i=1,\dots, N, t=1,\dots, T) \quad (8)$$

$$x_{mit} = \pi_{mi} + \delta_{mi}' g_{mt} + \rho_{1mi} f_{1mt} + \cdots + \rho_{nmi} f_{nmt} + \upsilon_{mit} \quad (m=1,\dots, k) \quad (9)$$

$$f_t = \varrho' f_{t-1} + \epsilon_t \quad g_t = \kappa' g_{t-1} + \epsilon_t \quad (10)$$

$x_{it}$ denotes observable covariates, $a_i$ refers to group-specific fixed effects, $f_t$ and $g_t$ denote country-specific factor loadings and unobserved common factors, and $\lambda_i$ represents country-specific factor loadings. Thus, the model is constructed by considering the cross-sectional dependence of observable and unobservable factors. The AMG estimator is obtained from the coefficients of the year dummy variables in the first difference regression equation and represents the average trend of common factors not observed in all countries, corresponding to levels (Eberhardt and Teal 5, 7).

## Analysis Results

In this study, in which analyses were conducted to determine the main macroeconomic factors impacting the ecological footprint for the independent Turkic Republics, first, the homogeneity of the slope parameters, then the cross-sectional dependencies of the variables were tested, and the results are presented in Table 3.

**Table 3**

Homogeneity and Cross-sectional Dependence Test Result

| | **Homogeneity Test in Model (Delta Test)** | | | |
|---|---|---|---|---|
| | $\hat{\Delta}$ | **Probability value** | $\widehat{\Delta}_{adj}$ | **Probability value** |
| | 4.339 | 0.000 | 5.203 | 0.000 |
| | **Cross-Sectional Dependency Tests T>N** | | | |
| **Variables** | **CD $LM_1$ (Breusch, Pagan 1980)** | | **Bias-Adjusted CD testi** | |
| | **Constant Model** | | **Constant Model** | |
| **lnEF** | 65.985 | (0.000) | 20.090 | (0.000) |
| **lnNonRenew** | 82.454 | (0.000) | 16.700 | (0.000) |
| **lnRenew** | 74.526 | (0.000) | 7.325 | (0.000) |
| **lnGDP** | 117.520 | (0.000) | 29.726 | (0.000) |
| **ECI** | 44.314 | (0.000) | 10.270 | (0.000) |
| **lnTrade** | 67.737 | (0.000) | 5.718 | (0.000) |

Note: Values in parentheses are probabilities.

As a result of the delta test in Table 3, the null hypothesis was rejected because the probability value (p value) of the test statistic ( $\widehat{\Delta}_{adj}$ ) calculated for the small sample was less than 0.05. Therefore, the slope parameters were found to be heterogeneous. Consistent with the results of Breusch and Pagan's $CDLM_1$ and Pesaran et al.'s bias-adjusted CD test applied to the cross-sectional dependence problem, there is cross-sectional dependence in the fixed model for all variables.

After determining cross-sectional dependence in the variables, the stationarity of the variables was examined using the CADF unit root test of Pesaran, which accounts for this problem; Table 4 contains the results.

**Table 4**

Pesaran (2007) CADF Unit Root Test Results

| **Variables** | **Constant Model** | |
|---|---|---|
| | ***Panel CIPS Statistics **** | ***Critical Values*** |
| **lnEF** | -3.171 | |
| **lnNonRenew** | -4.174 | |
| **lnRenew** | -3.120 | %1 -2,60<br>%5 -2,34<br>%10 -2.21 |
| **lnGDP** | -3.205 | |
| **ECI** | -3.082 | |
| **lnTrade** | -2.648 | |

* Estimates were made at 1 lag length.

According to the results in Table 4, the null hypothesis of the unit root was rejected because the CIPS statistics calculated for all variables are greater in absolute values than the critical values, and it was decided that the series are stationary.

In the study, the model was estimated using the AMG method because the slope parameters were heterogeneous, cross-sectional dependence was found in the variables, and the series were stationary. The results for the entire panel are presented in Table 5 and for individual countries in Table 6.

**Table 5**
AMG Results

| Variables | Coefficient | Standard Error | z Statistic | Probability Value |
|---|---|---|---|---|
| lnNonRenew | 0.270 | 0.089 | 3.02 | 0.003** |
| lnRenew | -0.049 | 0.048 | -1.03 | 0.305 |
| lnGDP | 0.303 | 0.128 | 2.37 | 0.018** |
| ECI | -0.037 | 0.022 | -1.71 | 0.087* |
| lnTrade | -0.027 | 0.080 | -0.34 | 0.731 |
| Constant | -1.432 | 0.718 | -1.99 | 0.046** |
| | Wald $chi^2(5)$ 189.21 | | Prob>$chi^2$= 0.0000 | |

*,**,*** denotes significance at 10%, 5% and 1% significance levels.

Consistent with the AMG results for the entire panel in Table 5, the coefficients of lnNonRenew and lnGDP are positive and significant at the 5% significance level. Thus, with an increase in non-renewable energy consumption and GDP per capita, the ecological footprint, which represents environmental degradation, also increases. These results are consistent with the studies of Ang (4772-4778), Hotunluoğlu and Tekeli (108-126), Sharma (376-382), Balogh and Jambor (217-226), Işık et al. (10846-10853), Günel (151-164), Neagu and Teodoru (1-29), Çetin and Saygın (529-546), Doğan et al. (1-12), Neagu (1-18), Destek and Sinha (118-137), Aller et al. (105-154), and Yeter et al. (405-432) in the literature. The coefficient of the ECI was found to be negative and significant at the 10% significance level. An increase in the economic complexity index decreases the ecological footprint. This result supports the findings from the studies of Can and Gözgör (16364-16370), Neagu and Teodoru (1-29), Doğan et al. (31900-31912), Neagu (1-18), and Pata (846-861). The coefficients of lnRenew and lnTrade were found to be negative but not significant

**Table 6**
AMG Results

| Country | Variables | Coefficient | Standard Error | z Statistic | Probability Value |
|---|---|---|---|---|---|
| Azerbaijan | lnNonRenew | 0.112 | 0.164 | 0.68 | 0.495 |
| | lnRenew | -0.087 | 0.064 | -1.36 | 0.175 |
| | lnGDP | 0.046 | 0.067 | 0.70 | 0.485 |
| | ECI | -0.061 | 0.067 | -0.91 | 0.363 |
| | lnTrade | 0.272 | 0.121 | 2.25 | 0.025** |
| | Constant | -1.177 | 1.047 | -1.12 | 0.261 |
| Kazakhistan | lnNonRenew | 0.529 | 0.223 | 2.37 | 0.018** |
| | lnRenew | 0.031 | 0.219 | 0.14 | 0.887 |
| | lnGDP | 0.460 | 0.141 | 3.25 | 0.001*** |
| | ECI | 0.043 | 0.085 | 0.51 | 0.608 |
| | lnTrade | -0.314 | 0.109 | -2.88 | 0.004*** |
| | Constant | -1.448 | 1.326 | -1.09 | 0.275 |
| Kyrgyzstan | lnNonRenew | 0.538 | 0.139 | 3.87 | 0.000*** |
| | lnRenew | 0.015 | 0.126 | 0.12 | 0.905 |
| | lnGDP | 0.801 | 0.137 | 5.81 | 0.000*** |
| | ECI | -0.038 | 0.103 | -0.37 | 0.713 |
| | lnTrade | 0.037 | 0.133 | 0.28 | 0.782 |
| | Constant | -3.99 | 0.730 | -5.48 | 0.000*** |
| Turkmenistan | lnNonRenew | 0.200 | 0.087 | 2.28 | 0.023** |
| | lnRenew | -0.257 | 0.057 | -4.52 | 0.000*** |
| | lnGDP | 0.389 | 0.102 | 3.79 | 0.000*** |
| | ECI | -0.049 | 0.096 | -0.52 | 0.605 |
| | lnTrade | -0.036 | 0.054 | -0.67 | 0.501 |
| | Constant | -2.735 | 0.997 | -2.74 | 0.006*** |

| | | | | | |
|---|---|---|---|---|---|
| Uzbekistan | lnNonRenew | 0.003 | 0.156 | 0.02 | 0.983 |
| | lnRenew | -0.070 | 0.045 | -1.55 | 0.121 |
| | lnGDP | -0.058 | 0.035 | -1.66 | 0.096* |
| | ECI | -0.115 | 0.071 | -1.62 | 0.104 |
| | lnTrade | 0.027 | 0.034 | 0.79 | 0.431 |
| | Constant | 0.899 | 0.275 | 3.27 | 0.001*** |
| Türkiye | lnNonRenew | 0.239 | 0.229 | 1.05 | 0.296 |
| | lnRenew | 0.070 | 0.068 | 1.04 | 0.299 |
| | lnGDP | 0.179 | 0.314 | 0.57 | 0.569 |
| | ECI | -0.004 | 0.152 | -0.03 | 0.977 |
| | lnTrade | -0.152 | 0.104 | -1.46 | 0.145 |
| | Constant | -0.133 | 2.567 | -0.05 | 0.959 |

*,**,*** denotes significance at 10%, 5% and 1% significance levels.

Considering the country-specific AMG estimation results in Table 6, the coefficient for non-renewable energy consumption in Kazakhstan, Kyrgyzstan, and Turkmenistan is positive and significant. It was found that renewable energy consumption is significant only in Turkmenistan and has a negative impact on the ecological footprint. This result is similar to the results of Doğan and Şeker (2016), Balogh and Jambor (217-226), Işık et al. (10846-10853), Destek and Sinha (118-137), Doğan et al. (1-12), Leitão et al. (1-15), and Pata (846-861). GDP per capita has a positive and significant impact on the ecological footprint in Kazakhstan, Kyrgyzstan, and Turkmenistan. Trade openness has a positive and significant effect on the ecological footprint in Azerbaijan and a negative and significant effect in Kazakhstan. The study by Destek and Sinha (118-137) also found that trade openness has a negative effect on the ecological footprint. In Türkiye, the signs of all other variables except renewable energy consumption were found to be statistically insignificant, although they were in line with expectations.

## Conclusion

It is important that countries reduce their ecological deficits by carrying out economic activities that are compatible with their biological capacities for environmental and economic sustainability. The extent of the relationship between the environment and people and expectations for the future require that the factors causing environmental degradation be clearly identified. Therefore, the study examined the main macroeconomic determinants of the environmental footprint through a panel data analysis using data for the period between 1996 and 2018 in the six independent Turkic Republics, including Azerbaijan, Kazakhstan, Kyrgyzstan, Turkmenistan, Uzbekistan and Türkiye, which continuously face an ecological deficit despite their relatively good condition in terms of underground (oil, natural gas, and precious metals) and surface (fertile agricultural land, forests, grasslands, and water basins) natural resources.

According to the results of the analysis, trade openness in Azerbaijan, non-renewable energy consumption, GDP per capita, and trade openness in Kazakhstan, non-renewable energy consumption and GDP per capita in Kyrgyzstan, non-renewable and renewable energy consumption and GDP per capita in Turkmenistan, and GDP per capita in Uzbekistan are crucial for the increase in the ecological footprint. The positive impact of GDP per capita on the ecological footprint in Kyrgyzstan is higher than those in Kazakhstan and Turkmenistan. While the impact of non-renewable energy consumption on the ecological footprint is close in Kyrgyzstan and Kazakhstan, the impact in Turkmenistan is lower compared to these two countries. It can be said that the results of this study are consistent with the results of the studies mentioned in the literature review in terms of the sign of the coefficients, but differ in terms of the magnitude of the coefficients, which is due to the differences in the time period, country group, number and definition of variables, and the method used.

Based on the results of the analyses, it can be stated that the negative impact of non-renewable energy consumption and GDP per capita on the ecological footprint in Türkiye and the independent Turkic Republics is because of the problems such as the backwardness of production technologies, waste from industrial production (petrochemical, chemical, metallurgical), raw materials extracted from underground sources (oil and gas extraction), waste generated from processing (power generation plants) and air pollution, lack of recycling or treatment processes, lack of sufficient capital due to inadequate functioning of the market mechanism, financing difficulties hampering the renewal of production technologies, and limited reverse logistics capabilities (waste treatment, recycling, storage, etc.). The unhealthy environmental conditions that result if these countries maintain their production, consumption, and export patterns based on non-renewable energy sources (which can lead to "Dutch disease") can threaten lives and economic and social sustainability. In other words: Unless these countries take precautionary measures today, the measures they will take in the future due to unacceptable living conditions may become significantly more expensive, and even the measures taken may not help improve environmental degradation.

Establishing programs for the local economy that are compatible with international environmental criteria, elaborating environmental projects and establishing various support programs for this purpose, ensuring the participation of stakeholders (relevant public and non-governmental organizations, sectoral producers and entrepreneurs, local governments, etc.) for the adoption of environmental regulations, organizing training and seminar activities to raise environmental awareness, developing cooperation among the Turkic Republics, establishing joint strategies, setting up joint data and information centers for today and tomorrow, and taking a common stance against monitoring by global hegemonic powers, so on, can be mentioned as measures to reduce the negative impact of basic economic activities on environmental degradation in the independent Turkic Republics.

On the other hand, it can be pointed out that it would be beneficial for the United Nations, international environmental organizations, and developed countries to provide physical, financial, and technical assistance to reduce the ecological deficits of the independent Turkic Republics, which are included among transition economies and are economically, politically, and strategically important.

**Contribution Rate Statement**

The authors' contribution rates in this study are equal.

**Conflict of Interest Statement**

There is no conflict of interest with any institution or person within the scope of this study. There is no conflict of interest between the authors.

## References

Aller, Carlos, Lorenzo Ductor, and Daryna Grechyna. "Robust Determinants of $CO_2$ Emissions." *Energy Economics*, vol. 96, 2021, pp. 105-154.

Ang, James B. "$CO_2$ Emissions, Energy Consumption, and Output in France." *Energy Policy*, vol. 35, no. 10, 2007, pp. 4772-4778.

Artan, Seyfettin, Pınar Hayaloğlu, and Burak Seyhan. "The Relationship Between Environmental Pollution, Trade Openness And Economic Growth in Turkey." *Journal of Management and Economics Research*, vol. 13, no. 1, 2015, pp. 308-325.

Asane-Otoo, Emmanuel. "Carbon Footprint and Emission Determinants in Africa." *Energy*, vol. 82, 2015, pp. 426-435.

Balogh, Jeremias Mate, and Atilla Jambor. "Determinants of $CO_2$ Emission: A Global Evidence." *International Journal of Energy Economics and Policy*, vol, 7, no. 5, 2017, pp. 217-226.

Breusch, Trevor, and Adrian Pagan. "The Lagrange Multiplier Test and Its Applications to Modelspecification Tests in Econometrics." *Review of Economic Studies*, vol. 47, no. 1, 1980, pp. 239-253.

Bucak, Çağla. "The Relationship Between Economic Complexity And Ecological Footprint in G8 Countries And Turkey: Toda-Yamamoto Causality Test Analysis." *The Journal of Social Economic Research*, vol. 22, no. 1, 2022, pp. 1-16.

Can, Muhlis, and Giray Gözgör. "The Impact of Economic Complexity on Carbon Emissions: Evidence From France." *Environmental Science Pollution Research,* vol. 24, 2017, pp. 16364-16370.

Cutler J. Cleveland, Robert Costanza, Charles A.S. Hall, and Robert Kaufmann. "Energy and the US Economy: A Biophsical Perspective." *Science*, vol. 225, no. 4665, 1984, pp. 890-897.

Çetin, Murat, and Selin Saygın. "Empirical Analysis of Environmental Kuznets Curve Hypothesis: The Example of Turkish Economy." *Journal of Management and Economics*, vol. 26, no. 2, 2019, pp. 529-546.

Damirova, Saharnoz, and Nihal Yayla. "The Relationship Between Environmental Pollution and Its Macroeconomic Determinants: A Panel Data Analysis For Selected Countries." *International Journal of Economics and Administrative Studies*, vol. 30, 2021, pp. 107-126.

Destek, Mehmet Akif, and Samuel Asumadu Sarkodie. "Investigation of Environmental Kuznets Curve for Ecological Footprint: The Role of Energy and Financial Development." *Science of the Total Environment*, vol. 650, no. 2, 2019, pp. 2483-2489.

Destek, Mehmet, and Avik Sinha. "Renewable, Non-Renewable Energy Consumption, Economic Growth, Trade Openness and Ecological Footprint: Evidence From Organisation For Economic Co-Operation and Development Countries." *Journal of Cleaner Production*, vol. 242, 2020, pp. 118-537.

Doğan, Buhari, Behnaz Saboori, and Muhlis Can. "Does Economic Complexity Matter for Environmental Degradation? An Empirical Analysis for Different Stages of Development." *Environmental Science and Pollution Research*, vol. 26, no. 31, 2019, pp. 31900-31912.

Doğan, Buhari, Oana M. Driha, Daniel B. Lorente, and Umer Shahzad. "The Mitigating Effects of Economic Complexity and Renewable Energy on Carbon Emissions in Developed Countries." *Sustainable Development*, vol. 1, no. 1, 2020, pp. 1-12.

Doğan, Eyüp, and Fahri Şeker. "The Influence of Real Output, Renewable and Nonrenewable Energy, Trade and Financial Development on Carbon Emissions in the Top Renewable Energy Countries." *Renewable and Sustainable Energy Reviews*, vol. 60, 2016, pp. 1074-1085.

Eberhardt, Markus, and Francis Teal. "Productivity Analysis in Global Manufacturing Production." *University of Oxford Department of Economics Discussion Paper, No: 515,* http://www.economics.ox.ac.uk/research/WP/pdf/paper515.pdf.

Eberhardt, Markus, and Stephen Bond. "Cross-Section Dependence in Nonstationary Panel Models: A Novel Estimator.", *Munich Personal RePEc Archive (MPRA) Paper 17692*, https://mpra.ub.uni-muenchen.de/17870/2/MPRA_paper_17870.pdf.

Eren, Kasım. "Turkic Republics in The Commonwealth of Independent States." *Journal of Economics and Management Research*, vol. 1, no. 1, 2012, pp. 43-73.

Ewing, Brad, Steven Goldfinger, Anna Oursler, Anders Reed, David Moore, and Mathis Wackernage. *The Ecological Footprint Atlas 2009.* Oakland: Global Footprint Network, 2009.

Global Footprint Network (2022). *National Footprint and Biocapacity Accounts (Data Year 2018).* https://data.footprintnetwork.org/?_ga=2.142359088.387322034.1654867648-2016969040.1654867648#/.

Grossman, Gene M., and Alan B. Krueger. "Economic Growth and The Environment." *Quarterly Journal of Economics*, vol. 110, no. 2, 1995, pp. 353-377.

Günel Tuğay. "Relationship between CO2 Emission and Economic Growth in Turkic Countries: A Panel Causality Analysis." *Sosyoekonomi,* vol. 27, no. 40, 2019, pp. 151-164.

Gylfason, Tharvaldur, and Gylfi Zoega. "Natural Resources and Economic Growth: The Role of Investment." *The World Economy*, nol. 29, no. 8, 2006, pp. 1091-1115.

Halıcıoğlu, Ferda. "An Econometric Study of CO2 Emissions, Energy Consumption, Income and Foreign Trade in Turkey." *Energy Policy,* vol. 37, no. 3, 2009, pp. 1156-1164.

Hotunluoğlu, Hakan, and Recep Tekeli. "Analysis and Effects of Carbon Tax: Does Carbon Tax Reduce Emission?" *Sosyoekonomi*, vol. 6, no. 6, 2007, pp.108-126.

Işık, Cem, Serdar Ongan and Dilek Özdemir. "Testing the EKC Hypothesis For Ten US States: An Application of Heterogeneous Panel Estimation Method." *Environmental Science and Pollution Research*, vol. 26, no. 11, 2019, pp. 10846-10853.

Khan, Danish Noheed, Muhammad A. Baloch, Shah Saud, and Tehreem Fatima. "The Effect of ICT on CO2 Emissions in Emerging Economies: Does The Level of Income Matters?" *Environmental Science and Pollution Research*, vol. 25, no. 23, 2018, pp. 22850-22860.

Kosifakis, Georgios, Athanasios Kampas, and Christos T. Papadas. "Economic Complexity and The Environment: Some Estimates on Their Links." *International Journal of Sustainable Agricultural Management and Informatics*, vol. 6, no. 3, 2020, pp. 261-271.

Leitão, Nuno Carlos, Daniel Balsalobre-Lorente and José María Cantos-Cantos. "The Impact of Renewable Energy and Economic Complexity on Carbon Emissions in BRICS Countries under the EKC Scheme." *Energies*, vol. 14, no. 16, 2021, pp. 1-15.

Nasreen, Samia, Sofia Anvar, and Ilhan Öztürk. "Financial Stability, Energy Consumption and Environmental Quality: Evidence From South Asian Economies." *Renewable and Sustainable Energy Reviews,* vol. 67, no. C, 2017, pp. 1105-1122.

Neagu, Olimpia, and Madalin-Ioan Neagu. "The Environmental Kuznets Curve Revisited: Economic Complexity and Ecological Footprint in The Most Complex Economies of the World." Studia Universitatis "Vasile Goldis" Arad. *Economics Series*, vol. 32, no. 1, 2022, pp. 78-99.

Neagu, Olimpia, and Mircea Constantin Teodoru. "The Relationship between Economic Complexity, Energy Consumption Structure and Greenhouse Gas Emission: Heterogeneous Panel Evidence from the EU Countries." *Sustainability*, vol. 11, no. 2, 2019, pp. 1-29.

Neagu, Olimpia. "Economic Complexity and Ecological Footprint: Evidence from the Most Complex Economies in the World." *Sustainability*, vol. 12, no. 21, 2020, pp. 1-18.

Ockwell, David G. "Energy and Economic Growth: Grounding our Understanding in Physical Reality." *Energy Policy*, vol. 36, 2008, pp. 4600-4604.

Özcan, Burcu. "The Nexus Between Carbon Emissions, Energy Consumption and Economic Growth in Middle East Countries: A Panel Data Analysis." *Energy Policy*, vol. 62, 2013, pp. 1138-1147.

Öztürk, İlhan, and Ali Acaravcı. "The Long-Run And Causal Analysis of Energy, Growth, Openness and Financial Development on Carbon Emissions in Turkey." *Energy Economics*, vol. 36, 2013, pp. 262-267.

Pata, Uğur Korkut. "Renewable and Non-Renewable Energy Consumption, Economic Complexity, $CO_2$ Emissions, and Ecological Footprint in the USA: Testing the EKC Hypothesis With A Structural Break." *Environmental Science and Pollution Research*, vol. 28, 2021, pp. 846-861.

Pesaran, M. Hashem, and Takashi Yamagata. "Testing Slope Homogeneity in Large Panels" *Journal of Econometrics*, vol. 142, 2008, pp. 50-93.

Pesaran, M. Hashem, Aman Ullah and Takashi Yamagata. "A Bias-Adjusted LM Test of Error Cross-Section Independence" *Econometrics Journal*, vol. 11, 2008, pp. 105-127.

Pesaran, M. Hashem. "A Simple Panel Unit Root Test in the Presence of Cross-Section Dependence." *Journal of Applied Econometrics*, vol. 22, 2007, pp. 265-312.

Salahuddin, Mohammad Khorshed Alam, and Ilhan Ozturk. "The Effects of Internet Usage and Economic Growth on $CO_2$ Emissions in OECD Countries: A Panel Investigation." *Renewable and Sustainable Energy Review*, vol. 62, 2016, pp. 1226-1235.

Sharma, Susan Sunila. "Determinants of Carbon Dioxide Emissions: Empirical Evidence From 69 Countries." *Applied Energy*, vol. 88, no. 1, 2011, pp. 376-382.

Soytaş, Uğur, and Ramazan Sarı. "Energy Consumption, Economic Growth, and Energy Emissions: Challenges Faced By an EU Candidate Member." *Ecological Economics,* vol. 68, no. 6, 2009, pp. 1667-1675.

Soytaş, Uğur, Ramazan Sari, and Bradley T. Ewing. "Energy Consumption, Income, and Carbon Emissions in the United States." *Ecological Economics*, vol. 62, no. 3-4, 2007, pp. 482-489.

T.R. Ministry of Environment and Urbanization (2018), https://webdosya.csb.gov.tr/db/bolu/icerikler/cevre-20180222082618.pdf.

Tamazian, Artur, Juan Piñeiro Chousa, and Krishna Chaitanya Vadlamannati. "Does Higher Economic and Financial Development Lead to Environmental Degradation: Evidence From BRIC Countries." *Energy Policy,* vol. 37, no. 1, 2009, pp. 246-253.

Tunay, K. Batu. "Interaction of Macroconomic Imbalances in Emerging Economies: The Case of Turkic Republics." *bilig,* no. 83, 2017, pp. 171-199.

Wang, S.S., Dequn Zhou, Peng Zhou, and Qunwei, Wang. "$CO_2$ Emissions, Energy Consumption and Economic Growth in China: A Panel Data Analysis." *Energy Policy*, vol. 39, no. 9, 2011, pp. 4870-4875.

World Wide Fund for Nature (WWF-Turkey). "Turkey Ecological Footprint Report." 2012, https://www.footprintnetwork.org/content/images/article_uploads/Turkey_Ecological_Footprint_Report_Turkish.pdf.

Yapraklı, Sevda, and Erdemalp Özden. "The Effect of Sustainable Development on Economic Complexity in OECD Countries." *International and Multidisciplinary Journal in Social Sciences*, vol. 10, no. 2, 2021, pp. 151-180.

Yapraklı, Sevda. *Energy-Driven Growth: Applications to the Turkish Industrial Sector.* 1st Edition, Istanbul: Beta Publications, 2013.

Yeter, Fatih, İlhan Eroğlu, Nalan Kangal, and Mustafa N. Çoban. "Relationship Between Economic Growth, Energy Consumption And Environmental Deterioration: Panel Data Analysis on Turkic Republics Abstract." *Turkish World Studies*, vol. 129, no. 255, 2021, pp. 405-432.

# Bağımsız Türk Cumhuriyetleri ve Türkiye'de Çevresel Bozulmanın Temel Makroekonomik Belirleyicileri: Panel Veri Analizleri*

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## Öz

Yaşamın devamı açısından önem arz eden çevresel bozulmayı önlemeye yönelik tedbirler tüm dünya ülkelerinin önem verdikleri temel konular arasında yer almaktadır. Sürdürülebilir çevre için hem küresel boyutta ortak hem de her ülkenin kendi imkânlarına göre bireysel politik tedbirler almaları gereklilik arz etmektedir. Uygulamalı literatürde yeraltı ve yer üstü doğal zenginliklerine rağmen ekolojik açık veren Bağımsız Türk Cumhuriyetleri'nde çevresel bozulmayı etkileyen temel makroekonomik faktörlerin neler olduğuna yönelik çok az sayıda çalışma bulunmaktadır. Bu nedenle çalışmada Türkiye ve Bağımsız Türk Cumhuriyetleri'nden Azerbaycan, Kazakistan, Kırgızistan, Türkmenistan ve Özbekistan için veri mevcudiyetine göre 1996-2018 dönemine ait yıllık veriler kullanılarak panel veri analizleri yapılmıştır. Analizlerde; çevresel bozulmayı temsilen ekolojik ayak izi bağımlı değişken, kişi başına GSYH, ekonomik karmaşıklık endeksi, yenilenemeyen ve yenilenebilir enerji tüketimi ile ticari dışa açıklık bağımsız

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değişkenler olarak ele alınmıştır. Analizlerden elde edilen bulgulara göre ekolojik ayak izinin temel belirleyicilerinin kişi başına GSYH, yenilenemeyen enerji tüketimi ve ekonomik karmaşıklık endeksi olduğu tespit edilmiştir.

**Anahtar Kelimeler**

Ekolojik açık, ekolojik ayak izi, biyokapasite, makroekonomik belirleyiciler, bağımsız Türk Cumhuriyetleri, panel veri analizi.

# Основные макроэкономические детерминанты деградации окружающей среды в независимых тюркских республиках и Турции: анализ панельных данных*

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**Аннотация**

Меры предосторожности по предотвращению деградации окружающей среды, важной для продолжения жизни, относятся к числу важнейших вопросов, которым придают значение все страны мира. Для устойчивой окружающей среды необходимо принять как глобальные общие, так и индивидуальные политические меры, соответствующие возможностям каждой страны. В литературе очень мало исследований основных макроэкономических факторов, влияющих на деградацию окружающей среды в независимых тюркских республиках и Турции, имеющих экологический дефицит, несмотря на наличие подземных и надземных природных ресурсов. По этой причине анализ па-

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нельных данных был проведен для независимых тюркских республик Азербайджана, Казахстана, Кыргызстана, Туркменистана, Узбекистана и Турции с использованием годовых данных за период 1996-2018 годов, в зависимости от наличия данных. В анализе экологический след, который представляет собой деградацию окружающей среды, рассматривается как зависимая переменная; ВВП на душу населения, индекс экономической сложности, потребление невозобновляемых и возобновляемых источников энергии, а также открытость торговли рассматриваются как независимые переменные. Результаты анализа показывают, что наиболее важными факторами воздействия на окружающую среду являются ВВП на душу населения, потребление невозобновляемой энергии и индекс экономической сложности.

**Ключевые слова**
Экологический дефицит, экологический след, биоемкость, макроэкономические детерминанты, независимые тюркские республики, анализ панельных данных.