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***Yıldız Sağlam Çeliköz*[1], *Tuba Yildiz*[1], *Ünal Arslan*[1], *Hale Kirmizioğlu*[2]**

[1]*Hatay Mustafa Kemal University*
[2]*Kirsehir Ahi Evran University*
[1,2]*Turkey*

THE RELATIONSHIP BETWEEN ECONOMIC GLOBALIZATION AND ECOLOGICAL FOOTPRINT: EMPIRICAL EVIDENCE FOR DEVELOPED AND DEVELOPING COUNTRIES

Purpose. *The aim of this study is to examine the relationship between economic globalization and the ecological footprint in countries with different levels of development using a Feasible Generalized Least Squares (FGLS) analysis.*

Methodology / approach. *The study covers the years 1970 to 2017 for 65 developed and developing countries. The ecological footprint is the dependent variable in the study's model, and the GDP and KOF Globalization Index (KOF) index are the independent variables. The CADF panel unit root test, which takes into account cross-sectional dependence, was used to choose the appropriate test method for the analysis. Feasible Generalised Least Square and Westerlund ECM panel cointegration analyses were performed for model estimation.*

Results. *Economic globalization and ecological footprint have a considerable relationship, according to the results of FGLS and Westerlund cointegration analysis. Economic globalization has a long-run negative impact on the ecological footprint. Environmental problems are being addressed as a result of more economic globalization, faster technology development, and consequently decreased usage of natural resources. Furthermore, as globalization and communication technologies develop, societies will have more information on the importance of the environment. As a result, they can show more eco-friendly behavior.*

Originality / scientific novelty. *Several studies in the literature include the cointegration relationship between economic globalization and ecological footprint. Although there are few studies on this topic in the literature, one aspect that distinguishes this study is the use of an estimation method that takes into account the cross-sectional dependent, second-generation unit root tests, FGLS cointegration analysis, and Westerlund ECM analysis.*

Practical value / implications. *The importance of the findings is that increased economic globalization has a negative effect on the ecological footprint. As economic globalization increases, so does communication technology, as well as international trade. Individuals become more environmentally conscious as a result of communication, which generally reduces ecological footprint.*

Key words: *ecological footprint, economic globalization, environment, panel analysis.*

Introduction and review of literature. The globalization trend that began in the 1980s affected all countries around the world, intensifying competition among countries to achieve economic progress (Saleem et al., 2019). Globalization has the potential to spur economic growth or further industrialization (Wiseley, 2020). Many studies show that globalization leads to economic growth (Ying et al., 2014; Gurgul & Lach, 2014; Samimi & Jenatabadi, 2014; Tekbaş, 2021; Chang & Lee, 2010; Kýlýcarslan & Dumrul, 2018; Dreher, 2006; Rao & Vadlamannati, 2011; Potrafke, 2015).

However, increasing competition has forced all countries to make greater use of their natural resources in order to achieve higher growth rates (Saleem et al., 2019). The goal of industrial and economic growth, supported by the process of globalization (Langnel & Amegavi, 2020), undoubtedly helps in development, but it also creates negative externalities in the manner of environmental degradation and ecological pollution (Shahzadi et al., 2019). Thus, according to Shahzadi et al. (2019), one of the main causes of global environmental change is the globalization process. On the other side Ahad & Khan (2016) asserted that globalization contributes to environmental damage in both the short and long run.

Many economies have achieved high growth rates and increased welfare as a result of globalization, at the expense of environmental quality. While growth and development have been achieved as a result of increased competition and striving for industrialization, climate change and global warming have also begun to increase. The costs of greenhouse gas emissions (GHG), of which carbon emissions represent approximately 60 %, have begun to raise concerns (Majeed & Mazhar, 2020). As a result, empirical studies on the environmental damage caused by globalization have been published in the economics literature.

This has led to empirical studies in the economic literature on the environmental damage caused by the excessive use of natural resources as a result of the growing desire caused by globalization. Studies have been conducted to investigate the relationship between growth and the environment in general, and the search for a relationship between environment and development begins with the Environment Kuznets Curve (EKC) (Sharif et al., 2019).

S. Kuznets developed the Kuznets Curve in 1955 to demonstrate the relationship between income distribution and economic growth. The hypothesis known as the “inverted U” or “bell curve” in literature argued that economic development increased the amount of income per capita, but income inequality also increased in the first stage of development, and then the increasing income inequality started to decrease after a certain turning point, depending on the continuation of economic development (Koçak, 2014).

Grossman & Kruger (1991) were the first to apply Kuznet’s inverted U curve, which depicts the relationship between income distribution and economic growth (Çetin & Saygın, 2019). Grossman & Krueger (1991) discovered that pollutants like sulfur dioxide and smoke rise with lower national income levels but fall with higher income levels. That is, pollution rises with GDP at lower income levels before reaching a peak and then falling with GDP at higher income levels.

However, no reference was made to the Environmental Kuznets Curve (EKC) in this study, which identified an inverse U relationship between economic growth and environmental pollution. Panayotou (1993) coined the term “Environmental Kuznets Curve” to describe the inverted-U-shaped relationship discovered in the studies (Çetin & Saygın, 2019).

Carbon dioxide emissions (CO_2) in particular were used to put the curve to the test (EKC). The Environmental Kuznets Curve (EKC) states that pollution increases during the early stages of economic growth but reverses when per capita income reaches a certain level, implying that economic growth leads to environmental improvement at high-income levels, expressing an inverted U-shaped relationship between pollution and income (Saleem et al., 2019; Mahmood et al., 2019; El Alaoui, 2017). Studies confirming the EKC hypothesis: Shahzadi et al. (2019), Destek (2020), Kalayci & Hayaloğlu (2019), Shahbaz et al. (2015), Shahbaz et al. (2018b), Destek & Sarkodie (2019), Saleem et al. (2019), Charfeddine (2017), Çetin & Saygın (2019), Özbek & Oğul (2022), Can et al. (2020). However, Tetteh & Baidoo (2022), Ahad & Khan (2016), Bataka (2021), Farhani & Ozturk (2015), Dinda (2006), Koçak (2014) show that Globalization causes environmental degradation through CO_2, and they claim that this increase has no threshold value; that is, as globalization increases, CO_2 levels rise indefinitely.

Because carbon dioxide emission (CO_2) is regarded as the primary cause of global warming (Can et al., 2020), it has been primarily used to test the EKC hypothesis in recent years (Saleem at al., 2019). Aside from increased CO_2 emissions, many other factors contribute to environmental degradation, such as the overuse of natural resources, increased energy use, and the desire for greater economic development (Hassan et al., 2022). Excessive use of natural resources for high economic growth results in soil, water, and air pollution (Saleem at al., 2019). CO_2 emissions do not recognize soil and water pollution. These findings suggest the need for a more comprehensive indicator of environmental degradation. As a result, Wackernagel & Rees (1996) developed the ecological footprint (EF) to calculate environmental degradation. Unlike CO_2 emissions, EF covers different dimensions of environmental degradation, including residential land, forest land, carbon footprint, grazing land, and ocean (Nathaniel, 2021).

In the empirical studies carried out in the literature review, it was observed that studies are usually conducted at the level of a country or a group of countries in a particular region, or the analysis is conducted by distinguishing between developed and developing countries. However, this study considered both developed and developing countries.

Globalization comes from the term "global", which means "concerning the whole world", "worldwide", and "universal", according to the Oxford English Dictionary (Karataş, 2016). Rudolf & Figge (2017) define globalization as "the establishment of transnational structures and the intensification of cultural, economic, ecological, political, technological and social processes in the international arena". Globalization is a multidimensional concept that includes not only economics but also other disciplines such as sociology and politics (Shahbaz et al., 2018a). Globalization primarily led to free trade, and ultimately, through foreign direct investment and imports, it enabled the transfer of technology from developed to developing countries and increased the comparative advantages of different economies (Shahbaz et al., 2017). Globalization positively affects economic growth by increasing factor productivity and encouraging foreign direct investment, but indirectly increases energy consumption and environmental degradation (Sabir & Gorus, 2019).

As can be seen in Figure 1, globalization, as defined by the various definitions, can be divided into three major categories: economic, social, and political (Sabir & Gorus, 2019) and it affects every person all over the world in terms of socio-economic-political aspects of life (Shahbaz et al., 2015). However, while economic, political, and social integration among nations has positive effects on the environment, it also has negative consequences (Ahmed et al., 2019). Through international mobility, personal contacts, and global media, globalization socially dissolves differences between people. Environmental awareness grows as a result of access to news and other resources via the Internet or international communication (Rudolf & Figge, 2017). Eco-friendly practices such as recycling, water conservation, energy conservation, and the use of renewable energy products can be supported through environmental sensitivity (Ahmed et al., 2019). Political globalization is the process by which nations are united through bilateral diplomatic negotiations, international organizations, and international agreements (Rudolf & Figge, 2017). This process increases countries' participation in global environmental agreements. According to international standards, countries are obliged to reduce energy consumption and emissions. Compliance with international standards for energy consumption and emissions will result in improved environmental quality (Ahmed et al., 2019). Economic "globalization" refers to the movement of goods, services, and capital across borders, as well as the increased integration of world economies (International Monetary Fund, 2008). Globalization can have an economic influence on the environment such as through trade and foreign direct investment (Ahmed et al., 2019). Indeed, economic liberalization is usually taken into account when evaluating how environmental degradation is occurring as a result of globalization or how it affects the environment. In this context, the environmental effects of globalization are investigated through foreign trade and foreign direct investment (FDIs), which represent trade in goods and services (Karasoy, 2021).

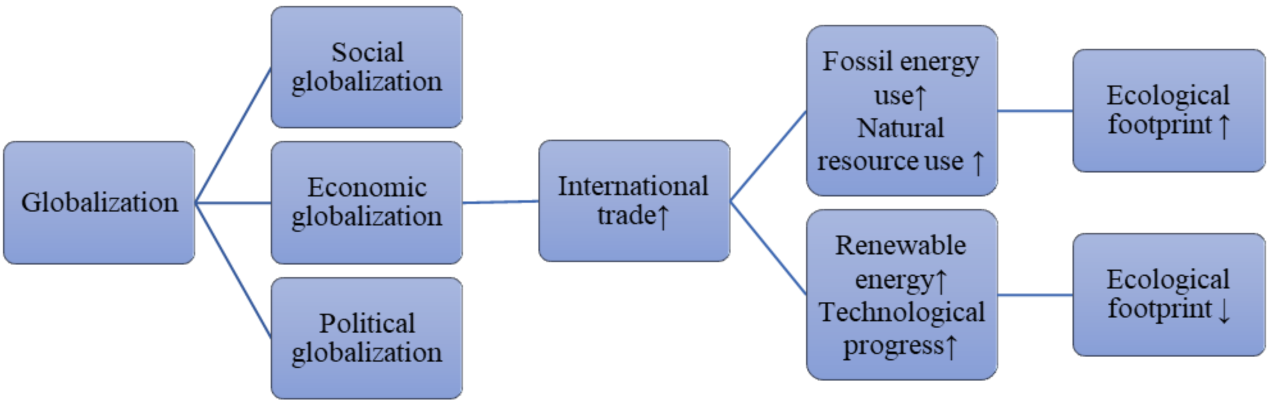

Figure 1. Relationship between globalization and environmental pollution

Source: formed by the authors based on a literature review.

In the literature, the consequences of globalization for the environment are divided into two types: indirect and direct (McAusland, 2008). Although the direct effects are underemphasized in the economics literature, they are the ones with the most serious consequences in the short run. The direct effects, on the other hand, emerge through transportation, specifically shipping, truck transportation, and aviation, which are realized as a result of the liberalization of foreign trade and globalization. The transportation techniques used as a result of increased international transportation have direct and negative effects on environmental quality through the emissions produced (Gallagher, 2009; Copeland et al., 2021).

Indirect effects are listed as scale effect, composition effect, and technical effect (Gallagher, 2009; McAusland, 2008; Panayotou, 2000; Bilgili et al., 2020; Karasoy, 2021; Grossman & Kruger, 1991; Cole, 2004; Copeland, 2009). Scale effects occur when trade liberalization causes the expansion of economic activity. Environmental pollution and resource consumption will rise in parallel with the output if the scale is increased without changing the nature of economic activity (Gallagher, 2009). In other words, the scale effect means that, while all other factors remain constant, globalization will cause an increase in energy consumption in parallel with increases in the scale of economic activity (Shahbaz et al., 2018c). The scale effect refers to the response of domestic production levels to international trade and refers to the fact that trade can have effects such as growth (Copeland, 2009). In other words, globalization boosts economic activity by increasing transportation services as well as the production and consumption of goods and services (Bilgili & Ulucak, 2020). Because foreign trade enhances economic growth, economic activity rises as a result of growth, and environmental degradation worsens (Karasoy, 2021). However, an increase in economic scale without changes in the type of economic activity or in reducing or protecting pollution will have negative environmental effects (Copeland, 2009). In summary, the scale effect refers to the possibility of rising pollution as a result of economic growth caused by greater access to the market (Cole, 2004). Ahmed et al. (2019) argued that if the scale effect is dominant, globalization will increase energy consumption and emissions as economic activities increase. However, Panayotou (2000) has argued that increased trade will have a positive impact when it leads to better environmental protection through economic growth and policy development that encourages changes in product composition and technology that result in less pollution per unit of production.

The composition effect is caused by any change in trade policy (Grossman & Kruger, 1991) and refers to the effect of free trade on the composition of production between countries (Bilgili & Ulucak, 2020). Trade liberalization causes countries to change the composition of their production and consumption by specializing in activities where they have a comparative advantage (Cole, 2004). The composition effect can increase or decrease environmental degradation depending on the nature of the specialized product(s) (Karasoy, 2021). If the comparative advantage is due to differences in environmental regulations between countries, the composition of goods produced for foreign trade will aggravate existing environmental problems in countries with a relative lack of regulations (Gallagher, 2009). Each country will then tend to specialize in activities that are not strictly regulated by its government and will leave industries where the local costs of reducing pollution are relatively high (Grossman & Kruger, 1991). The Heckscher-Ohlin (H-O) theory in international economics, on the other hand, assumes that each country has a comparative advantage in industries that use the factor that it has in abundance (Gallagher, 2009). If the sources of international comparative advantage are abundance of factors and technical differences between countries, foreign trade liberalization will lead each country to transfer its resources to sectors that make extensive use of their plentiful factors (Grossman & Kruger, 1991). In terms of pollution, the H-O hypothesis might be claimed that a developing country with less severe environmental standards will have an abundance of polluting factors. As a result, liberalizing commerce between developed and developing countries while the developed country has stronger restrictions may increase polluting economic activity in the poorly regulated developing country (Gallagher, 2009). This supports the pollution hypothesis, which refers to the movement of polluting activities to countries with weak environmental laws and explains how polluting industries move from developed to developing countries. Similarly, the factor endowment hypothesis claims that when environmental regulations are not strict enough, natural resource-rich countries will specialize through globalization in the production and export of goods for which they can make intensive use of their natural resources, usually using environmentally damaging production techniques (Bilgili & Ulucak, 2020).

The other indirect effect of globalization on the environment is the technical effects (Copeland, 2009). The technological effect refers to changes in production techniques as a result of international trade (Cole, 2004). In other words, as a consequence of globalization, countries will be able to obtain power technology from international markets, enabling them to improve their production methods to use energy more efficiently and minimize carbon dioxide emissions levels (Bilgili & Ulucak, 2020). Economic liberalization, according to the technical effect, could decrease environmental degradation by enabling the transfer of technology and new eco-friendly production techniques (Karasoy, 2021; Kucher et al., 2019).

Globalization is a process by which individuals, companies, and governments interact and integrate. This process is driven by international trade and investment and is supported by information technology (Herrmann & Hauschild, 2009). Globalization is expected to lead to increased global production (scale effect), increased technological development (technological effect), and changes in the composition and location of production and consumption activities (structural effect), as well as the ability to produce and consume different product combinations (product effect) (Apaydın, 2020). On the other hand, it should be emphasized that free international commerce and foreign direct investment (FDI) caused by globalization will expand economic activity, technology transfer, and energy use, each of which will affect the environment (Abid et al., 2021). According to the Ecological Footprint Atlas, human demands have exceeded Earth's biological capacity since the 1970s, resulting in an ecological overshoot. Human demands are the ecological assets required by a particular population to generate the natural resources it consumes, whereas biocapacity is the productivity of these ecological assets. Human demands affect ecosystems by creating ecological pressures such as land use changes, resource extraction and depletion (such as deforestation and overfishing), waste emissions and pollution, and organism modification and movement. Climate change, land degradation, species extinction, and pollution are some of the environmental pollutions (Rudolf & Figge, 2017). Climate change harms the terrestrial ecosystem, food availability, land quality, and human life. The main impact of climate change is greater carbon emissions in the atmosphere. These emissions are generated by the use of conventional energy sources (fossil fuels), which represent about 80 % of total energy. Furthermore, excessive resource use increases environmental stress and the ecological footprint (EF) globally (Abid et al., 2021). For example, while the biologically productive area (ecological footprint) needed to carry out all economic activities worldwide in 1961 was 7.05 billion hectares (kha), the bio-capacity reflecting the area required to create these resources in total was 9.6 billion kha. In other words, there is no ecological deficit and the world's ecological reserves are sufficient. However, this situation has started to change since 1980, which is widely regarded as the start of the globalization movement. As of 1980, the total ecological footprint was 12.2 billion kha, whereas the total biocapacity was 10.3 billion kha. When examined for 2016, the ecological footprint is 20.5 billion kha compared to the biocapacity of 12.1 billion kha, indicating that the ecological deficit has reached significant proportions (Apaydın, 2020).

Economic globalization (EG) can affect the EF negatively or positively. If EG rises as a result of increased business globalization and the elimination of trade barriers like tariffs, so will commercial activity and the economy. Consequently, the exchange of goods and services accelerates and increases production and consumption in all countries. Therefore, activities such as industrial production, foreign direct investments, and transportation are increased (Ahmed et al., 2021b). Although more foreign direct investment benefits industrialized nations in terms of environmental quality, it harms developing countries.

Developed countries move harmful industrial output to developing countries, increasing environmental pollution in developing countries. At the same time, as economic activity and production levels increase, so does environmental pollution as the amount of energy consumed increases (Yilanci & Gorus, 2020). However, when commercial activities grow because of EG, production may shift away from industrial economies, where more energy is required as an input, toward eco-friendly and service-based economies. As a result, these changes in economic structure may have a lower impact on environmental pollution. EG also encourages technical advancement (Abid et al., 2021). Technological progress, on the other hand, prevents environmental destruction caused by natural resource depletion by enabling more output with less resource use.

Based on the results of literature research, there are three conclusions on the relationship between EG and EF (Table 1).

Table 1

Studies in the literature on EG and EF

Author(s), date	Country	Sample period	Method	Results
1	2	3	4	5
Ahmad et al. (2021)	G7 countries	1980–2016	Westerlund panel cointegration analysis, Dumitrescu and Hurlin causality test	EG negatively affects EF. There is a bidirectional causality relationship between EG and EF
Ahmed et al. (2021a)	Japan	1971–2016	ARDL analysis and Granger causality	In linear ARDL, EG increases EF EG decreases EF in non-linear ARDL. There is unidirectional causality from EG to EP
Ahmed et al. (2021b)	United States	1970–2016	Asymetric ARDL	EG positively affects EF
Aluko et al. (2021)	27 industrialized countries	1991–2016	STIRPAT (stochastic impact by regression on population, affluence and technology) model	EG negatively affects EF
Yang et al. (2021)	27 OECD countries	1970–2017	Pooled Mean Group (PMG) cointegration analysis, the Dumitrescu-Hurlin causality analysis	EG affects EF positively in the long run and negatively in the short run. There is a unidirectional causality relationship between EG and EF
Langnel et al. (2020)	Ghana	1971–2016	ARDL analysis	EG positively affects EF
Suki et al. (2020)	Malaysia	1970–2018	Quantile autoregre-ssive distributed lag (QARDL) analysis	In the long run, EG positively affects EF. In the short run, EG does not affect EF
Omoke et al. (2020)	Nigeria	1971–2014	NARDL (nonlinear autoregressive distributed lag) analysis	EG reduces EF both in the short and the long run
Wiseley (2020)	182 countries of varying globalization levels	1996–2014	Panel regression analysis	There is a positive relationship between EG and EF
Yilanci & Gorus (2020)	14 MENA countries	1981–2016	Dumitrescu-Hurlin panel causality	EG does not affect EF unidirectional causality from EF to EG
Ahmed et al. (2019)	Malaysia	1971–2014	Bayre and Hanch cointegration analysis	EG does not affect EF
Figge et al. (2017)	171 countries	2012	Multivariate regression analysis	While EG increases EF related to import, it has no effect on EF related to export or consumption
Rudolf & Figge (2017)	146 countries	1981–2009	Extreme bound analysis (EBA) Granger causality	EG positively affects EF

Continuation of Table 1

1	2	3	4	5
Kassouri & Altıntaş (2020)	13 MENA countries	1990–2016	Panel cointegration test	For the entire sample and across the two subsamples, the results reveal a significant trade-off between the ecological footprint and human well-being as measured by the human development index
Apaydin, et al. (2021)	130 countries	1980–2016	CCE-MG and AMG	There is no significant relationship between EF and globalization
Farhani & Ozturk (2015)	Tunisia	1971–2012	ARDL ECM	Financial development, which is a branch of economic globalization, takes place at the expense of environmental pollution
Kirikkaleli et al. (2020)	Turkey	1985–2017	Dual adjustment approach	Globalization affects EF positively-trade openness reduces EF in the short run
Shahbaz et al. (2018b)	25 developed economies	1970–2014	Time series panel data	Globalization increases carbon emissions
Shahbaz et al. (2015)	India	1970–2012	ARDL bound test	CO_2 emission are increasing as the process of globalization intensifies
Sabir & Gorus (2019)	South Asian countries	1975–2017	ARDL model	Globalization has a positive and statistically significant impact on EF
Sharif et al. (2019)	15 globalized countries	1970–2016	Quantile-on-quantile regression (QQ) Granger causality	The results indicate that globalization has a positive effect on EF in some countries while there is a negative effect between globalization and EF in other countries
Usman et al. (2020)	USA	1985:Q1–2014:Q4	ARDL	Globalization has a positive impact on EF in both the long and short run
Kalayci & Hayaloğlu (2019)	NAFTA countries	1990–2015	Panel data analysis	There is a positive relationship between EG and trade openness, and CO_2 emission
Destek (2020)	Central and Eastern European countries	1995–2015	Panel data analysis	EG increases carbon emission which increases environmental pollution
Shahzadi et al. (2019)	Low-income countries	1996–2015	Panel data analysis	Globalization has a positive effect on environmental degradation
Bataka (2021)	38 Sub-Saharan African countries	1980–2017	FGLS	Globalization contributes positively to environmental pollution in SSA by increasing carbon dioxide emission (CO_2)
Tunçbilek & Ulucak (2021)	15 developing countries	1970–2016	Panel data analysis	EG reduces EF
Wang et al. (2021)	148 countries	2001–2018	GMM estimation	EG reduces EF

Source: formed by the authors based on a literature review.

The first is that economic globalization reduces the ecological footprint. Likewise Ahmad et al. (2021), Ahmed et al. (2021a), Aluko et al. (2021), Omoke et al. (2020), Wang et al. (2021) discovered a negative relationship between economic globalization and ecological footprint. In other words, increasing EG decreases EF. Technology transfer takes place between countries because of increased economic activity related to the growth of EG. As a result of technical development, more output is obtained with fewer resources. Consequently, reduced resource use decreases resource waste and enables the product to be less harmful to the environment. The second result is that EG increases EF. EG increases EF, according to Ahmed et al. (2021b), Yang et al. (2021), Langnel & Amegavi (2020), Suki et al. (2020), Wiseley (2020), Figge et al. (2017), Rudolf & Figge (2017), Kirikkaleli et al. (2020), Sabir & Gorus (2019), Sharif et al. (2019), Usman et al. (2020) and Shahzadi et al. (2019). Energy use increases with increased production due to commercial activities, which have become more common with the growth of EG. The majority of the world's energy resources are fossil fuels, and the environmental damage caused by fossil fuels is much greater than from other energy sources. As a result, as energy use rises, so does environmental degradation. In contrast, Shahbaz et al. (2018b), Shahbaz et al. (2015), Kalayci & Hayaloğlu (2019), Destek (2020), Bataka (2021) and Farhani & Ozturk (2015) found in their studies that expanding globalization raises the ecological footprint by increasing carbon emissions. That is, when carbon emissions grow, EG raises EF. This shows that, as a result of economic globalization and the removal of barriers to capital movement and foreign direct investment (FDI), polluting multinational corporations that use higher CO_2 emissions in their production are beginning to relocate from countries with strict environmental regulations to countries with weaker environmental regulations. The third conclusion is that there is no relationship between EG and EF: Yilanci & Gorus (2020), Ahmed et al. (2019) and Apaydin et al. (2021) did not find any significant relationship between EG and EF in their studies.

The purpose of the article. The aim of this study is to examine the relationship between economic globalization and the ecological footprint in countries with different levels of development using a Feasible Generalized Least Squares (FGLS) analysis.

Methodology. This study examines the relationship between EG and EF. Within the framework of data availability, 65 countries were included in the analysis. We used annual data from 1970 to 2017. FGLS (Feasible Generalised Least Square) analysis developed by Hansen (2007) and Westerlund analysis developed by Westerlund (2007) were used to investigate the long and short-run cointegration relationship between the variables.

The data for the economic globalization index was taken from the official website of the KOF Swiss Economic Institute, the data for the EF from the official website of the Global Footprint Network, and the data for economic growth from the World Bank's official website. The model obtained using variables included in the study is as follows:

Model: $EF_{it} = \alpha_0 + \alpha_1 GDP_{it} + \alpha_2 KOFGDF + \epsilon_{it}$

In the resulting model, EF represents the ecological footprint, GDP represents real national income per capita, KOFGDF represents the economic globalization index, and ϵ_{it} represents the error term coefficient.

Results and discussion. The following are the outcomes of economic globalization: Economic globalization (EG) refers to the liberalization of international commerce in products and services, as well as capital flows. EG enhances the country's economy by increasing national income as a result of increased international trade and production. Increasing international trade because of economic globalization results in more technological transfer. Thus, technological development accelerates in low-technology countries, and higher production efficiency may be achieved using economies of scale. Capital transfers and investments are growing because of EG. As a result of foreign direct investments, a country has the opportunity to invest in a foreign country. Consequently, the cost of the investing countries falls and profit rates rise. The investing country's capital, employment opportunities, and technology transfer are increasing. As a consequence, each country's economy grows and its competitive advantages rise.

Cross-Sectional Dependency Test. In panel data analysis, unlike time series analysis, cross-sectional dependence and homogeneity tests are applied to the variables used in the model in order to determine the level at which the variables are stationary. According to the results obtained in the analysis, if the series contain cross-section dependence, the second-generation unit root test is applied (Pesaran, 2007). There are various cross-section dependency tests, one of which, the LM test (Berusch & Pagan, 1980), is applied when the time dimension is greater than the cross-section dimension ($T>N$).

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

In equation (1), p_{ij} shows the correlation coefficients obtained from the error terms of the model. The asymptotic distribution of x^2 is obtained from N for all (i, j) while $T(i,j) \to \infty$. According to Pesaran (2004), in some cases, the cross-section dimension is equal to the time dimension and when N is bigger than T, errors in the analysis may exist. In this case, Pesaran (2004) developed the CD_{LM} (Cross Section Dependent) test:

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

where $\hat{p}_{ij}$ = correlation of sections between error terms.

Pesaran et al. (2008) LM_{adj} test, on the other hand, corrects any errors that may occur if the cross-section dimension is greater than the time dimension. The test statistic in the LM_{adj} test is calculated as follows:

$$LM_{adj} = \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} (T\hat{\rho}_{ij}^2 \; \frac{(T-k)\hat{\rho}_{ij}^2 - \mu_{Tij}}{\vartheta_{Tij}} \quad (3)$$

where K = regressors number;

μ_{Tij} = average;

ϑ_{Tij} = variance.

If the probability value is less than 0.05, it is concluded that there is a cross-section dependence.

Homogeneity Test. The homogeneity test is an analysis method created by (Pesaran & Yamagata, 2008) that analyzes the heterogeneity of the slope coefficient. The heterogeneity of the slope coefficient indicates that the coefficients obtained in the panel data analysis are not valid for every country included in the analysis (Pesaran & Yamagata, 2008). This analysis method was created by developing the Swamy (1970) model:

$$\tilde{N} = \sqrt{N}\left(\frac{N^{-1}\,\tilde{S}-k}{\sqrt{2k}}\right) \quad (4)$$

$$\tilde{N}_{adj} = \sqrt{N}\left(\frac{N^{-1}\,\tilde{S}-E(\tilde{Z}_{iT})}{\sqrt{Var}\,(\tilde{Z}_{iT})}\right) \quad (5)$$

Table 2 shows the results of an analysis of the cross-section dependency test in terms of the model and variables used in the model. The LM, CD_{LM}, and LMadj tests all reject the hypothesis that there is no cross-section dependency. International trade between countries, which has emerged throughout economic globalization, helps countries' economic growth on the one hand, but it also causes the growth of companies that pollute the environment, resulting in an increase in ecological footprint. According to the model's cross-section dependency test, there is a cross-section dependency as a result of all three tests. Therefore, the second-generation unit root test is more appropriate for variables stationarity analysis.

Table 2

Cross-Sectional Dependency Test

Variables and Models	Breusch and Pagan (1980) LM Test	Pesaran (2004) CDLM Test	Pesaran et al. (2008) LMadj	Result of Cross-Sectional Dependence
EF	1504 (0.000)	23.46 (0.000)	734.6 (0.000)	accepted
KOFGDF	1604 (0.000)	45.38 (0.000)	834.9 (0.000)	accepted
GDP	3004 (0.000)	56.21 (0.000)	1665 (0.000)	accepted
Model	5341 (0.000)	14.09 (0.000)	173.7 (0.000)	accepted
Model				
$\tilde{N}$	96.098 (0.000)			
$\tilde{N}_{adj}$	100.371 (0.000)			

Source: authors' calculations.

Panel Unit Root Test. According to the results of the cross-section dependency test for the variables used in the model, it is seen that there is a cross-section dependency in the variables. Therefore, it is more appropriate to use the CADF (Cross-sectional Augmented Dickey-Fuller) second-generation unit root test, which takes into account the cross-sectional dependency and was developed by Pesaran (2007) for the analysis of stationarity. The CADF unit root test also gives reliable results in that it can be applied when the cross-section dimension is larger than the time dimension and the time dimension is larger than the cross-section dimension (Pesaran, 2007). The equation for the CADF unit root test is shown as follows:

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

CADF test statistics are calculated as follows:

$$t_i(N,T) = \frac{\Delta Y_i' \bar{M}_W Y_{i,-1}}{\hat{\sigma}_i (Y_{i,-1}' \bar{M}_W Y_{i,-1})^{\frac{1}{2}}} \qquad (7)$$

According to Pesaran (2007), the CIPS statistics were obtained through the CADF test by calculating the basic arithmetic average of each series. CIPS statistics are as follows:

$$CIPS(N,T) = N^{-1} \sum_{i=1}^{N} t_i(N,T) \qquad (8)$$

The results of the analysis in Table 3 show that the ecological footprint (EF) and economic growth (GDP) variables are stationary at the I(1) level, whereas the economic globalization index (KOFGDF) variable is stationary at the I(0) level. In performing the stationarity analysis of the variables used in the unit root analysis, the trend value was not taken into account.

Table 3

CADF Panel Unit Root Test Results

Variables	CIPS statistics		
	Test statistics	*P*-value	Result
EF	-1.452	0.997	I(1)
d.EF	-5.074***	0.000	I(0)
KOFGDF	-2.306***	0.000	I(0)
GDP	-1.374	1.000	I(1)
d.GDP	-3.462***	0.000	I(0)

Note. *** Indicates significance at the 1 % level.
Source: authors' calculations.

FGLS Estimation. A feasible GLS estimator is a more efficient analysis method since it consistently estimates the large error covariance matrix when heteroskedasticity, serial and cross-sectional correlations are found (Bai et al., 2021). The regression equation of the FGLS model is shown as follows:

$$y_{it} = x_{it}' \beta + \mu_{it} \qquad (9)$$

$$Y = X\beta + U \qquad (10)$$

where $Y = (y'_1, \ldots\ldots y'_T)'$ is the NT*1 vector of y_{it} with each y_t being an N*1 vector;

$X = (X'_1, \ldots\ldots X'_T)'$ is the NT*d matrix of x_{it} with each x_t being an N*d vector;

$U = (u'_1, \ldots\ldots u'_T)'$ is the NT*1 vector of u_{it} with each u_t being an N*1 vector.

$$\tilde{\beta}_{GLS}^{inf} = (X'\Omega^{-1}X)^{-1}X'\Omega^{-1}Y \qquad (11)$$

$\Omega = (Eu_t u_s')$ be an NT*TN matrix, (t, s) is N*N covariance matrix $Eu_t u_s'$.

Table 4 shows the estimation results from the FGLS analysis. According to the findings in Table 4, there is a long-term negative relationship between ecological footprint and economic globalization. As economic globalization increases, so does technological transfer between countries. As a consequence of technological advancement, countries begin to use more eco-friendly production methods. Furthermore, the process of natural resource extinction decreases as countries try to produce more with fewer resources because of modern technology. These developments have resulted in less environmental destruction and, as a result, less EF. While there is a positive and significant relationship between EF and economic growth in the short term, there is no significant relationship between EF and EG. In the process of economic growth, society tries to improve output at any cost. As a result, environmental protection remains in the background. Although economic growth increases the EF in the short term, this effect fade over time as countries embrace more eco-friendly behaviors.

Table 4

FGLS Estimations Results

Dependent Variable: EF	MODEL: FGLS
KOFGDF	-0.002* (0.000)
GDP	1.167* (0.000)
Cons	-6.545* (0.000)
Number of groups	65
Number of observations	3102
Heteroscedasticity and Correlation Tests	
Heteroscedasticity test: Breusch-Pagan F-test	177.60 (0.000)
Heteroscedasticity test: White: x^2	595.92 (0.000)
Wooldridge serial correlation F-test	48.306 (0.000)
Pesaran’s cross-sectional correlation test	15.981 (0.000)

Note. The values in parentheses show the probability value (*p*-value).

*Indicates significance at the 5 % level.

Source: authors’ calculations.

To show that the results are robust, we applied the Breusch-Pagan and White tests. According to Breusch-Pagan and White tests’ null hypothesis, error variances are equal, i.e., homoscedastic, and according to the alternative hypothesis, error variances are a multiplicative function, i.e., heteroscedasticity (Xu et al., 2022). As a result, we have rejected the null hypothesis. As a result of the findings, the model shows heteroscedasticity. Then, for serial correlation, we used the Wooldridge Serial

Correlation *F*-test, and for cross-sectional dependence, we used Pesaran's Cross-Sectional Correlation test. We rejected the null hypothesis in both the Wooldridge *F*-test (observations are not serially correlated) and Pesaran's test (no cross-section correlation).

Westerlund ECM panel cointegration. Because the series shows cross-sectional dependency properties, it is important to apply cointegration tests that account for both cross-sectional dependency and heterogeneity to improve the reliability of the results. According to Westerlund (2007), in the Westerlund analysis, the Ga and Gt methods are used to examine the cointegration relationship among the variables when the slope coefficient derived from the model is heterogeneous, and the Pa and Pt methods are used when the slope coefficient shows homogenous properties. The null and alternative hypotheses for the Westerlund cointegration analysis are shown as follows:

H_0: Pi=0 (for all i)
H_1: Pi<0 (for all i)

The regression equation of the Westerlund cointegration analysis is shown as follows:

$$\Delta Y_{it}=\delta'_{dt}+\mu'_i\Delta X_{it}\gamma_i Y_{it-1}\varphi_i X_{it-1}+\varepsilon_{it} \quad (12)$$

where d_t = vector showing constant and trend;

μ'_i = long run γ_i and φ_i short-run parameters. After that, Pa and Pt statistics are calculated to test these hypotheses.

Pa statistics: $Pa=(\sum_{i=1}^{N} L_{i11})^{-1}\sum_{i=1}^{N} L_{i12}$ (13)

Pt statistics: $Pt=\tilde{\sigma}^{-1}(\sum_{i=1}^{N} L_{i11})^{-1/2}\sum_{i=1}^{N} L_{i12}$ (14)

In the calculation of Ga and Gt, the weighted average of the estimated Pi's and the t ratios of the Pi's for each cross-section unit are taken.

Ga statistics: $Ga=\sum_{i=1}^{N} L_{i11}^{2} L_{i12}$ (15)

Gt statistics: $Gt=\sum_{i=1}^{N} \bar{\sigma} L_{i11}^{-1/2} L_{i12}$ (16)

Table 5 shows the panel cointegration analysis results of EF and economic globalization variables (Robust value was taken as 100 in the analysis). Table 5 shows the statistical and probability values for the Gt, Ga, Pt, and Pa tests. Because the *P*-values and Robust *P*-values are less than 0.05, the hypothesis Ho: no cointegration relationship between the variables is rejected via Ga, Pt, and Pa estimations. As a result, there is a long-term and significant relationship between EF and EG. Commercial activities between nations expand as EG increases. As a result, manufacturing, industrialization, urbanization, and technical progress accelerate. As a result, the pressure on people and the environment grows. However, as the EG level rises, so does the transfer of knowledge and technology in countries. Societies are starting to choose eco-friendly production methods. As a result, an increase in EG may have the effect of reducing EF.

Table 5

Westerlund ECM panel cointegration

Statistics	Value	Z-value	P-value	Robust P-value
Gt	-1.928	-1.220	0.111	0.280
Ga	-9.285	-3.100	0.001	0.010
Pt	-16.942	-4.989	0.000	0.010
Pa	-8.894	-7.974	0.000	0.000

Source: authors' calculations.

Although there are several studies in the literature examining the cointegration relationship between economic globalization and ecological footprint, one aspect that distinguishes this study is the use of an estimation method that takes into account the cross-sectional dependence, second-generation unit root tests, FGLS cointegration analysis, and Westerlund ECM analysis. In the econometric analysis part of this study, which shows the relation between EG and EF, FGLS developed by Hansen (2007) and Westerlund analyses developed by Westerlund (2007) have been used to search for the cointegration relationship of the variables. According to the results of FGLS analysis, a negative relationship emerged in the long term. These results agree with studies performed by Ahmad et al. (2021), Ahmed et al. (2021a), Aluko et al. (2021), Omoke et al. (2020), Wang et al. (2021).

Policy recommendations. EG reduces EF in the countries analyzed. In this case, economic globalization should be supported in these countries, and the benefits of globalization should be utilized. Foreign capital should be encouraged into the country, and policies should be executed to facilitate this. However, it should be calculated whether the incoming capital will use environmentally-friendly production methods. Foreign investors should be given significant incentives and lower taxes to encourage investment in environmentally friendly projects, while investments in polluting production methods should be restricted.

Conclusions. Globalization has started to accelerate in recent years, affecting all countries around the world in social, economic, and political terms. Foreign trade has become more widespread all over the world, capital flows have accelerated, and as a result, competition in the international arena has reached greater levels. Because of greater international trade, technological transfer accelerated, production of goods and services increased and so significant changes arose in the economic field. Along with these economic developments, there have been rapid technical developments, increased employment opportunities, and therefore significant increases in national income levels. The increase in capital has occurred as a result of more foreign direct investments as a consequence of EG, investment opportunities have expanded, technological development has accelerated, and so employment opportunities and economic development have accelerated.

In addition to the changes that EG has brought to the global economy, its effects on the environment, and hence the EF, cannot be ignored. The effects of EG on the environment can be categorized as direct or indirect. Direct effects include trade, transportation, and aviation. Because emissions from international transportation, trade, and travel have a direct impact on the environment. Indirect environmental effects of EG includes: scale effect, composition effect, and technical effect.

The scale effect reflects environmental pollution caused by natural resource depletion as a consequence of increased production and consumption as a result of greater economic activity, as well as increased use of energy resources. Increased use of natural resources, as well as the increased consumption of fossil energy resources, raise environmental pollution to such an extent that it disrupts the natural balance of the ecosystem.

The composition effect refers to the impact of trade policy changes and international trade on the composition of production among countries. While developing countries with weak environmental regulations specialize in products that cause environmental pollution, other developed countries specialize in cleaner production sectors. Furthermore, as globalization has increased, foreign direct investments have gained traction. Developed countries have an advantage over this. Environmental order is more important in developed economies than in other countries. As a result, they produce in industries that cause environmental pollution in developing countries. Consequently, while environmental pollution is decreasing in developed countries, it is increasing in developing countries.

According to the technical effect, increasing globalization reduces environmental pollution by enabling technological development and the development of new environmentally friendly production techniques. With economic globalization, technology transfer is increasing due to increased international trade and foreign direct investment. As a result, technological advancements accelerate and more production can be achieved while using fewer natural resources. This prevents the depletion of natural resources and the pollution of the environment. Furthermore, as globalization and technological development speed up, information exchange between societies expands. As a consequence, individuals can obtain more information by using communication tools such as media and become more eco-friendly.

Considering the effects of economic globalization on the environment, the EF that exists as a result of human pressure on nature affects a function of activities such as production, consumption, and trade. The EF is going up due to the pressures placed on nature by humans because of increased production and consumption, as well as the competitive environment driven by increased international trade. However, technological development is minimizing the use of natural resources, and societies can develop more environmentally-friendly production methods. As a result, the EF is reduced. In the econometric analysis part of this study, 65 countries were included in the analysis due to data availability limitations. We used annual data from 1970 to 2017. According to the results of the FGLS analysis, a negative relationship emerged in the long term. During the relevant period, as EG rises, EF falls. As a result of the increase in EG, the acceleration of technological development, and thus the less use of natural resources, the environmental problems are reduced. Moreover, as globalization and communication technology advance, societies will have more information about the importance of the environment. As a consequence, they can show more eco-friendly behavior.

The value of the environment in human life is rising by the day. The environmental damage caused by societies ultimately affects human life. As environmental damage disrupts nature's balance, human life suffers economically and socially. As a result, individuals in society can become more eco-friendly. Recycling efforts can be increased to make post-consumer waste recyclable. Increasing investments in renewable energy sources that produce less CO_2 and providing government support in this direction may be beneficial in terms of both reducing production costs and minimizing environmental damage.

Future research could investigate whether the standards developed by developing countries during economic globalization correspond to the standards developed by developed countries regarding globalization.

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