Research Article

The Causal Dynamics of Globalization, Human Development, and Economic Growth on Ecological Footprint: An HDI-Based Cross-Country Analysis

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Abstract: This study aims to investigate the causal relationships among globalization, economic growth, human development, and the ecological footprint. Employing the panel Granger causality test developed by Juodis et al. (2021), this study utilizes data from 118 countries spanning the period from 1990 to 2021. I also conduct a multivariate causality analysis for four distinct country groups based on their human development index (very high HDI, high HDI, medium HDI, and low HDI). A key finding of this study is the consistent emergence of a joint causal relationship between globalization and human development and the ecological footprint across all country groups. Similarly, I find globalization and economic growth to be joint Granger causes of the ecological footprint, except for the medium HDI group. Consequently, globalization, along with growth and human development as fundamental economic objectives, emerges as significant drivers of the ecological footprint across all countries. In light of these findings, it is imperative for policymakers to revisit economic policies, giving due consideration to the sustainability of ultimate economic goals.

Keywords: Globalization, Economic Growth, Human Development, Ecological Footprint, Panel Causality
Jel Codes: F64, F40, O15, Q01, C33

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Küreselleşme, İnsani Gelişme ve Ekonomik Büyümenin Ekolojik Ayak İzi Üzerindeki Nedensel Dinamikleri: İGE'ye Dayalı Ülkeler Arası Bir Analiz

Öz: Bu çalışmanın temel amacı, küreselleşme, ekonomik büyüme, insani gelişim ve ekolojik ayak izi arasındaki nedensel dinamikleri incelemektir. Juodis ve arkadaşları (2021) tarafından geliştirilen panel Granger nedensellik testi kullanılarak, 1990-2021 dönemini kapsayan ve 118 ülkeyi içeren veriler analiz edilmiştir. Çalışmada ayrıca, insani gelişme endeksi (İGE) temel alınarak dört farklı ülke grubu (çok yüksek İGE, yüksek İGE, orta İGE ve düşük İGE) için çok değişkenli nedensellik analizi gerçekleştirilmiştir. Çalışmanın önemli bulgularından biri, tüm ülke gruplarında küreselleşme ile insani gelişim ve ekolojik ayak izi arasında ortak bir nedensel ilişki olduğunun tutarlı bir şekilde ortaya çıkmasıdır. Benzer şekilde, küreselleşme ve ekonomik büyümenin ekolojik ayak izinin ortak Granger nedeni olduğu bulunmuştur, ancak bu durum orta İGE grubu için geçerli değildir. Sonuç olarak, küreselleşme, ekonomik büyüme ve insani gelişim gibi temel ekonomik hedefler, tüm ülkelerde ekolojik ayak izinin önemli belirleyicileri olarak öne çıkmaktadır. Bu bulgular ışığında, politika yapıcıların ekonomik politikaları gözden geçirmesi ve nihai ekonomik hedeflerin sürdürülebilirliğine gereken önemi vermesi hayati önemdedir.

Anahtar Kelimeler: Küreselleşme, Ekonomik Büyüme, Beşerî Kalkınma, Ekolojik Ayak İzi, Panel Nedensellik
Jel Kodları: F64, F40, O15, Q01, C33

1. Introduction

Historically, the primary objective of economic activity, both theoretically and empirically, has been to foster economic growth and development and enhance societal well-being. Yet, especially in the aftermath of the 18th and 19th century Industrial Revolution, factors such as mechanization, accelerating growth and development rates, rising energy consumption, and fossil fuel use commensurate with global population growth, rapid urbanization, and technological advancements have precipitated substantial environmental challenges. The employment of agricultural chemicals, artificial fertilizers, and other chemical substances in agricultural production has aggravated these issues. In essence, growth and development processes have exposed humanity to severe environmental problems, including air pollution, climate change, toxic chemicals, and waste.

Initiated by the Industrial Revolution, this process became particularly pronounced in the latter part of the 20th century, especially during the era of Neoliberal Globalization, which Arrighi (2000) characterizes as a phase within the American Hegemony. Globalization occurs when national economies integrate into global markets and capitalist dynamics shape economic decisions (Yeldan, 2001). Improvements in information and communication technologies, increased foreign direct investment, and the emergence of numerous international and regional governmental and non-governmental organizations contribute to increased international trade, finance, and industrial capital, fostering greater interdependence and cooperation among nations. Globalization is, of course, a complex concept with multiple facets, including economic, cultural, political, scientific, social, environmental, and other dimensions (Keohane and Nye, 2000). Consequently, globalization can be defined as the intensification of international interactions that promote the global integration of cultural, ecological, political, technological, and social processes at global, transnational, national, regional, and local levels and encourage the formation of transnational structures (Rennen and Martens, 2003).

The escalating interdependence and interactions among societies characteristic of globalization (Jones, 2010) have driven up demands for economic growth, development, and human progress. However, the rapid depletion of natural resources and mounting ecological pressures have accompanied this. Global issues like dwindling arable land, biodiversity loss, and environmental pollution have evolved from local or regional concerns into global crises such as climate change (OECD, 1997; Panayotou, 2000).

Ultimately, humanity has reached a point of ecological overshoot where human demands exceed the Earth's biocapacity (Eving et al., 2010). For example, while the world had adequate ecological reserves and no ecological deficit in 1961, this balance began to shift in the 1980s, marking the onset of neoliberal globalization. The ecological deficit reached significant proportions in the 2000s, when globalization gained momentum.[1]

There is a substantial body of literature examining the relationships between globalization, economic growth, human development, and ecological footprint. However, most studies employing time series or panel data analyses at the country, regional, or global levels have focused on determining the short- and/or long-term effects of these variables. [2] Consequently, studies investigating the causal relationships between globalization, growth, and human development are relatively limited. Moreover, the scarcity of studies considering different levels of human development across countries is quite striking. Aiming to fill this gap, this study investigates the causal relationships between globalization, economic growth, human development, and ecological footprints.

[1] In 1961, the total bioproductive area required to support all economic activities (ecological footprint) was 7.05 global hectares (gha), while the biocapacity, representing the area capable of generating these resources, was 9.6 billion gha. By 1980, the ecological footprint had increased to approximately 11.9 billion gha, while the biocapacity was around 10.4 billion gha. In 2022, the ecological footprint reached approximately 21 billion gha, and the biocapacity stood at 12 billion gha (Global Footprint Network, 2024).

[2] Some recent studies include those by Ahmad et al. (2020), Kassouri & Altıntaş (2020), Yunani et al. (2020), Kihombo et al. (2021), Yang et al. (2021), Ullah et al. (2021), Ali et al. (2021), Ansari et al. (2021), Apaydin et al. (2021), Mrabet et al. (2021), Nathaniel (2021), Pata (2021), Pata et al. (2021), Ahmed et al. (2022), and Ullah et al. (2023).

Additionally, by categorizing countries into four groups based on their Human Development Index levels, the study aims to reveal how the causal dynamics among variables differ across different development levels. This study adds to the body of empirical literature in two important ways: it looks at 118 countries and divides them into four separate subgroups based on their level of human development; and it uses a method called the multivariate panel causality test, which was created by Juodis et al. (2021) and uses data from 1990 to 2021. The literature review section clearly shows that my study distinguishes itself from previous research through its methodology, the selection of countries, its thematic focus, and the variables included. Consequently, I believe that this research has the potential to make a significant contribution to empirical literature.

I will dedicate the initial section of my study to a comprehensive literature review. Following this, a section will present the data, empirical methodology, and the findings. Finally, a conclusion section will provide an overall evaluation.

2. Literature review

While numerous studies have explored the interconnections between globalization, economic growth, human development, and the ecological footprint, empirical investigations into the causal relationships among these variables remain relatively scarce. Existing research has primarily focused on analyzing the short-term and/or long-term impacts of various factors on the ecological footprint using time series or panel data methods. However, in recent years, there has been a growing trend toward employing panel data methods to examine causality in greater depth, particularly through individual country case studies. The following is a summary of the panel data studies I have identified on this topic.[3]

Sabir and Görüş (2019) investigate the impact of globalization on the ecological footprint of South Asian countries using the panel ARDL method and data from 1975-2017. According to the findings, there is a bidirectional causality between the ecological footprint and per capita GDP and a unidirectional causality from the KOF globalization index to the ecological footprint.

Ahmad et al. (2020) examines the effects of natural resources, technological innovations, and economic growth on the ecological footprint by analyzing data from 22 emerging market economies between 1984 and 2016. By applying the Dumitrescu-Hurlin causality test, they discover a reciprocal causal relationship between economic growth and the ecological footprint. The authors argue that any changes in growth accelerate the ecological footprint, while changes in the ecological footprint also influence growth.

Yılancı and Görüş (2020) investigate the relationship between economic globalization and the ecological footprint in 14 Middle East and North Africa (MENA) countries over the period of 1981 to 2016, employing both the Dumitrescu-Hurlin and Fourier Toda-Yamamoto methods. The D-H test results do not indicate any causality between the variables. The authors attribute this to the neglect of cross-sectional dependence. The Fourier Toda-Yamamoto test results show a one-way causality from the ecological footprint to economic globalization in Algeria, Bahrain, Libya, and Tunisia, while indicating a two-way causality for Morocco. They find no causality between the variables for other countries. In summary, the authors conclude that there is evidence of a causal link connecting globalization and ecological footprints in the countries examined.

In their 2020 study of the G7 countries from 1980 to 2015, Pata and Yılancı look at the connections between environmental impact, globalization, and financial growth. They do this by using a causality analysis that considers soft structural breaks through a fractional frequency flexible Fourier function. The findings indicate that globalization causes the

[3] The empirical literature discussed here uses the ecological footprint as a measure of environmental degradation. Additionally, a corpus of studies exists that examines the ecological footprint at the individual country level. Notable examples include the works of Ahmed et al. (2019), Danish et al. (2019), Etokakpan et al. (2020), İbrahiem and Hanafy (2020), Abid et al. (2021), Hussain et al. (2021), Kırıkkaleli et al. (2021), and Bi et al. (2024).

ecological footprint in all G7 countries except France. The authors also emphasize the need to take advantage of the opportunities offered by globalization to solve environmental problems.

To find out if there is a link between economic growth, financial and trade globalization, and the ecological footprint, Ahmad et al. (2021) use the Dumitrescu-Hurlin (2012) causality analysis on data from G7 countries from 1980 to 2016 and come to the conclusion that there is one. Empirical findings show a one-way causality from financial globalization and economic growth to the ecological footprint, while indicating a two-way causality with economic globalization

Yang et al. (2021) investigates the effects of industrialization, economic growth, and globalization on the ecological footprint. Using the Dumitrescu-Hurlin (2012) causality analysis, they examine data from 1995-2018 for the ten countries with the highest healthcare expenditures. Their findings indicate a one-way causal relationship where economic growth and globalization affect the ecological footprint.

In another study, Yang et al. (2021) measures the effects of globalization and an aging population on the ecological footprint across 27 OECD countries from 1970-2017. Using the Dumitrescu-Hurlin (2012) method, they find a bidirectional causality between overall globalization, social globalization, political globalization and the ecological footprint. However, they find a unidirectional causality between economic and financial globalization and the ecological footprint. The authors assert that these findings support their results from the panel data analysis.

Radmehr et al. (2022) analyze data from G7 countries between 1990 and 2018 using the panel GMM method. Their study reveals a bidirectional causality between GDP and the ecological footprint. Moreover, they find a unidirectional causality between economic and financial globalization, economic growth, and the ecological footprint.

Mehmood et al. (2023) investigate the interactions among growth, human capital, biocapacity, and the ecological footprint in South Asian countries using Granger causality analysis. Their findings indicate a bidirectional causality between growth and the ecological footprint, suggesting a feedback relationship between the two variables.

In their research on Asian nations, Javeed et al. (2023) analyzed how the ecological footprint is connected to globalization and economic growth. Using Granger causality tests on data from 1990 to 2017, the authors found a bidirectional causality between globalization and the ecological footprint while finding a unidirectional relationship from real income to the ecological footprint.

Mazlum (2024) conducted another study using D-H causality analysis to investigate the relationship between the Human Development Index, urbanization, economic growth, and the ecological footprint in the MINT countries (Mexico, India, Nigeria, and Turkey) from 2003 to 2022. The findings revealed a unidirectional causal relationship from the ecological footprint to the Human Development Index and from economic growth to the ecological footprint.

Karimli et al. (2024) conducted one of the latest studies on this topic. The study investigated the causal relationships between globalization and the ecological footprint using data from 35 European countries from 1970 to 2020. It employed the Juodis et al. (2021) panel Granger non-causality test to examine both overall globalization and its subcomponents. The results indicated that globalization is generally the Granger cause of the ecological footprint in European countries. Multivariate causality analysis showed that economic, social, and political globalization are Granger causes of the ecological footprint. Individual causality tests revealed a unidirectional relationship from economic globalization to the ecological footprint, a bidirectional relationship with social globalization, and no causal relationship with political globalization.

A review of the relevant literature reveals that causality analyses predominantly rely on pairwise comparisons, often employing the Dumitrescu-Hurlin (D-H) method. A notable exception is the study by Karimli et al. (2024), which utilized a multivariate causality approach. Furthermore, Mazlum's (2024) research is the only one to include

human development as a variable in these studies, which primarily focus on the relationships between globalization, growth, and the ecological footprint.

3. Data and empirical analysis

In this study, I performed an analysis of causal relationships between globalization, human development, economic growth, and the ecological footprint in two stages. First, I examine the causality among the variables using two distinct multivariate models. In the second stage, I focused on a univariate causality analysis. Throughout both stages, the Global Footprint Network database (https://data.footprintnetwork.org) serves as the primary source of the ecological footprint per capita (measured in global hectares), an indicator of environmental degradation. I use the Human Development Index (HDI) from the United Nations Development Program website (https://hdr.undp.org/data-center/human-development-index#/indices/HDI) to represent human development. For economic growth, I include real GDP per capita (constant 2015 US$), sourced from the World Bank database (https://data.worldbank.org/). Finally, for globalization, I utilize the KOF Globalization Index, sourced from the KOF Globalization Database.[4]

Moreover, in both the two multivariate causality models and the univariate causality analyses, I examine data from a total of 118 countries over the period 1990-2021. Additionally, I conduct the same analysis for different country groups (countries with very high, high, medium, and low levels of human development), based on the assumption that the level of human development may be a determining factor in causality relationships. This approach allows me to perform five distinct panel causality estimations. In other words, in my study, I conduct five different panel causality analyses, including four separate panels composed of countries with varying levels of human development and an additional "full panel" that includes all 118 countries combined. Table 1 provides descriptive statistics for the variables used in the five different models.

Table 1. Descriptive Statistics

	Obs	Mean	Std. Dev.	Min	Max
Full Panel (118 countries)					
lnefp	3776	0.925	0.788	-1.05	3.777
lngdp	3776	8.523	1.507	5.112	11.63
lnhdi	3776	-0.44	0.291	-1.551	-0.036
lnkof	3776	-0.58	0.296	-1.539	-0.095
Very High HDI (45 countries)					
lnefp	1440	1.707	0.495	0.182	3.777
lngdp	1440	10.099	0.764	7.866	11.63
lnhdi	1440	-0.18	0.093	-0.543	-0.036
lnkof	1440	-0.315	0.157	-0.862	-0.095
High HDI (29 countries)					
lnefp	928	0.786	0.412	-0.528	2.05
lngdp	928	8.325	0.511	6.512	9.326
lnhdi	928	-0.382	0.093	-0.73	-0.207
lnkof	928	-0.608	0.199	-1.345	-0.221
Medium HDI (25 countries)					
lnefp	800	0.308	0.437	-1.05	1.147
lngdp	800	7.398	0.684	5.112	9.101
lnhdi	800	-0.623	0.152	-1.124	-0.335
lnkof	800	-0.782	0.215	-1.539	-0.36
Low HDI (19 countries)					
lnefp	608	0.098	0.318	-0.562	1.026
lngdp	608	6.571	0.545	5.314	7.843
lnhdi	608	-0.904	0.196	-1.551	-0.594
lnkof	608	-0.898	0.208	-1.473	-0.475

The two models in the study, where all variables are logarithmic, are outlined below:

[4] The index was created by Dreher (2006) and Dreher et al. (2008).

$$lnefp_{i,t} = a_0 + a_1 lnhdi_{i,t} + a_2 lnkof_{i,t} + u_{1i,t} \quad (1)$$

$$lnefp_{i,t} = b_0 + b_1 lngdp_{i,t} + b_2 lnkof_{i,t} + u_{2i,t} \quad (2)$$

In equations (1) and (2), *lnefp, lnhdi, lnkof,* and *lngdp* denote ecological footprint per capita, human development, globalization, and real GDP per capita, respectively. u_1 and u_2 are error terms.

Cross-Section Dependency

As global interconnections and interdependencies intensify, analyzing the links among the components of each panel becomes crucial. Amidst rising globalization, mutual impacts and interactions among countries have become widespread. To identify the most suitable panel unit root test for examining causality, I begin by conducting a cross-sectional dependence analysis on the entire panel sample, as well as on groups of countries at different levels of development. This test allows me to increase the rigor of my research by investigating interrelations within the data. This approach enables a more precise assessment of the impacts of economic shocks, policies, or changes in one country on others, particularly regarding interactions among countries with similar levels of human development.

This study employs the Pesaran (2004) test, which is widely used in empirical research and is especially preferred when N exceeds T. The null hypothesis of this test, based on the aggregate correlation coefficients among cross-sectional residuals, suggests that no link exists among the cross-sections. The test results presented in Table 2 indicate that all variables exhibit cross-sectional dependence across all panels.

Table 2. Pesaran (2004) CD Test Results

	Full Panel	Very High HDI	High HDI	Medium HDI	Low HDI
lnefp	42.13	49.69	18.61	8.06	3.51
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
lngdp	282.50	139.72	96.86	42.07	18.14
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
lnhdi	424.88	173.31	107.96	76.44	64.75
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
lnkof	432.29	168.79	104.68	88.10	68.42
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Unit Root Analysis

After rejecting the null hypothesis of "no cross-section dependence" between the panels, I use Pesaran's (2007) CIPS panel unit root test, which takes into account cross-section dependence, to see whether the panels are stationary. The CIPS test relies on the cross-section augmented Dickey-Fuller (CADF) test. Equation (3) outlines this method by calculating the CADF test for each cross-section unit and averaging them to obtain the CIPS test statistics:

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} CADF_i \quad (3)$$

Table 3 shows the test results for all specifications of the CIPS unit root analysis (with and without trend). Accordingly, all variables, particularly those in the models with trend, contain a unit root. Thus, I utilize the initial difference between all variables in both univariate and multivariate panel causality analyses.

Table 3. Pesaran (2007) unit root test results

		constant				constant and trend			
		levels		1st difference		levels		1st difference	
		Z [t bar]	*p* value	Z [t bar]	*p* value	Z [t bar]	*p* value	Z [t bar]	*p* value
Overall Panel	*lnefp*	0.0230	0.509	-15.952	0.000*	-0.069	0.473	-9.919	0.000*
	lnhdi	-0.175	0.431	-8.158	0.000*	3.206	0.999	-5.669	0.000*
	lngdp	0.018	0.507	-6.977	0.000*	4.363	1.000	-2.138	0.016**
	lnkof	-4.408	0.000*	-	-	1.373	0.915	-11.178	0.000*
Very High HDI	*lnefp*	0.599	0.725	-10.299	0.000*	-1.877	0.057***	-6.180	0.000*
	lnhdi	-1.581	0.057**	-6.322	0.000*	1.219	0.889	-3.033	0.001*
	lngdp	-0.073	0.471	-5.522	0.000*	2.192	0.986	-1.877	0.030**
	lnkof	-3.257	0.001*	-	-	0.280	0.610	-6.676	0.000*
High HDI	*lnefp*	-1.228	0.110	-7.560	0.000*	0.704	0.759	-5.652	0.000*
	lnhdi	-1.596	0.055***	-4.313	0.000*	1.414	0.921	-2.504	0.006*
	lngdp	-0.959	0.169	-3.375	0.000*	2.934	0.998	-4.500	0.000*
	lnkof	-1.901	0.029**	-8.546	0.000*	-0.606	0.272	-6.315	0.000*
Medium HDI	*lnefp*	-1.409	0.079***	-8.253	0.000*	1.851	0.968	-6.836	0.000*
	lnhdi	0.610	0.729	-2.413	0.008*	2.382	0.991	-5.890	0.000*
	lngdp	0.111	0.544	-4.616	0.000*	1.505	0.934	-2.896	0.002*
	lnkof	-4.608	0.000*	-	-	-0.904	0.183	-4.719	0.000*
Low HDI	*lnefp*	-0.158	0.437	-8.043	0.000*	-0.202	0.420	-6.124	0.000*
	lnhdi	-1.812	0.035**	-2.816	0.000*	1.303	0.904	-1.231	0.100***
	lngdp	1.188	0.883	-2.712	0.003*	1.440	0.925	-1.905	0.028**
	lnkof	-2.278	0.011**	-5.219	0..000*	-0.346	0.365	-3.860	0.000*

Notes: The symbols *, **, and *** indicate confidence levels of 1%, 5%, and 10%, respectively. I have established the maximum lag length at 2.

Causality Analysis

In this study, I employ Juodis, Karavias, and Sarafidis's (2021) causality analysis to examine the causal relationships between globalization, human development, economic growth, and ecological footprints across all panels. This method verifies the absence of Granger causality and applies to both homogeneous and heterogeneous coefficient panel data models. The method's main innovation is its assumption of zero and homogeneous Granger causality parameters. This feature employs a pooled fixed effects estimator on specific parameters, achieving a √NT convergence rate. Furthermore, to mitigate the "Nickell bias", the method utilizes the Split Panel Jackknife method and subsequently conducts a Wald test based on the bias-corrected estimator (Juodis et al., 2021; Xiao et al., 2023). In addition, the method enables both univariate and multivariate causality analyses. Table 4 shows the panel non-causality test results.

Table 4 Panel A provides a detailed account of the multivariate causality test outcomes. Consistent with Model 1 predictions, the results consistently demonstrate a causal linkage from globalization and human development to the ecological footprint across all panels. Moreover, a comparable causal pattern is evident for globalization and economic growth, with the exception of countries categorized as having medium human development levels. These findings conclude that both globalization and human development, and globalization and economic growth, serve as robust explanatory variables for the ecological footprint.

Panel B of Table 4 presents the results of the univariate causality analysis, revealing some striking findings. The most notable finding is the unidirectional causality between economic growth and ecological footprint, specifically the shift from growth to footprint in very high HDI countries and vice versa in medium HDI countries. No other country group exhibits a causal relationship between these two variables. Similarly, while there is a bidirectional causality between globalization and ecological footprints in the full panel of 118 countries, this relationship varies across subgroups. For instance, there is no causality for Medium HDI countries, unidirectional causality from globalization to footprint for Low HDI countries, and bidirectional causality only for Very High and High HDI countries. Likewise, while there is a causal relationship from human development to ecological footprint for the full panel, this relationship holds only for very high and

medium HDI countries but not for the other two models. Conversely, the causality from ecological footprint to globalization is evident only in the High and Medium HDI subgroups but not for the full panel.

Table 4. Causality Analysis Results

Panel A: Multivariate causality											
		Full Panel		Very High HDI		High HDI		Medium HDI		Low HDI	
H_0 : No Granger causality from selected covariates to lnefp		Lag	HPJ Wald Test Stat.	Lag	HPJ Wald Test Stat.	Lag	HPJ Wald Test Stat.	Lag	HPJ Wald Test Stat.	Lag	HPJ Wald Test Stat.
Model 1	lnkof, lnhdi ⇒ lnefp	1	25.3862* (0.0000)	1	34.7676* (0.000)	1	7.9913** (0.0184)	1	4.7258*** (0.0941)	1	6.8565** (0.0324)
Model 2	lnkof, lngdp ⇒ lnefp	1	19.5741* (0.0001)	1	28.6255* (0.000)	1	9.4750* (0.0088)	1	3.1806 (0.2039)	1	7.1365** (0.0282)
Panel B: Univariate causality											
H_0 : No Granger causality from x to y		Lag	HPJ Wald Test Stat.	Lag	HPJ Wald Test Stat.	Lag	HPJ Wald Test Stat.	Lag	HPJ Wald Test Stat.	Lag	HPJ Wald Test Stat.
lnhdi ⇒ lnefp		1	10.3945* (0.0013)	1	13.4993* (0.0002)	1	2.5120 (0.1130)	1	3.8466** (0.0498)	1	0.2945 (0.5874)
lnefp ⇒ lnhdi		1	1.9146 (0.1665)	1	0.1176 (0.7317)	1	2.9350*** (0.0867)	1	3.1772*** (0.0747)	1	0.5996 (0.4387)
lnkof ⇒ lnefp		1	14.5285* (0.0001)	1	17.6396* (0.0000)	1	5.3300** (0.0210)	1	0.3567 (0.5503)	1	5.4371** (0.0197)
lnefp ⇒ lnkof		1	5.3341** (0.0209)	1	2.6992*** (0.1004)	1	2.8843*** (0.0894)	1	2.0520 (0.1520)	1	0.0071 (0.9329)
lngdp ⇒ lnefp		1	1.2231 (0.2687)	1	9.6922* (0.0019)	1	2.0775 (0.1495)	1	2.4500 (0.1175)	1	0.5920 (0.4416)
lnefp ⇒ lngdp		1	0.0991 (0.7529)	1	2.1907 (0.1388)	1	0.0298 (0.8630)	1	3.0410*** (0.0812)	1	0.3750 (0.5403)

*, **, and *** indicate that the null hypothesis of no causality is rejected at 1%, 5%, and 10% significance levels, respectively. Moreover, half-panel Jackknife test statistics show the estimation results of cross-sectional heteroskedasticity-robust variance. The optimal lag length is determined automatically according to the Bayesian information criteria.

The findings of this study are highly consistent with those of Karimli et al. (2024), both methodologically and in terms of the results obtained. Both the multivariate analysis results and the pairwise causality tests indicate that globalization (and its subcomponents) is the Granger cause of the ecological footprint, and there is a bidirectional causal relationship (except for political globalization). However, in contrast to this study, the causality relationship was also explored for country subgroups, revealing that globalization Granger-causes the ecological footprint within these specific groups. Additionally, no causality was detected for countries with medium Human Development Index (HDI) values within the country subgroups.

When comparing the findings of my univariate causality analysis with previous studies, it is evident that there are both convergent and divergent results. For instance, the findings regarding human development align with Mazlum's (2024), indicating a unidirectional relationship between human development and the ecological footprint. However, this study also identifies a group of countries (Medium HDI) that exhibit a feedback effect between the ecological footprint and human development. Consequently, I argue that a direct comparison of the findings of this study with previous research is not appropriate, both technically and from an economic perspective.

In summary, multivariate causality analysis of the full panel of 118 countries reveals statistically significant causal relationships between the variables in both Model 1 and Model 2. Consequently, both globalization and human development, as well as globalization and economic growth, are Granger causes of the ecological footprint. This finding is largely robust across different subgroups of the 118 countries, with the

exception of the medium HDI group, where globalization and economic growth are not Granger causes of the ecological footprint. Therefore, we can conclude that both the globalization-human development and the globalization-economic growth variables significantly explain the ecological footprint. However, the univariate analysis presents a more nuanced picture. While there is bidirectional causality between human development and the ecological footprint and between globalization and the ecological footprint for the full panel, no such relationship is found for economic growth and the ecological footprint. Furthermore, the direction and magnitude of causal relationships vary significantly across different subgroups of countries with similar development levels.

4. Conclusion

This research employs panel data from 118 countries over the 1990-2021 period to investigate the causal relationships among globalization, human development, economic growth, and the ecological footprint. I conduct a panel causality analysis using two distinct models. The first model examines the hypothesis that human development and globalization jointly influence the ecological footprint, while the second model explores the causal relationship between economic growth, globalization, and the ecological footprint. I adopt the multivariate approach to capture the complex interdependencies among these variables, acknowledging that the ecological footprint is a result of multiple interconnected factors. I also divide the sample into four subgroups according to the Human Development Index to analyze how these relationships vary across different development levels.

The findings obtained from the analyses have confirmed my initial hypotheses. Globalization and human development, or globalization and economic growth, can explain the ecological footprint according to multivariate causality analyses conducted on a sample of 118 countries. In countries with medium levels of human development, the analysis revealed a significant exception, identifying no causal relationship between globalization, economic growth, and the ecological footprint. This stands out against the backdrop of largely consistent findings across the various subgroups. The results from univariate analyses were even more pronounced, reinforcing my belief that a monistic explanatory framework is inadequate.

In conclusion, when conducting panel causality or panel data analyses, selecting country groups with similar characteristics can lead to more robust results. Moreover, prioritizing multivariate causality models over univariate causality analyses when investigating the determinants of a dependent variable is important for more consistent results.

On the other hand, the findings of the study provide valuable insights for policymakers. The study identifies globalization-growth and globalization-human development variables as contributing factors to environmental degradation, even though globalization, economic growth, and human development are indispensable goals for improving societal well-being. The fact that similar causal relationships exist even in countries with different levels of human development highlights the need for a re-evaluation of current strategies.

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