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RESEARCH ARTICLE

An analysis of the environmental impacts of ethnic diversity, financial development, economic growth, urbanization, and energy consumption: fresh evidence from less-developed countries

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Abstract

Improving the quality of environmental indicators has become a global concern that necessitates the identification of possible channels through which environmental welfare can be enhanced worldwide. Against this backdrop, this current study aims to elucidate the environmental effects of ethnic diversity, controlling for financial development, urbanization, economic growth, and energy consumption in the context of 51 less-developed countries during the period from 1996 to 2016. For measuring the environmental impacts, we use both the ecological footprint and carbon dioxide emission figures of these countries. Overall, the cointegration analysis confirms the existence of long-run relationships among the study variables. Besides, the regression analysis reveals that ethnic diversity deteriorates environmental quality by surging the ecological footprint and carbon dioxide emission levels of the selected nations. Similarly, financial development and energy consumption are found to impose identical adversities on the environment while urbanization is evidenced to ensure environmental welfare. Lastly, for both the environmental indicators considered in this study, the environmental Kuznets curve hypothesis is verified from the findings. Hence, considering these key outcomes, a set of relevant environmental welfare-related policy interventions are recommended in the context of less-developed countries.

Keywords Ethnic diversity · Ecological footprint · Carbon dioxide emissions · Urbanization · Financial development · EKC hypothesis

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Introduction

In the contemporary era of ever-increasing and escalating social fragmentation, there has been growing inquisitiveness towards the socioeconomic and environmental consequences of ethnic diversity. Robust episodes of globalization and population growth, worldwide, have triggered large influxes of migrants around the globe, thus enlarging the overall bandwidth of ethnic diversity in the global domain. Although a decent number of studies have reconnoitered the impacts of ethnic multiplicity on economic growth and other socioeconomic indicators (Alesina et al. 2019), the corresponding environmental effects of ethnic diversification have not been adequately captured in the literature. Ethnic diversity typically refers to the discernable differences among ethnic groups of people who share cultural practices, nature, language, and perspective. In this regard, the environmental consequences of ethnic diversity may either be constructive or destructive; thus, it implies that ethnic diversity can be responsible for both environmental degradation and environmental improvement. Accordingly, counter-arguments have been put forward in demonstrating these ambiguous environmental effects associated with ethnic diversity.

Alesina and Zhuravskaya (2011), Collier (2001), and Madni (2018) argued that higher ethnic diversity reduces cooperative behavior, disrupts the provision of public goods, dampens economic performance, and weakens institutional quality while Montalvo and Reynal-Querol (2005) argued that it significantly slashes down investments to impede economic development. As a result, these studies have broadly argued that ethnic diversity hampers, via these above-mentioned channels, is likely to instigate environmental degradation by boosting Carbon dioxide (CO_2) emissions, in particular. Likewise, Alesina et al. (2019) advocated that ethnic diversity adversely affects trust, social capital, and locals' ability to partake in communal activities which are largely responsible for the upsurge in deforestation propensities. As forests are major carbon sinks, rising rates of deforestation erode environmental quality by shifting CO_2 from the biosphere to the atmosphere. Contrarily, in support of the notion regarding ethnic diversity facilitating environmental improvement, several studies have also highlighted that ethnic diversity brings technological advancements through knowledge dissemination and innovation which may induce abatement of CO_2 emissions (Florida and Gates 2003).

Against this backdrop, this current study aims to add to the limited literature related to the ethnic diversity-environmental quality nexus by exploring this relationship, controlling for financial development, economic growth, urbanization, and energy use, in the context of 51 less-developed global economies during the 1996–2016 period. The environmental consequences of these macroeconomic variables in these selected nations are primarily captured using their ecological footprint (EF) figures. The decision to choose EF over CO_2 emissions as an environmental quality proxy is nudged by the understanding that CO_2 emissions capture only that emission aspect of environmental degradation while EF emphasizes the CO_2 absorption capacity dimension as well (Destek and Sinha 2020, Sharma et al. 2021; Sharif et al. 2020). Moreover, EF also considers non-carbon emission-induced environmental consequences since degradation of the environment is not caused by emissions of CO_2 alone. The concept of EF was initially put forward by Rees (1992) and later on developed by Wackernagel and Rees (1998). Specifically, the authors of these studies refer that EF of a nation captures the demand for biologically productive aquatic and land areas that are needed for meeting the overall natural resource demand of humans and also considers the biologically productive land area required for soaking up the anthropogenic effluences that result from consumption of natural resources (Ahmed et al. 2019; Usman et al. 2022; Murshed et al. 2022; Yasin et al. 2020a). However, despite EF being a more comprehensive indicator of environmental degradation, we also assess how ethnic diversity influences the CO_2 emission levels for comparison purposes.

An additional contribution of the study is that it examines the ethnic diversity-environmental quality nexus by innovatively controlling for the level of financial development in the selected less-developed countries of concern. This innovative contribution is in terms of constructing a composite financial development index by compiling data regarding several financial development indicators. The previous studies have mostly used a single variable to proxy financial development (Salahuddin et al. 2018; Ajmi and Inglesi-Lotz 2021; Huang et al. 2022); however, using a single indicator cannot comprehensively capture the extent of development of the financial sector. In this regard, the environmental outcomes derived using a financial development index can be assumed to provide a better understanding of the relationship between financial development and environmental quality. The rest of the study has been systematized as follows: the second section presents a comprehensive review of the existing literature. The third section specifies the empirical models while the incorporated methodology is provided in the fourth section. The fifth section documents the empirical results and discusses them. Finally, the sixth segment develops the conclusion and recommends the possible policy interventions.

Literature review

In the last decade, an extensive load of studies has been performed to analyze the determinants of environmental quality (Baloch et al. 2019; Charfeddine and Kahia 2019; Chen et al. 2019; Destek and Sarkodie 2019; Yasin et al.

2020a). However, the literature concerning the environmental impacts associated with ethnic diversity is yet to be adequately developed. Nonetheless, only a few of the preceding studies have shed light on this issue. Among these, Churchill et al. (2019) found that ethnic diversity curb CO_2 emissions in low-, middle-, and high-income nations. They argued that ethnic diversity may result in the synthesis of talent which may lead to development and innovation which are necessary for abating the emissions. Similarly, Ahmad and Amin (2019) claimed that ethnic diversity improves environmental conditions in high- and middle-income economies while it deteriorates environmental quality in low-income economies. Conversely, Alesina et al. (2019) incorporated district-level data from Indonesia for the period between 2000 and 2012 and concluded that ethnic diversity/fractionalization causes deforestation which ultimately triggers erosion of environmental quality. On the other hand, Das and DiRienzo (2010) incorporated cross-country data from 149 countries and researched the environmental impacts of ethnic diversity using an environmental performance index (EPI) to proxy environmental well-being. The authors concluded that higher levels of ethnic diversity dampen environmental quality since ethnic diversity weakens governance and deteriorates institutional quality to trigger environment deterioration.

Moreover, Papyrakis (2013) argued that a greater level of ethnic fractionalization and ethnic polarization cause disagreement and conflict of interest which may adversely affect the provision of environmental goods; consequently, environmental well-being is hampered by instigating greenhouse gas emissions. Similarly, the detrimental environmental impact of ethnic diversity has also been supported in the study by Rupasingha et al. (2004) in which the authors found that more ethnically diverse states in the United States face relatively worse environmental conditions. Hence, based on the review of the aforementioned studies, it is apparent that no previous study has tried to use a large panel of less-developed countries to explore the nexus between ethnic diversity and EF.

Apart from ethnic diversity, the level of economic growth is also recognized as another key influencer of environmental quality (Lin et al. 2021; Chishti et al. 2021; Kihombo et al. 2021). In this regard, Grossman and Krueger (1991) pioneered the studies on the non-linear impacts of economic growth on environmental quality by recognizing an inverse U-shaped association between these variables. By establishing the environmental Kuznets curve (EKC) hypothesis, Grossman and Krueger (1991) elucidated that pollutant emissions are extensively upsurged at the early stages of economic development but are declined later on during the advanced stages of economic growth (Dogan and Inglesi-Lotz 2020; Jahanger 2022; Zeraibi et al. 2022; Yasin et al. 2020b). However, the validity of the EKC hypothesis is not guaranteed because empirical findings have both verified and condemned this hypothesis for different global economies (Banerjee and Murshed 2020; Murshed et al. 2021). Among the ones supporting this hypothesis, Ahmad et al. (2021a) incorporated annual data from 1980 to 2016 and examined the impacts of financial development, urbanization, and economic growth on the EF of the Group of Seven (G7) members. They found that the EKC hypothesis is true for these developed countries and concluded that urbanization is detrimental for environmental quality whereas financial development is beneficial for the environment. Similarly, Munir and Ameer (2022) investigated the impacts of urbanization, economic growth, and trade on the carbon emissions in 17 African and Asian countries for the 1975–2018 period. They found that there is an inverted-U shaped association between economic growth and carbon emissions; thus, the EKC hypothesis was verified for these nations. Besides, Dogan et al. (2019) investigated the environmental influences of financial development and urbanization on EF of Mexico, Indonesia, Nigeria, and Turkey during 1971 and 2013. Their findings supported the validity of the EKC proposition and also portrayed the detrimental environmental effects associated with fossil-fuel consumption, financial development, exports, and urbanization. Likewise, Pincheira et al. (2021) and Hassan et al. (2019) conducted panel data analyses and also confirmed the existence of the EKC hypothesis.

On the other hand, among the studies not verifying the authenticity of the EKC hypothesis, Ozcan et al. (2018) examined the EKC hypothesis for Turkey from 1961 to 2013 by using EF as a proxy for Turkey's environmental well-being. The results showed that the EKC hypothesis does not hold for Turkey as the inverted U-shaped economic growth-EF nexus could not be established. Bagliani et al. (2008) used panel data of 141 economies and also investigated the presence of the EKC hypothesis for EF but could not prove it. Similarly, Caviglia-Harris et al. (2009) employed panel data from 146 global countries from 1961 to 2000 and also concluded that the EKC hypothesis does not hold. Mikayilov et al. (2019) examined the associations between urbanization, energy consumption, trade, tourism, and EF in Azerbaijan, covering the period from 1996 to 2014. They incorporated international tourism as a proxy of national income and rejected the EF-related EKC hypothesis for Azerbaijan. Besides, they also concluded that trade and energy consumption upsurge the EF while greater international tourism and better institutional quality were found to have an insignificant impact on EF. Destek and Sinha (2020) also inspected the incidence of the EKC hypothesis for the cases of 24 members of the Organisation for Economic Co-operation and Development (OECD) and remarked that the EKC hypothesis does not hold for these nations. In addition, the authors established that higher use of renewable energy curbs the EF while nonrenewable energy boosts them. Similar findings were also reported by Onifade (2022) for oil-producing African nations, Pata and Samour

(2022) for France, Islam et al. (2022) for Bangladesh, and Bhowmik et al. (2022) for the United States.

Regarding the literature on the empirical studies on the financial development-environmental quality nexus, Baloch et al. (2019) used separate indicators of financial development for the private, banking, and financial sector to assess their independent impacts on the levels of EF in 59 Belt and Road Initiative (BRI) countries. Based on the findings, the authors confirmed that positive shocks to the level of all three financial development indicators devastate the environmental quality by amplifying the EF levels. Nathaniel et al. (2019) examined the relationship between financial development, in terms of the share of private sector credit in the gross domestic product (GDP) of South Africa, and EF and also found that financial development deteriorates environmental quality by amplifying EF. In another similar study on Turkey, Godil et al. (2020) also used the share of private sector credit in the GDP to proxy financial development and found that positive changes in the financial development level positively influence the Turkish EF figures. For the case of China, Zia et al. (2021) also the similar financial development proxy and concluded that the development of the financial sector upsurges the Chinese EF levels. Correspondingly, identical studies have also been conducted to explore the impacts of financial development on CO_2 emissions. Among these, Le and Ozturk (2020) stated that as the share of financial sector credit in the GDP of 47 emerging markets and developing nations goes up, synonymous with financial development, the CO_2 emission figures of these nations go up as well. Besides, the authors also found evidence of a bidirectional causal association between these variables. Similar findings, in the context of consumption- and territory-based CO_2 emissions in both the short and long run, were also reported by Abbasi et al. (2022) for the case of Pakistan.

Concerning the urbanization-environmental quality relationship, it can be said that urbanization may affect the environmental indicators either constructively or destructively (Ren et al. 2021; Rehman et al. 2021; Chien et al. 2022; Farooq et al. 2022). Poumanyvong and Kaneko (2010) and Mrabet and Alsamara (2017) argued that urbanization may diligently mend environmental conditions by endorsing efficient and coherent uses of the land area, public infrastructure, and urban agglomeration. Conversely, Ali et al. (2019) asserted that urbanization may bring environmental deterioration by triggering higher demand for energy consumption and transportation services. Accordingly, though several preceding studies have explored the role of urbanization in determining environmental well-being, the equivocal findings documented in the literature have made the connotation a bit more complex. Among these, Danish et al. (2020) explored the urbanization-EF nexus for the cases of the emerging economies of Brazil, the Russian Federation, India, China, and South Africa from 1992 to 2016. The authors concluded that urbanization improves environmental well-being by inhibiting the EF levels of these developing countries. In another recent study on four members of the Association of Southeast Asian Nations (ASEAN), Salman et al. (2022) found evidence of urbanization monotonically enhancing EF in Indonesia while failing to affect the EF figures of Malaysia and the Philippines. However, the authors concluded that in Thailand, urbanization initially boosts the EF but the impacts do not sustain later on. Likewise, both favorable and detrimental impacts of urbanization on CO_2 emissions have been documented in the the preceding studies conducted by Anwar et al. (2022), Sufyanullah et al. (2022), and Kocoglu et al. (2022).

Lastly, the role of energy use on environmental quality has also received extensive attention from researchers (Liu et al. 2022; Sadiq et al. 2022; Khan et al. 2022). Among the related studies using EF to proxy environmental well-being, Shahzad et al. (2021) remarked that as the level of energy use goes up in the United States, the nation's EF levels tend to increase, as well. Similarly, for the cases of 13 Asian nations, Lu (2020) found statistical evidence of energy consumption positively influencing the EF of the concerned Asian nations. In contrast, Sharma et al. (2021) opined that consumption of clean energy resources inflicts favorable environmental outcomes in Asia by lowering EF. Similarly, in the context of the top-10 most polluted global economies, Caglar et al. (2021) argued that scaling up renewable energy consumption enhances the prospects of inhibiting EF.

While the above review of the literature confirms the association between ethnic diversity, urbanization, financial development, and environmental quality, it also reveals that the literature regarding the environmental impact of ethnic diversity is in its earliest stage and therefore these relationships need to be further explored. As far as we are aware, this is the first study that examines the impacts of ethnic diversity on the ecological footprint in the case of less-developed economies. Besides, it is also apparent that the previous findings on the effects of financial development on environmental quality indicators are somewhat biased since these studies did not pay adequate attention to capturing the true extent of financial development by simultaneously considering data regarding different financial development-related indicators. Hence, taking into account this gap in the literature, this current study aims to bridge it by constructing a composite financial development index for scrutinizing the financial development-EF nexus in the context of a large group of less-developed nations.

Model specification and methodology

Empirical model

To analyze the environmental effects of anthropogenic actions, Ehrlich and Holdren (1971) established the widely recognized Impacts by Regression on Population, Affluence, and

Technology (IPAT) model in which the environmental impacts (denoted by I) of demographics/population (denoted by P), affluence/economic growth (denoted by A), and technology (denoted by T) are assessed as follows:

$$I = PAT \tag{1}$$

This model has definite limits, for instance, it assumes that the environmental impacts are unitary elastic to population, affluence, and technological shocks, thus implying that all the determining factors of environmental well-being have equivalent weightage in the abovementioned model. Hence to overcome the shortcomings of the IPAT model, Dietz and Rosa (1994) extended it and articulated the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model given below:

$$\mathrm{I_{it}} = \bar{\mathrm{O}} + \mathrm{P_{it}^{\pi}} + \mathrm{A_{it}^{\delta}} + \mathrm{T_{it}^{\varpi}} + \varepsilon_{\mathrm{it}} \tag{2}$$

In the STIRPAT model, the IPAT model's assumption of equal weightage of the impacts of each macroeconomic factor on the environment is relaxed. In Eq. 2, the cross-sections and time dimensions have been symbolized by the subscripts i and t, respectively. The constant and error terms have been represented by symbols $\bar{\mathrm{O}}$ and $\varepsilon_{\mathrm{it}}$, respectively. The coefficients of P, A, and T have been designated by the parameters π, δ, and ϖ, respectively. The abovementioned STIRPAT model can be transformed and linearized, by taking the natural logarithm, as follows:

$$\ln \mathrm{I_{it}} = \bar{\mathrm{O}} + \pi \ln \mathrm{P_{it}} + \delta \ln \mathrm{A_{it}} + \varpi \ln \mathrm{T_{it}} + \varepsilon_{\mathrm{it}} \tag{3}$$

In relation to the objectives of the study and the theoretical modeling of the EKC hypothesis, we augment the STIRPAT model as follows:

$$\textbf{Model 1}: lnEF_{it} = \theta_0 + \Omega lnY_{it} + \nu lnY_{it}^2 + \xi lnED_{it} + \tau lnU_{it} + oFD_{it} + \sigma lnE_{it} + \in_{it} \tag{4}$$

$$\textbf{Model 2}: lnC_{it} = \theta_0 + \Omega lnY_{it} + \nu lnY_{it}^2 + \xi lnED_{it} + \tau lnU_{it} + oFD_{it} + \sigma lnE_{it} + \in_{it} \tag{5}$$

where the dependent variables *EF* and *C* designate environmental damage in terms of EF and CO_2 emissions, respectively. Besides, in line with the theoretical settings of the EKC hypothesis, we include Y and Y^2 which represent income per capita and squared income per capita, respectively. Besides, ethnic diversity, urbanization, financial development, and energy consumption are symbolized by *ED*, *U*, *FD*, and *E*, respectively.

Data description and variable construction

This paper intends to empirically probe the environmental impacts associated with increments in the levels of ethnic diversity, economic growth, urbanization, financial development, and energy consumption in 51 less-developed countries using annual frequency data from 1996 to 2016. Table 1 presents the list of the less-developed countries considered in this study.

Table 1 List of the less-developed countries

Armenia	Guinea-Bissau	Nigeria
Bangladesh	Haiti	Pakistan
Benin	Honduras	Philippines
Bhutan	Indonesia	Rwanda
Bolivia	Kenya	Senegal
Burkina Faso	Kyrgyz Republic	Sierra Leone
Burundi	Lesotho	Sri Lanka
Cambodia	Liberia	Sudan
Central African Rep	Madagascar	Swaziland
Chad	Malawi	Tajikistan
Comoros	Mali	Tanzania
Congo, Dem. Rep	Moldova	Togo
Congo, Rep	Mongolia	Tunisia
Egypt, Arab Rep	Morocco	Uganda
Gambia	Nepal	Ukraine
Ghana	Nicaragua	Vietnam
Guatemala	Niger	Zimbabwe

Referring to our empirical models (shown in Eqs. 4 and 5), the data concerning the two dependent variables *EF* and *C* are retrieved from the Global Footprint Network database (GFN 2022) and the World Bank's World Development Indicators database (World Bank 2022). Similarly, the data for the independent variables including per capita GDP (*Y*), urbanization (*U*), and energy consumption (*E*) are also retrieved from World Bank (2022). Besides, the data for the ethnic diversity index (*ED*) is estimated using the approach of Alesina et al. (2003). Further, the variable *FD*, abbreviating the financial development index, is constructed using the principal component analysis (PCA) technique.[1] This particular method of index construction has been widely adopted in the literature (Razzaq et al. 2021; Murshed et al. 2022). The unit of measurement of the variables and their expected signs (i.e., impacts on the dependent variables *EF* and *C*) are presented in Table 2.

The ethnic diversity index

The ethnic fractionalization index data has been combed to develop the Herfindahl index of ethnic diversity by following the approach of Alesina et al. (2003). The ethnic fractionalization index has been depicted as follows:

$$\mathrm{FRAC_j} = \sum_{\mathrm{i}}^{\eta} \varepsilon_{\mathrm{i}}(1 - \varepsilon_{\mathrm{i}}) = 1 - \sum_{\mathrm{i}}^{\eta} \varepsilon_{\mathrm{i}}^2 \tag{6}$$

where represents the share of ethnic group i, where $i = 1 \ldots\ldots ..\eta$, in country j. The ethnic fractionalization

[1] The details regarding the construction of the financial development index are discussed later.

Table 2 Description of the variables and their expected environmental impacts

Variable	Symbol	Unit	Expected Effect
Ecological footprint	*EF*	Global hectors	-
CO_2 emissions per capita	*C*	Metric ton	-
Real income per capita	*Y*	Constant 2010 US$	Positive
Real income per capita squared	Y^2	Constant 2010 US$ squared	Negative
Ethnic diversity	*ED*	Index (range 0 to 1)	Ambiguous
Urbanization	*U*	People living in urban areas	Ambiguous
Financial development index	*FD*	Index	Ambiguous
Total energy consumption per capita	*E*	Kilogram of oil equivalent	Positive

Ambiguous indicates that the expected environmental impact can be either positive or negative.

index,$FRAC_j$, computes the probability that two individuals randomly selected from a country j are from dissimilar ethnic groups. The index value ranges from 0 to 1, where 0 implies the least diverse society and 1 means society is ethnically the most diverse.

Financial development index

Yasin et al. (2020a) explained that though there are a large number of proxies in the literature to capture financial development, still there is no accurate and precise way to represent financial development. Typically, domestic credit to the private sector by the banking sector, broad money, bank assets, liquid liabilities, and domestic credit to the private sector by financial corporations are amalgamated to measure financial development; nevertheless, all of the above-stated proxies are assumed to be flawed and inaccurate (Tyavambiza and Nyangara 2015; Yasin et al. 2020a). For instance, although domestic credit to the private sector is normally used as a proxy to capture financial development, it excludes the provision of information on financial services and transaction cost measurement. Moreover, no doubt domestic credit by the banking sector is extensively incorporated to capture financial development, but it is a better way to capture financial development for developing economies only as developing countries' governments typically borrow from depository corporations; hence, credit by the banking sector is a superior way to measure financial development in developing economies (Adusei 2012). Furthermore, broad money is also considered a decent substitution for financial development, but researchers such as Shahbaz et al. (2017) kept that as it primarily consists of currency; hence, it is a better method to capture monetization rather than financial development. Creane et al. (2006) maintained that liquid liabilities are not a decent and reasonable way to capture measure financial development appropriately as allocations of savings are ignored and overlooked by them.

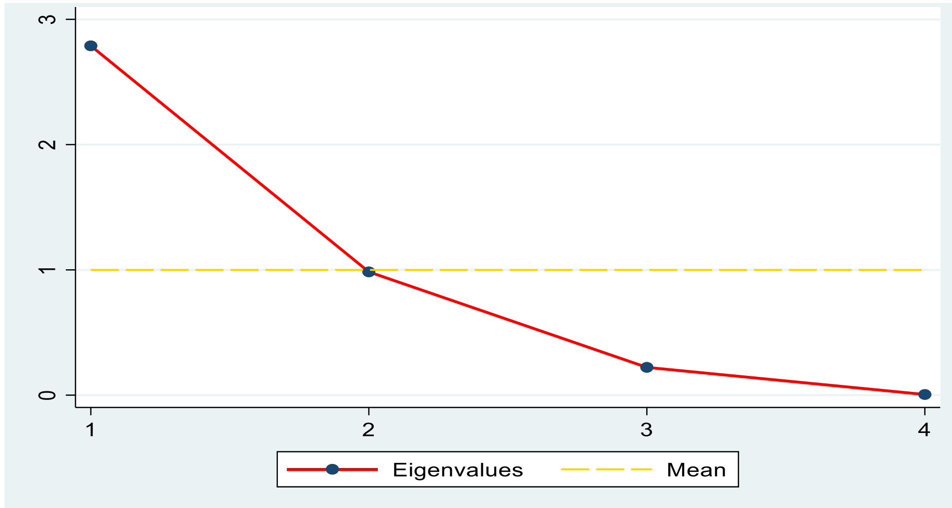
To overcome the deficiencies of the above-stated proxies of financial development cannot be incorporated altogether due to extremely high correlations among the series. Such high correlations may lead to misinterpretation of the ordinary least square (OLS)–based outcomes, due to the issue of potential multicollinearity. Hence, to overcome the probable problem of multicollinearity, we integrated the PCA technique. The PCA develops an index of plenty of correlated series while retaining most of the concrete and definite information from the series (Feridun and Sezgin 2008; Katircioğlu and Taşpinar 2017). To capture the diverse

Table 3 The PCA output for the construction of the financial development index

Component	Eigenvalue	Difference	Proportion	Cumulative
1	2.789	1.805	0.697	0.697
2	0.984	0.762	0.246	0.943
3	0.222	0.217	0.056	0.999
4	0.005		0.001	1.000
FD indicators	Factor loadings	Unexplained	FD indicators	KMO
DCPS	0.582	0.057	Overall	0.628
DC	0.585	0.457		
BM	0.130	0.953		
LL	0.550	0.156		
Bartlett's test for sphericity: 6148.298 (0.000)				

Only the first component has been extracted; KMO (Kaiser-Meyer-Olkin) measures sampling sufficiency; the probability value of the test statistic concerning the Bartlett's test is provided within ()

Fig. 1 Scree plot of eigenvalues after PCA for constructing the financial development index. Source: authors' computation



characteristics of financial development, we utilized data regarding several financial indicators: (a) domestic credit by banking sector (DC), broad money (BM), (b) domestic credit to private sector (DCPS), and (c) liquid liabilities (LL). The outcomes of the PCA analysis to develop a composite index have been reported in Table 3. Only one component has been retained by following the criteria of Kaiser (1974) and the scree plot (refer to Fig. 1) which suggests considering only the factors whose eigenvalues exceed one. It is exhibited in Table 2 that there is purely a distinct single component whose eigenvalue, 2.79, exceeds one. Overall Kaiser–Meyer–Olkin (KMO) statistics, 0.63, exhibits that sample is sufficiently adequate to accomplish the analysis. Furthermore, Bartlett's test for sphericity designates that the constructing indicators are also adequately correlated to perform the analysis.

Econometric methodology

To scrutinize the effects of ethnic diversity, financial development, urbanization, and energy use on the environmental quality in 51 less-developed economies, we follow Berk et al. (2022) to employ the Blundell-Bond generalized method of moment (B-B GMM)[2] and Arellano-Bond generalized method of moment (A-B GMM) regression estimators by Blundell and Bond (1998) and Arellano and Bond (1991), respectively. The selection of these GMM techniques is influenced by several of their advantageous features: (a) primarily, GMM is best suitable when the number of countries (N) exceeds the number of years (T) (Roodman 2009); this is the circumstance in this study as the number of countries considered is 51 (i.e., $N=51$) while the number of years (from 1996 to 2016) is 21 (i.e., $T=21$); (b) the GMM estimator solves the possible endogeneity concerns in the regressors through incorporating instrumental variables (Omri and Chaibi 2014); (c) the GMM technique takes into account the potential issues of cross-sectional dependency in the data; (d) while the usual estimation methods like the least-squares regressions cannot control for country-specific heterogeneities and therefore involves a dynamic panel bias, the GMM technique neutralizes this bias; (e) the GMM estimator is robust to handling small sample size of panels by eliminating finite sample bias whereby the B-B GMM estimator is preferred over the A-B GMM estimator (Baltagi 2008; Blundell and Bond 1998). The A-B GMM may suffer from finite sample bias in the case of highly persistent variables like GDP level and CO_2 emissions (Blundell and Bond 1998). Under such a circumstance, the A-B GMM cannot be applied. Hence, to overcome such problems, Blundell and Bond (1998) proposed the B-B GMM technique. A system of equations, in both levels and first-differences, is estimated by B-B GMM, where the incorporated instruments in level equations are the lagged first differences of the employed variables. Therefore, to overcome the potential issues of the A-B GMM estimator, we incorporated the B-B GMM method in this study, as well.

However, before conducting the GMM analysis, it is pertinent to perform cross-sectional dependency, unit root analysis, and cointegration analyses. Firstly, to identify the possible issue of cross-sectional dependency, we follow Tu et al. (2022) to apply the Pesaran (2021) cross-sectional dependence (CD) test. This method predicts CD issues for each variable (or series) by estimating a test statistic to reject the null hypothesis of cross-sectional independence. For robustness check, we follow Güney (2022) and utilize the CD estimation technique proposed by Breusch and Pagan (1980) which considers a similar null hypothesis of cross-sectional independence. The outcomes from the Pesaran (2021) and Breusch and Pagan (1980) Lagrange multiplier (LM) tests are presented in Table 4. It can be seen that for both the methods,

[2] The B-B GMM technique is also known as the system GMM technique.

Table 4 The cross-sectional dependency test results

Test	ln EF	ln C	ln Y	ln ED	FD	ln U	ln E
Pesaran CD	2.7946[a]	55.657[a]	91.443[a]	4.064[a]	81.976[a]	126.64[a]	10.068[a]
Breusch Pagan LM	8142.0[a]	8499.1[a]	15988[a]	20666[a]	12712[a]	26099[a]	10305[a]

The optimal lags are as per the Akaike Info. Criterion (AIC); a designates statistical significance at 1%

the predicted test statistics are significant at the 1% level; thus, the results reject the null hypothesis of cross-sectional independence to confirm that the panel data set used in this study suffers from CD concerns. Under such circumstances, the conventional first-generation techniques available for checking the unit root and cointegration properties cannot be applied.

Following the confirmation of the problem of cross-sectional dependency, we follow Mehmood et al. (2022) to employ the second-generation panel unit root estimation technique of Pesaran (2007). Specifically, Pesaran (2007) introduced the cross-sectionally adjusted Im-Pesaran-Shin (CIPS) test which builds upon the limitations of the first-generation cross-sectionally unadjusted Im-Pesaran-Shin test introduced by Im et al. (2003). The CIPS statistic is predicted considering the null hypothesis of the existence of a unit root. Similarly, considering the finding of cross-sectional dependency, we follow Caglar et al. (2022) and utilize the Westerlund (2007) technique to check for cointegration among the variables under a panel data setting. The decision to use this second-generation technique is influenced by the fact that the first-generation techniques provide misleading cointegration properties in the presence of cross-sectional dependency problems in the data. Specifically, a bootstrapping approach is followed to eliminate the concerns regarding cross-sectional dependency. The Westerlund (2007) technique considers the null hypothesis of no cointegration among the model variables in the entire panel and predicts four test statistics: Gt (between groups), Ga (among groups), Pt (between panels), and Pa (among panels) (Raheem et al. 2020). Although considering the same null hypothesis, the Gt and Ga statistics assume the alternative hypothesis of cointegration among the variables in at least one cross-sectional unit while the Pt and Pa statistics assume cointegration among the variables in all cross-sectional units (Dauda et al. 2019). Similarly, following Caglar et al. (2022), we check the robustness of the cointegration outcomes by employing the Westerlund (2008) method which predicts a single test statistic to check for cointegration under the null hypothesis of no cointegration against the alternative hypothesis of cointegration among the variables in the corresponding model.

Empirical results and discussion

The findings from the CIPS unit root analysis are presented in Table 5. The results, as perceived from the statistical significance of the predicted test statistics, suggest a that the variables *lnEF*, *lnC*, *lnY*, *FD*, and *lnE* are integrated at the first difference, I(1), while the other two variables *lnED* and *lnU* are integrated at the level, I(0). Once the order of integration is affirmed, the next step involves the analysis of cointegration.

Table 6 reports the findings from the Westerlund (2007; 2008) cointegration analyses. It can be seen that for both models 1 and 2 and across both the estimation techniques, cointegration among the models' variables is confirmed by the statistical significance of the estimated test statistics at the 1% significance level. Accordingly, we can claim that EF and CO_2 emissions are associated with ethnic diversity, economic growth, urbanization, financial development, and energy use in the context of the selected less-developed economies considered in this study. Hence, the confirmation of cointegration permits us to conduct the long-run regression analysis.

Table 7 reports the regression outcomes for both models 1 and 2 derived using the B-B GMM estimator and checked for robustness using the A-B GMM estimator. Overall, we see that the findings are not robust across these two alternative estimation techniques. The contrasting findings might be due to the fact that the A-B GMM estimator is less efficient since it considers the additional assumption regarding the first differences of the instruments being uncorrelated with the fixed effects (Roodman 2009). Moreover, the A-B GMM estimator has been acknowledged to be biased in case of weak instruments (Blundell and Bond 2000). As a result, the application of the B-B GMM estimator is more applicable. Besides, the estimates derived using the B-B GMM estimator can be considered consistent if the error term is free of autocorrelation and the incorporated instruments are valid. Accordingly, we applied the Arellano-Bond test to the residuals in differences to ensure the absence of autocorrelation and found that the model does not experience this problem. In addition, we also utilized the Hansen test to validate the use of the instruments. The statistical insignificance of the Hansen test statistics implies that the instruments used are

Table 5 Results from the panel unit root analysis

Order	ln EF	ln C	ln Y	ln ED	ln U	FD	ln E
Level	−1.513	−1.562	−1.826	−1.851[a]	−2.704[a]	−1.617	−1.497
Δ	−4.157[a]	−3.913[a]	−3.706[a]	−1.673[a]	−1.754[a]	−3.648[a]	−4.053[a]

Δ indicates first difference; lag optimality is based on AIC; a designates statistical significance at 1%

Table 6 Results from the panel cointegration analysis

Test	Model 1		Model 2	
Westerlund (2007) test	Value	Probability	Value	Probability
Gt statistic	−6.300[a]	0.000	−6.500[a]	0.000
Ga statistic	−16.450[a]	0.003	−16.320[a]	0.002
Pt statistic	−38.450[a]	0.000	−41.250[a]	0.000
Pa statistic	−18.509[a]	0.000	−20.400[a]	0.000
Westerlund (2008)	Value	Probability	Value	Probability
Variance ratio	−2.621[a]	0.004	−2.294[a]	0.002

Lag optimality is based on AIC; the Westerlund (2007) test was conducted with a maximum of four covariates; a indicates significance at 1%

Table 7 Results from the panel regression analysis

Dep. variable	Model 1		Model 2	
Estimator	B-B GMM	A-B GMM	B-B GMM	A-B GMM
$lnEF_{t-1}$	0.907[a]	0.266[a]		
lnC_{t-1}			0.819[a]	0.591[a]
lnY_t	0.601[a]	4.707[a]	4.887[a]	4.691[a]
lnY_t^2	−0.045[a]	−0.280[a]	−0.353[a]	−0.315[a]
$lnED_t$	0.098[a]	−1.029[a]	0.694[a]	0.617[a]
lnU_t	−0.033[a]	−0.644[a]	−0.126[a]	−0.042
FD_t	0.005[a]	−0.046[a]	0.049 [a]	0.011[a]
lnE_t	0.111[a]	0.930[a]	0.537[a]	0.407[a]
C	−2.154[a]		18.427[a]	
Obs	1071	1071	1071	1071
Diagnostic tests				
AR(1)	0.000	0.108	0.000	0.000
AR(2)	0.985	0.429	0.602	0.582
Hansen	0.823	0.378	0.824	0.324

[a], [b], and [c] designate significance levels of 1%, 5%, and 10%, respectively. For AR (1), AR (2), and Hansen tests, *P* values have been quoted

valid. Hence, considering the limitations of the A-B GMM estimator and the outcomes from the autocorrelation and Hansen tests, we claim the outcomes derived using the B-B GMM estimator (presented in Table 7) to be appropriate; consequently, we discuss the B-B GMM findings only.

The estimates from the B-B GMM analysis, as shown in Table 7, unveil that ethnic diversity deteriorates environmental conditions by instigating the EF and CO_2 emission levels in the selected less-developed nations. The results indicate that a 1% rise in the value of the ethnic diversity index causes 0.098% and 0.694% increases in the EF and CO_2 emission figures, respectively, as these coefficients are observed to be positive and statistically significant at a 1% level. These results are consistent with the findings highlighted in the study by Churchill et al. (2019) in which the authors argued that the deteriorating environmental impact of ethnic diversity might be because greater ethnic diversity reduces economic performance whereby improving environmental quality becomes difficult; thus, ethnic diversity results in poor environmental quality. Besides, since ethnic diversity has often been linked with poor institutional quality and weaker governance (Alesina and Zhuravskaya 2011), facilitating environmental improvement amid high levels of ethnic diversity can be expected to be cumbersome task.

Besides, the results found in this study confirm the incidence of the EKC hypothesis in the case of both EF (i.e., model 1) and CO_2 emissions (i.e., model 2). This is evident because for both models the coefficients of lnY_t and lnY_t^2 are positive and negative, respectively, and these coefficients are also statistically significant at a 1% significance level. Therefore, these findings imply that economic growth affects environmental quality in less-developed economies nonlinearly whereby the economic growth-EF and economic growth-CO_2 emissions nexuses depict inverted U-shapes consistent with the theoretical framework concerning the EKC hypothesis of Grossman and Kruger (1991). In this regard, it can be assumed that the economic growth policies followed by the selected less-developed nations initially do not guarantee environmental well-being but can be assumed to improve environmental quality once a certain level of economic growth is attained in the future. The EKC hypothesis was also verified in the previous studies conducted by Ahmad et al. (2021b); Ulucak and Bilgili (2018), and Yasin et al. (2020b).

As far as urbanization is concerned, it can be seen that urbanization has a beneficial role to play in improving the environmental quality indicators (i.e., EF And CO_2 emissions) as the associated coefficients of urbanization are observed to depict negative signs and statistical significance. Specifically, a 1% rise in the urban population size is predicted to reduce EF by 0.033% while curbing CO_2 emissions by 0.126%. These favorable environmental impacts of urbanization can be explained by the understanding that urbanization drives economic growth which makes it easier to implement environmental welfare-enhancing policies in the less-developed countries of concern (Yasin et al. 2020a). Besides, higher economic growth-led national income levels can be hypothesized to mend the environment hardships by expanding the environmentally-safe nonpolluting services sector, in particular. Similar findings were documented in the study by Mrabet and Alsamara (2017) in which the authors strongly argued that urbanization improves environmental quality by initiating technological innovation and research and development-related investments.

In contrast, the results shown in Table 7 indicate that financial development degrades the environment in the less-developed economies of concern since the associated coefficients are positive and statistically significant as well. A rise in the value of the financial development index by 1% is predicted to increase EF by 0.005% and CO_2 emissions by 0.049%. Similar findings were reported in the previous study conducted by Charfeddine (2017). Financial development might be detrimental to the environmental condition because higher financial development has often been acknowledged to boost the demand for ecological resources. Consequently, higher ecological resource consumption, in this regard, can be anticipated to trigger greater volumes of ecological wastes whereby the finding of the positive correlation between financial development and EF can be justified. Similarly, the finding regarding the positive nexus between financial development and CO_2 emissions can be explained by the fact that financial development can amplify higher energy demand which, in turn, can be assumed to stimulate higher emissions of CO_2. This assumption is verified by the other key finding in this study regarding the environmental impacts accompanying higher energy use. Specifically, the estimates shown in Table 7 highlight that energy use does not harness the objective of ensuring environmental sustainability in the less-developed countries of concern. The positive signs and statistical significance of the associated coefficients suggest that as the level of energy consumption goes up 1%, the EF and CO_2 emission figures surge by 0.111% and 0.537%, respectively. This is an expected finding since the less-developed countries heavily depend on fossil fuels for meeting their respective energy demand. Consequently, extracting and combusting fossil fuels are justifiably be held responsible for amplifying the EF and CO_2 emission levels in these countries. The negative environmental consequences stemming from energy consumption were also highlighted in the study by Katircioğlu and Katircioğlu (2018).

Conclusion and policy implications

Improving the quality of environmental indicators has become a global concern that necessitates the identification of possible channels through which environmental welfare can be enhanced. Hence, this study has empirically elucidated the environmental impacts of ethnic diversity, controlling for financial development, economic growth, urbanization, and energy consumption, in the context of 51 less-developed countries over the period from 1996 to 2016. For holistically quantifying the changes in the quality of the environment, we measured environmental well-being in terms of changes in both the EF and CO_2 emission figures of the selected less-developed economies. The long-run relationships among the study variables were confirmed from the cointegration analysis. Besides, the regression analysis led to the finding that ethnic diversity deteriorates environmental quality by surging the EF and CO_2 emission levels of the less-developed countries of concern. Similarly, financial development and energy consumption were also found to impose similar environmental adversities while urbanization was evidenced to induce environmental welfare by reducing the levels of these environmental indicators. Lastly, for both the cases of EF and CO_2 emissions, the EKC hypothesis was verified. In line with these findings, a set of relevant policy interventions are recommended.

Firstly, considering the finding of ethnic diversity negatively impacting environmental well-being, it is important for the less-developed countries to enact strict rules/regulations and strengthen the quality of institutions in order to withstand the possible ethnic diversity-led disobeying of the laws and simultaneously limit the extent of deterioration in the quality of institutions. The rationale behind these policy interventions is that if rule of law can be established alongside making institutions free of corruption, in particular, implementation and compliance with environmental laws would become easier whereby the ethnic people would also have to abide by them. Under such circumstances, the quality of the environment can be expected to improve. Secondly, since urbanization was evidenced to promote environmental well-being, the less-developed nations should aim at greening their respective urbanization strategies further since often in the literature we find that unplanned urbanization is a major cause of environmental degradation.

Thirdly, taking into account the finding of financial development exerting adverse environmental consequences, greening the financial services should be considered an important agenda for the less-developed countries. In this regard, these countries can introduce green bonds and other financial instruments that can stimulate green innovation. In addition, it is pertinent to impose higher interest rates on funds borrowed for investment in unclean production processes. In this regard, charging higher interest rates can be expected to discourage dirty investments while encouraging investments in cleaner economic sectors by availing loans at relatively lower rates of interest. More importantly, the future financial development policies of the less-developed countries should emphasize the issue of green innovation which is largely conditional on private sector finance and investment for research and development purposes. Fourthly, regarding the issue of energy consumption-led environmental degradation, two key policy reforms can be considered by the less-developed nations in question: (a) these nations should gradually switch from unclean to clean energy use and (b) enhance the rate at which energy resources are utilized. Both these energy sector-related policy interventions can limit the extraction and combustion of unclean energy resources whereby the EF and CO_2 emission levels can be expected to decline. Lastly, since the EKC hypothesis was found to be valid, it is important for the less-developed countries to adopt new economic growth policies that can catalyze the respective economic growth rate of these countries. However, these nations should be cautious in designing their future growth policies since these new policies should not trigger environmental degradation. Rather, the issue of environmental sustainability should be emphasized and embedded within the new economic growth policies so that these nations can achieve the threshold growth level needed for securing environmentally sustainable economic growth.

Among the few limitations faced in conducting this study, we could not expand our sample of less-developed countries beyond 51 due to the unavailability of data. Similarly, data unavailability has also confined our period of analysis from 1996 to 2016 and has restricted us from performing country-specific analysis as well. Moreover, the outcomes and the policy suggestions recommended in this study apply to the less-developed nations, in particular. However, these may not be totally applicable for developed nations without replicating the study for a panel of developed nations. Hence, in the future, this study can be extended by considering data from developed nations to test the external reliability of the findings. Furthermore, causality analysis can also be conducted to identify the direction of causation among the study variables which could not be accurately identified from the outcomes obtained from the regression analysis.

Author contribution IY conceptualized, conducted the econometric analysis, wrote the original draft, and analyzed the findings. SN wrote the literature review and the conclusions and recommendations section. HM conducted the econometric analysis and analyzed the findings. MM conceptualized, wrote the introduction, conducted the literature review, analyzed the findings, wrote the original draft, reviewed the draft, and compiled the overall manuscript. MAA prepared the methodology, analyzed the findings, and conducted the literature review. GRM reviewed the article.

Data availability The data will be provided on a reasonable request to the corresponding author.

Declarations

Ethics approval and consent to participate Not applicable.

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