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RESEARCH ARTICLE

What does export diversification do for energy demand? Evidence from the Global North

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Abstract

This paper contributes to the trade-energy literature by examining the effect of export product diversification on the energy demand of 30 countries located in the Global North over the period 1980–2014. A nonparametric time-varying coefficient panel data model with fixed effects is employed for its ability to produce robust outcomes in the presence of parameter instabilities, nonstationarity, regime shifts, and time variations. As a second step, the paper also utilizes the nonparametric fixed effects extension of Driscoll and Kraay, which is robust to spatial/cross-sectional dependence, as well as to autocorrelation and heteroscedasticity. The results indicate that export diversification lowers overall energy demand in the Global North, and the size of the impact has been on a gradual increase over the years. The paper concludes that if a conscious effort is made to ensure that product diversification is towards energy-efficient goods, export product diversification can serve as a useful strategy for managing energy consumption and mitigating its negative environmental effects.

Keywords Global North · Export product diversification · Nonparametric panel data · Time-varying parameter model

JEL Classification C33 · F1 · F14 · Q40

Introduction

Energy consumption considerably influences sustainable development and contributes significantly to environmental degradation (Tajudeen et al. 2018; Qi et al. 2019). Thus, scholars consider energy saving and greenhouse gas emission moderation as important elements for the control of abnormal climate changes. Identification of the determinants of energy consumption is an extensively researched topic in energy economics literature. Many of these studies have established international trade as a key determinant of energy demand (Cole 2006; Hossain 2011; Sadorsky 2011; Shahbaz et al. 2013). Countries generally increase their energy demand to power domestic production as well as to fuel the transportation of their products over relatively long distances across international borders (Alkhateeb and Mahmood 2019; Coskuner et al. 2020). International trade also facilitates the relocation of low-technology dirty production processes to less developed energy-intensive economies by highly developed technology-intensive countries (pollution haven hypothesis). On the other hand, energy-efficient products display relatively high levels of product complexity. Thus, their production requires more complex processes than the production of energy-intensive products (Alkhateeb and Mahmood 2019). Countries with complex productive compositions are therefore likely to be able to lower energy demand through the adoption of energy-efficient technologies as they increase their trade volume.

While extant literature has firmly established international trade as an important driver of energy demand, it has predominantly measured international trade via trade

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openness—the ratio of the sum of imports and exports to GDP. In recent times, however, the importance of export basket product diversification as an international trade indicator has come to the fore in empirical trade literature. For instance, studies by Gozgor and Can (2016) and Apergis et al. (2018) identify export product diversification as a driver of energy demand and a causal factor of pollution. Also, Koengkan (2018) argues that trading relations along with product quality and innovative production structure raises energy consumption. Studies examining the impact of export product diversification are however still limited in extant literature. This study therefore seeks to evaluate the role of export product diversification in energy efficiency in the Global North.

This study contributes to the development of theory and public policies on energy economics on several fronts. To start with, it is a pioneer article on the investigation of the role of export diversification on energy demand in the Global North. So far, little scholarly attention has been directed towards the energy-trade nexus in the Global North, a term referring to the rich and technologically advanced group of countries traditionally regarded as First and Second World countries (Odeh, 2010). Global capital allocation for energy-efficient technology, is heavily skewed in favor of the developed countries of the Global North (Goldthau et al. 2020). In fact, finance needs for mitigation technologies are lower in the Global North when compared with the developing countries of the Global South (Lazarus & Tempest 2014). Moreover, energy-efficient/low-carbon technology is most heavily concentrated in the Global North, as can be seen from the number of patents (Goldthau et al. 2020). Moreover, the clean development mechanism (CDM) of the Kyoto Protocol grants permission to the advanced countries of the Global North with a greenhouse gas reduction commitment to invest in emission-lowering projects in the Global South as opposed to investing in costlier emission-lowering alternatives in their home countries (Moner-Girona et al. 2016).

Second, on the empirical front, to the best of the authors' knowledge, it is the first in the body of international trade literature to employ a nonparametric time-varying framework in investigating the connection between export diversification and energy demand. This panel estimation technique is superior on many accounts to the more conventional time-invariant parametric techniques. Third, also on the empirical front, this study further examines the trade-energy nexus using the panel fixed effects extension proposed by Driscoll and Kraay (DK-FE, 1998) in order to deal with the potential impacts of cross-sectional dependence in the underlying data series. Finally, it contributes to literature by employing the export diversification index recently developed by the International Monetary Fund (IMF) which ranks countries based on the level of diversity displayed in their export baskets.

The rest of the study is structured thus; "Literature review" reviews relevant literature and presents the theoretical issues, "Empirical research data" details the data used, "Methodology" presents the methodology adopted, "Empirical results" discusses the empirical findings, and "Conclusion" provides the conclusion.

Literature review

Theoretical issues

In this era of trade globalization with advancement in modern economies, export and import product diversification have been recognized to influence energy demand (Shahbaz et al. 2019). Cross-border trade encourages efficiency and speeds up production and consumption processes (Heil and Selden 2001; Cadot et al. 2013). This is consistent with the Ricardian theory of trade which explains that an economy should focus on exporting goods in which it has a relative advantage over others, while the Heckscher-Ohlin theory argues that the host country ought to concentrate on the production and exportation of goods in the light of its factor intensity in the manufacturing process (Laursen 2015). In this sense, cross-border trade may drive energy demand and economic growth.

In the same vein, export diversification may control energy intensity and ensure efficiency in energy usage. Imbs and Wacziarg (2003) argue that diversification of export products may improve based on the level of income at which the diversification may be substituted with export concentration after a certain threshold level, meaning that developed economies may concentrate on producing products that can promote energy efficiency. Therefore, diversification of the economy in terms of its exportation may be a developmental strategy in its first level of economic development, especially at a level of $20,000–$25,000 per capita nominal GDP, with a reduction in the level of export diversification at a second stage.

The advanced countries of the Global North, through production and export diversification, can afford to relocate energy-intensive production processes to the less developed nations of the Global South (Stark et al. 2012; Alhassan et al. 2020; Bashir et al. 2020). According to the International Energy Agency (IEA 2019), this reconfiguration of global production pattern can lead to a reduction in energy demand and pollution in the more advanced Global North countries, and at the same time lead to a surge in industrial energy use in the developing nations of the Global South. This relocation of low-technology dirty production processes

to less developed energy-intensive economies by highly developed technology-intensive countries is referred to as the pollution haven hypothesis.

Empirical evidences

Papers focused on energy demand are quite popular in extant literature. In the analysis by Fuerst et al. (2020), energy demand is reported to be influenced by the socioeconomic characteristics of households. The result is based on multivariate OLS using English Household Survey. Güngör et al. (2020) consider the impact of energy consumption on carbon emissions in 9 democratic countries, within the environmental Kuznets curve (EKC) framework. Using pooled mean group estimating technique and Emirmahmutoglu-Kose Granger causality based on data spanning the period 1990–2014, the authors find that energy consumption aggravates pollution. The study of Akadiri et al. (2019a) exploring the South African data for the period 1973–2014 find that per capita energy use and output per person significantly impact environmental quality. Wang and Lee (2022) finds that financial development, government expenditure, and human capital can help ICT reduce energy demand, while foreign direct investment has the opposite effect.

Furthermore, Akadiri et al. (2019b) investigate the long-run and causal relationship between carbon emissions, economic growth, and energy consumption in Iraq over the period 1972–2013. The results, based on Toda-Yamamoto Granger causality, show that there is a one-way causality moving from carbon emissions to energy demand/consumption in the long run. However, there is no feedback relationship between carbon emissions, growth, and energy consumption in Iraq. In the study conducted by Odhiambo (2021) over the period 1990–2019 in Africa, it is documented that trade openness drives energy consumption. The result is based on ECM panel Granger causality technique. Alkhateeb and Mahmood (2019) reveal that trade openness has an asymmetric impact on energy consumption in Egypt between 1971 and 2014. Majeed and Asghar (2021) show that in both developed and developing economies, energy consumption reduces environmental quality.

In the recent study of Akadiri et al. (2022), the impacts of globalization, income, urbanization, and energy consumption on environmental degradation are examined, using Nigerian data over the period 1971–2018. It is revealed that globalization, real income, and energy consumption have positive impacts on environmental degradation. The same applies to urbanization. The results are based on quantile–quantile regression. Ogunsola and Tipoy (2022) investigate the factors affecting energy consumption in 6 oil-exporting African economies from 1980 to 2018. The results, based on cross-sectional autoregressive distributed lag and cross-sectional distributed lag approaches, reveal that per capita income does not have any significant impact on energy consumption, while economic openness has a positive impact. However, economic structure reduces the consumption of energy in the oil-rich African countries.

Few studies have also been carried out on the interaction between energy demand and export diversification. By employing bootstrap ARDL, Shahbaz et al. (2019) examine the impacts of education and export diversification on energy demand in the US economy. It is observed that education and export diversification have negative effects on energy demand. The VECM-based Granger causality results also confirm a feedback effect between education and energy demand, while export diversification Granger causes energy demand. Lv et al. (2019) and Waheed et al. (2019) conduct similar studies. Lv et al. (2019) however focus more on income and urbanization as a determinant of energy intensity in 224 Chinese cities. Applying spatial panel data estimation technique, the authors document a positive relationship between income and energy intensity, while urbanization is found to reduce energy intensity. Waheed et al. (2019) confirm that GDP growth positively impacts energy demand in the economy.

Sinha and Sengupta (2019) explain that crude oil price might negatively affect energy consumption. Samargandi (2019) also reveals that trade openness, energy price, and advancement in technology influence energy intensity after applying panel causality test on data from 11 OPEC countries. Huo et al. (2019) document that residential energy consumption significantly influences energy intensity in China. Bashir et al. (2020) examine how export diversification affects energy and carbon intensity in 29 OECD countries. By employing GMM, sequential estimation, and panel quantile regressions, the results show that export diversification reduces energy intensity and can be employed as a policy instrument in enhancing sustainable environmental development. In a related study, Shahzad et al. (2021) demonstrate that export product diversification and extensive as well as intensive margins assist in reducing energy demand in 10 newly industrialized countries (NICs) after employing a battery of panel estimations including GMM, FGLS, FOLS, and DOLS.

Other studies investigate the nexus between export diversification and energy demand within the framework of the environmental Kuznets curve (EKC) hypothesis. This reveals another interesting effort in the world of economic research. For instance, Gozgor and Can (2016) investigate the EKC hypothesis for export diversification in Turkey. The study provides empirical evidence that export diversification results in more carbon emissions in the Turkish economy and shows that export diversification may be useful in the determination of attitude towards energy consumption. Liu et al. (2018) examine the EKC hypothesis by incorporating ecological footprint into the relationship between GDP and export diversification in Japan, China, and Korea over the period 1990–2013. Employing error correction methodology

(ECM), findings reveal that Korea and Japan satisfy the EKC theory, while China does not seem to demonstrate this relationship. The study further concludes that the more the diversification of export, the more the ecological footprint.

In a study by Alomari and Bashayreh (2020), it is revealed that export diversification promotes economic growth in the Gulf Cooperation Council (GCC) in the long run, while no significant evidence is found in the short run. The study employs pooled mean group (PMG) on GCC data over the period 1992–2017. Liu et al. (2018) further carry out an investigation in 125 countries to establish the EKC hypothesis in export product diversification. The study employs Driscoll and Kraay standard errors to correct for any contemporaneous errors in the estimation which extends from 2000 to 2014. It is documented that a U-shaped relationship exists between economic development and CO_2. This is also consistent with the study of Mania (2020), where EKC hypothesis is shown to be valid in a group of 98 developed and developing countries. The study again confirms that CO_2 emission is positively impacted by export diversification after employing system GMM for short-run estimations and PMG for long-run analyses. The paper written by Lee, Yuan and Ho (2022) concludes that export diversification exacerbatesincome inequality for countries with low and medium levels of inequality.

It is apparent from the review that the literature focusing on the relationship between export diversification and energy demand is still nascent, while some studies also show that the extent of energy demand depends on the stage of economic development, estimation techniques employed, and nature of data (Paramati et al. 2018). Therefore, this study examines the impact of export diversification on energy demand in the Global North.

Empirical research data

For empirical analysis, energy demand (kilogram of oil equivalent per-capita) serves as the dependent variable, while export product diversification (Theil index) serves as the explanatory variable of interest. Based on theory and empirics, trade openness, gross domestic product, and urbanization are also included as control variables. Data on these variables are collected over the period 1980–2014 for 30 countries located in the Global North as per data availability. The export diversification data stops at 2014. Data on export product diversity is obtained from the IMF database and is freely downloadable at https://data.imf.org/?sk=A093DF7D-E0B8-4913-80E0-A07CF90B44DB. Data for all other variables—energy demand, trade openness, gross domestic product, and urbanization—are obtained from World Development Indicators of the World Bank (https://databank.worldbank.org/source/world-development-indicators). The logarithmic forms of all the variables are used for empirical analysis for ease of interpretation and also to deal with non-normality, non-linearity and heteroscedasticity in the data series. The summary statistics of the variables used for empirical analysis are presented in Table 1, and the Global North countries included in the empirical analysis are listed in Table 5 of the appendix.

Methodology

Nonparametric time-varying coefficient panel data model with fixed effects

Time-invariant parametric linear regression models often produce incorrect parameter estimates because they require restrictive functional form assumptions (Dogan et al. 2018). Also, policy changes, business cycles, and macroeconomic fluctuations are some of the potential sources of nonlinearities and parameter instabilities in the export diversity-energy demand nexus. Consequently, this study adopts a nonparametric time-varying framework which does not only get rid of the need for prior knowledge of the exact nature of functional forms, but also relaxes the assumption of linearity that time-invariant parametric models often require. Relative flexibility in data exploration is therefore provided through the nonparametric time-varying framework (Lee and Robinson 2015; Dogan et al. 2018). Overall, nonparametric time-varying models are preferred due to their robustness to the challenges posed by factors such as parameter instabilities, nonstationarity, regime shifts, and time variations.

Table 1 Summary statistics

	Energy demand	Export product diversification	Gross domestic product	Trade openness	Urbanization
Mean	3837.647	2.187110	1,100,000,000,000	88.11703	24,404,600
Median	3488.954	2.044415	301,000,000,000	66.14678	6,302,186
Maximum	18,178.14	4.437639	16,200,000,000,000	442.6200	259,000,000
Minimum	384.5950	1.137947	2,910,000,000	16.01388	201,355.0
Std. Dev	2279.777	0.704701	2,250,000,000,000	75.29121	42,054,135
Skewness	2.001204	1.087792	4.126961	2.599506	3.366977
Kurtosis	11.09920	3.740350	22.46094	9.850092	15.68952
Jarque–Bera	3570.710***	231.0560***	19,549.93***	3235.465***	9028.693***

(1)***$P < 0.01$

Moreover, the nonparametric time-varying approach permits common trend functions to be treated as functions of time so as to capture common global shocks that may be present due to factors such as recessions and booms. Finally, the time-varying coefficient functions adequately capture potential nonlinearities and country-specific heterogeneities present in the data series (Liddle et al. 2020). The nonparametric time-varying coefficient panel data model with fixed effects as described by Li et al. (2011) is followed. The econometric model relating export diversification to energy demand in the panel of Global North countries is given as follows;

$$ED_{it} = f_t + X_{it}^{\mathrm{T}}\beta_t + \alpha_i + e_{it}, i = 1, \cdots, N, t = 1, \cdots, T \quad (1)$$

where ED_{it} is energy demand; $f_t = f_i(t/T)$ refers to the unknown trend functions; $X_{i.t} = \left(EPD_{it}, TRADE_{it}, GDP_{it}, URB_{it}\right)^{\mathrm{T}}$ represents the vector of independent variables—export diversification, trade openness, GDP, and urbanization; $\beta_t = \left(\beta_{t,1}, \cdots, \beta_{t,4}\right)^{\mathrm{T}}$ stands for an unknown vector of time-varying coefficients; α_i refers to unobserved individual effects; N stands for the cross section size; T stands for the time series length; and e_{it} is the disturbance.

The time-varying coefficients that show the effects of the regressors on energy demand are obtained from the local linear dummy variable estimate (LLDVE).[1] This choice is based on the superiority displayed by this technique in terms of rate of convergence of coefficient functions (Li et al. 2011; Sadik-Zada and Loewenstein 2020). The time-varying function confidence intervals are calculated through wild bootstrapping.[2]

Nonparametric fixed effects extension of Driscoll and Kraay

A shortcoming of the nonparametric time-varying coefficient panel data model with fixed effects is that it assumes cross-sectional independence (Li et al. 2011). Thus, as a form of robustness check, Eq. (1) is estimated using the fixed effects extension proposed by Driscoll and Kraay (DK-FE, 1998). DK-FE is based on nonparametric variance–covariance matrix estimations and standard errors that exhibit robustness to spatial/cross-sectional dependence, as well as to autocorrelation and heteroscedasticity. The execution of the estimator occurs in two stages. In the first stage, all model variables $W_{it} \in \{Y_{it}, X_{it}\}$ are within-transformed thus;

$$\widetilde{W}_{it} = W_{it} + \overline{W}_i + \overline{\overline{W}} \quad (2)$$

where $\overline{W}_i = T_i^{-1}\sum_{t=t_{i1}}^{T_i} W_{it}; \overline{\overline{W}} = \left(\sum T_i\right)^{-1}\sum_i \sum_i W_{it}$, W_{it} = vector of model variables, and T = time dimension.

In the final stage, the transformed regression model represented in Eq. (3) is estimated using pooled ordinary least squares (OLS) with Driscoll and Kraay standard errors, and the within-estimator corresponds to the OLS estimator represented by the equation.

$$\widetilde{y}_{it} = \widetilde{x}_{it}'\theta + \widetilde{\varepsilon}_{it} \quad (3)$$

where $\widetilde{y}_{it}$ and $\widetilde{x}_{it}$ refer to the transformed variables, while $\widetilde{\varepsilon}_{it}$ represents the transformed error term.

Empirical results

As a form of pre-estimation analysis, unit root tests were first conducted for all the variables used for the empirical analysis. The cross-sectionally augmented IPS (Im et al. 2003) second-generation panel unit root test of Pesaran (2007) was employed. The results produced by this unit root test are valid even when the data series are cross-sectionally dependent. The panel unit root results presented in Table 2 reveal that all the variables are stationary at level. Consequently, all the variables are used in their level forms for the empirical analysis.

The findings of the nonparametric time-varying model with fixed effects are shown in Table 3. The common trend function coefficients are found in Table 3, column 1. The results imply that the common trend function for energy demand has been on a linear increase over time. This shows that the energy demand average in the Global North has consistently risen over the sampled period. The year-on-year parameter estimates showing the impact of export product diversity on energy demand are negative and significant over the years covered in the study. The results further indicate that the size of the coefficients has been on a gradual but consistent rise (in absolute terms) over time

Table 2 CIPS unit root test

Variables	Intercept only		Intercept and trend	
	Level	First difference	Level	First difference
EU	−5.792***	−6.190***	−6.179***	−6.420***
ED	−4.696**	−6.160***	−4.749***	−6.294***
TRADE	−5.305***	−6.190***	−5.281***	−6.412***
GDP	−4.612***	−6.118***	−5.011***	−6.253***
URB	−4.559***	−6.183***	−6.183***	−6.407***

(1) The null hypothesis for the test is the "presence of unit-root in panel data with cross-sectional dependence." (2) Critical values are obtainable in Pesaran (2007). (3) CIPS generates panel averages of cross-sectional ADF test statistics. (4) ***$P < 0.01$, **$P < 0.05$, *$P < 0.1$

[1] Detailed information about LLDVE can be obtained in Silvapulle et al. (2017) and Hailemariam et al. (2019).

[2] Detailed information on wild bootstrapping can be obtained in Mammen (1993) and Davidson and Flachaire (2008).

Table 3 Nonparametric time-varying coefficient panel data model with fixed effects

Year	Common trend	ED	TRADE	GDP	URB
1980	−12.822 [0.000]	−0.028 [0.075]	−0.042[0.787]	0.798 [0.000]	0.004 [0.637]
1981	−12.783 [0.000]	−0.029 [0.072]	−0.047[0.758]	0.797 [0.000]	0.004 [0.607]
1982	−12.744 [0.000]	−0.031 [0.070]	−0.052[0.729]	0.795 [0.000]	0.004 [0.607]
1983	−12.705 [0.000]	−0.033 [0.067]	−0.056[0.698]	0.794 [0.000]	0.005 [0.592]
1984	−12.666 [0.000]	−0.035 [0.064]	−0.061[0.666]	0.792 [0.000]	0.005 [0.578]
1985	−12.627 [0.000]	−0.036 [0.061]	−0.066[0.633]	0.791 [0.000]	0.005 [0.564]
1986	−12.588 [0.000]	−0.038 [0.057]	−0.071[0.599]	0.790 [0.000]	0.005 [0.550]
1987	−12.549 [0.000]	−0.040 [0.054]	−0.075[0.564]	0.788 [0.000]	0.005 [0.537]
1988	−12.510 [0.000]	−0.041 [0.055]	−0.080[0.528]	0.787 [0.000]	0.005 [0.524]
1989	−12.471 [0.000]	−0.043 [0.046]	−0.084[0.492]	0.785 [0.000]	0.005 [0.511]
1990	−12.432 [0.000]	−0.045 [0.042]	−0.089[0.455]	0.784 [0.000]	0.006 [0.500]
1991	−12.393 [0.000]	−0.046 [0.038]	−0.094[0.417]	0.782 [0.000]	0.006 [0.488]
1992	−12.354 [0.000]	−0.048 [0.034]	−0.098[0.380]	0.781 [0.000]	0.006 [0.477]
1993	−12.314 [0.000]	−0.050 [0.035]	−0.103[0.343]	0.780 [0.000]	0.006 [0.467]
1994	−12.275 [0.000]	−0.051 [0.026]	−0.108[0.306]	0.778 [0.000]	0.006 [0.457]
1995	−12.236 [0.000]	−0.053 [0.023]	−0.112[0.271]	0.777 [0.000]	0.006 [0.448]
1996	−12.197 [0.000]	−0.055 [0.019]	−0.117[0.236]	0.775 [0.000]	0.006 [0.440]
1997	−12.158 [0.000]	−0.056 [0.017]	−0.122[0.204]	0.774 [0.000]	0.007 [0.432]
1998	−12.119 [0.000]	−0.058 [0.018]	−0.126[0.173]	0.772 [0.000]	0.007 [0.425]
1999	−12.080 [0.000]	−0.060 [0.013]	−0.131[0.145]	0.771 [0.000]	0.007 [0.419]
2000	−12.041 [0.000]	−0.061 [0.017]	−0.136[0.120]	0.769 [0.000]	0.007 [0.413]
2001	−12.001 [0.000]	−0.063 [0.018]	−0.141[0.098]	0.768 [0.000]	0.007 [0.407]
2002	−11.962 [0.000]	−0.065 [0.014]	−0.145[0.079]	0.767 [0.000]	0.007 [0.403]
2003	−11.923 [0.000]	−0.066 [0.012]	−0.150[0.062]	0.765 [0.000]	0.007 [0.398]
2004	−11.884 [0.000]	−0.068 [0.010]	−0.154[0.049]	0.764 [0.000]	0.008 [0.395]
2005	−11.845 [0.000]	−0.070 [0.010]	−0.159[0.038]	0.762 [0.000]	0.008 [0.391]
2006	−11.805 [0.000]	−0.071 [0.011]	−0.164[0.029]	0.761 [0.000]	0.008 [0.389]
2007	−11.766 [0.000]	−0.073 [0.012]	−0.169[0.023]	0.759 [0.000]	0.008 [0.386]
2008	−11.727 [0.000]	−0.075 [0.013]	−0.173[0.017]	0.758 [0.000]	0.008 [0.384]
2009	−11.688 [0.000]	−0.076 [0.014]	−0.178[0.014]	0.757 [0.000]	0.008 [0.383]
2010	−11.648 [0.000]	−0.078 [0.015]	−0.183[0.011]	0.755 [0.000]	0.008 [0.382]
2011	−11.609 [0.000]	−0.079 [0.016]	−0.187[0.009]	0.754 [0.000]	0.008 [0.381]
2012	−11.570 [0.000]	−0.081 [0.018]	−0.192[0.007]	0.752 [0.000]	0.009 [0.380]
2013	−11.531 [0.000]	−0.083 [0.019]	−0.197[0.006]	0.751 [0.000]	0.009 [0.380]
2014	−11.491 [0.000]	−0.084 [0.020]	−0.202[0.006]	0.749 [0.000]	0.009 [0.380]
Mean	**−12.157**	**−0.056**	**−0.171**	**0.774**	

(1) Mean refers to the average of the significant coefficients. (2) 10,000 bootstrap replicates were performed. (3) *P*-values are in parentheses

with a mean value of −0.056. This suggests that export product diversity has a negative impact on energy demand such that, on the average, a percentage increase in export product diversity results in 0.056% decline in energy demand. It also suggests that the size of the impact has been on a gradual increase over the years. Figure 1 is the graphical illustration of the coefficients showing the impact of export product diversity on export growth provided in Table 3, and shows the evolution of the time-varying parameter estimates over time. The graph confirms the gradual but consistent increase (in absolute values) in the size of the coefficients over time, thus confirming the growing importance of export product diversity for energy demand in the Global North. This finding aligns with those of Shahbaz et al. (2013), Bashir et al. (2020), and Shahzad et al. (2021) where export diversification lowers energy intensity in the developed OECD nations.

Regarding the control variables, trade openness has a negative impact on energy demand, although the impact is not significant until year 2001. The size of the coefficients of trade openness also increased gradually (in absolute terms) over the period for which they were significant. This suggests that the Global North countries may have been taking advantage of free trade to relegate low-technology dirty production processes to less developed energy-intensive economies while focusing on the production

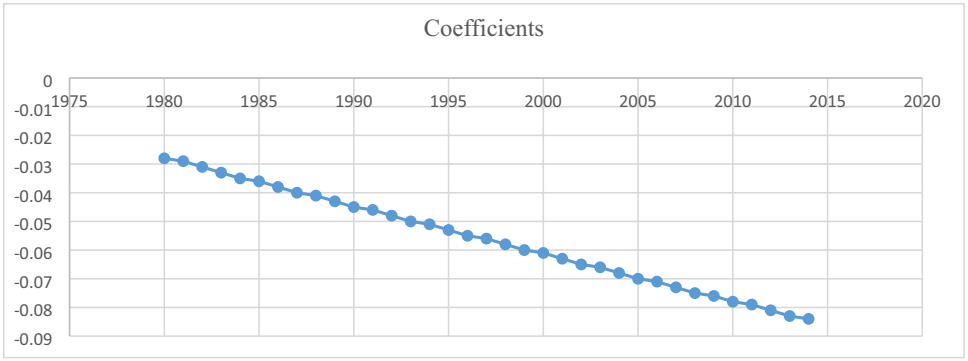


Fig. 1 Coefficients of export product diversity

of technology-intensive goods using energy-efficient techniques. The finding corroborates those of Koengkan (2018), Samargandi (2019), and Bashir et al. (2020). The impact of gross domestic product on energy demand is positive and significant for the entire sample period. There is however a gradual decline in the size of the impact over time. This finding lends credence to the argument that as countries move from middle to higher levels of economic growth, their concern for the environment grows and they actively seek ways to mitigate environmental damage by lowering fossil fuel consumption (Gouldson and Murphy 1997; Mol and Spaargaren 2000). The impact of urbanization on energy demand is however insignificant, making it impossible to reach any conclusion about the nature of the relationship between both variables in the Global North.

As a final stage of the empirical analysis, to ensure robustness of the study outcomes, the nonparametric fixed effects extension of Driscoll and Kraay was also conducted. This technique produces robust results in the presence of spatial/cross-sectional dependence, autocorrelation, and heteroscedasticity. The estimation outcomes obtained are again reported in Table 4. The results once again show that export product diversity has a negative and significant impact on export growth even after controlling for potential cross-country dependence in the data series. A percentage increase in export product diversification is able to stimulate a 0.085% reduction in energy demand. The size of the coefficient is not too far from what was obtained earlier. Once again, the impact of trade openness on energy demand turns out to be negative and significant, while the impact of gross domestic product remains positive and significant. The results indicate that a percentage increase in trade openness is capable of lowering energy demand by 0.087%, and a percentage increase in gross domestic product has the ability to raise energy demand by 0.619%. The impact of urbanization remains insignificant.

Conclusion

The structural changes that led to the economic progress witnessed by the countries of the Global North also resulted in a massive demand for energy as well as increased carbon emissions. Moreover, the Global North is critical to global energy, trade, and environmental regulations due to the concentration of energy-efficient technology in the countries and their ability to invest in emission-lowering projects in the Global South as opposed to investing in costlier emission-lowering alternatives in their home countries.

This paper therefore examined the hypothesis that export product diversification impacts export growth in the Global North. The empirical strategy employed to achieve this objective was in two steps. First, a nonparametric time-varying coefficient panel data model with fixed effects methodology was employed to model the impact of export product diversification on energy demand over a 35-year period (1980–2014), while controlling for the effects of trade openness, gross domestic product and urbanization. Second, to ensure robustness, we again tested the same relationship using the nonparametric fixed effects extension of Driscoll and Kraay.

The empirical findings indicated that export product diversification has the ability to lower overall energy demand, and that the size of the impact has been on a gradual increase over the years. Export product diversification induces structural changes by compelling countries to invest in new industries and improve existing products. If a conscious effort is made to ensure that product diversification is towards energy-efficient goods, export product diversification can serve as a useful strategy for managing energy consumption and mitigating the negative environmental effects.

Table 4 DK-FE results

Variables	Estimates	*P*-values
ED	−0.085*	0.067
TRADE	−0.087**	0.050
GDP	0.619***	0.000
URB	0.082	0.233
Constant	1.22	0.511
Obs	1050	
Groups	35	
F stat	10.12***	
R^2	0.485	

(1) ***$P<0.01$, **$P<0.05$, *$P<0.1$

The empirical results also showed that while gross domestic product enhances energy demand in the Global North, the size of its impact has been on a gradual decline over time. This finding confirms that higher economic activities lead to higher energy demand. It also lends credence to the argument that as countries move from middle to higher levels of economic growth, they are increasingly concerned about the environment and actively seek ways to mitigate environmental damage by lowering energy consumption. Trade openness, on the other hand, lowers energy demand, with the size of the coefficients increasing over time. This suggests that the rich countries of the Global North may have been taking advantage of free trade to relegate low-technology dirty production processes to less developed energy-intensive economies while diversifying into the production of energy-efficient goods.

Appendix

Table 5 List of Global North countries

No	Country	Export product diversification average values (1980–2014)
1	Albania	2.974
2	Austria	1.452
3	Australia	2.388
4	Bulgaria	1.945
5	Canada	2.046
6	Cyprus	2.352
7	Denmark	1.664
8	France	1.424
9	Germany	1.518
10	Finland	2.168
11	Switzerland	1.874
12	Spain	1.627
13	United Kingdom	1.650
14	Greece	2.156
15	Hong Kong	2.539
16	Ireland	2.558
17	Israel	2.696
18	Iceland	4.067
19	Italy	1.438
20	Japan	2.128
21	Korea	2.183
22	Malta	3.692
23	Netherlands	1.421
24	Norway	3.284
25	New Zealand	2.278
26	Portugal	1.983
27	Sweden	1.807
28	Singapore	2.765
29	Turkey	2.024
30	USA	1.513

Author contribution Godwin Olasehinde-Williams collected and analyzed the data, and also worked on the methodology. Folorunsho M. Ajide wrote the introduction and literature review. Chien-Chiang Lee worked on the study development.

Data availability Corresponding authors can provide data used in the study on appropriate request.

Declarations

Ethics approval and consent to participate NA

Consent for publication NA

Competing interests The authors declare no competing interests.

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