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Original Research Article

Globalisation and Primary Energy Consumption: Evidence from a Global Panel, 2000–2023

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Abstract: This study examines the relationship between globalisation and primary energy consumption using an unbalanced panel of 170 countries from 2000 to 2023. Employing fixed-effects models, the study finds that globalisation is positively associated with energy consumption. The positive relationship remains robust across alternative specifications. Further analysis of the three dimensions of globalisation shows that social globalisation has a significant positive association with energy consumption, whereas economic and political globalisation are not statistically significant. The findings suggest that the energy implications of globalisation may differ across its dimensions and that the additional energy demand associated with deeper international integration may outweigh potential efficiency gains.

Keywords: Globalisation, primary energy consumption, energy demand, economic globalisation, social globalisation, political globalisation, panel data.

1. INTRODUCTION

Energy is a central input into economic development (Stern, 2011), but rising energy demand is also associated with resource and environmental pressures. Globalisation is a multidimensional process involving economic, social, and political integration through channels such as trade, finance, information flows, migration, and international institutions (Dreher, 2006; Gygli *et al.,* 2019). Through these channels, globalisation may reshape both the level and composition of energy use. Understanding this relationship is important because deeper international integration may generate both energy-demand pressures and efficiency improvements.

The effect of globalisation on energy consumption is theoretically ambiguous. On the one hand, globalisation expands markets, stimulates production, increases transport activity, and accelerates the diffusion of consumption-intensive lifestyles. These scale effects can raise energy demand (Cole, 2006). On the other hand, international integration can facilitate the transfer of energy-efficient technologies, improve management practices, and shift production towards less energy-intensive activities. These technique and composition effects may reduce energy use (Cole, 2006; Ghani, 2012). The overall impact therefore depends on which mechanisms dominate.

Existing studies provide mixed evidence on the relationship between globalisation and energy consumption. Shahbaz et al. (2016) find that globalisation reduces long-run energy demand in India, whereas Ahmed et al. (2016) report a short-run reduction but a long-run increase in China. For 25 developed economies, Shahbaz et al. (2018a) show that globalisation increases energy consumption in most countries, although negative effects are observed in some cases, including the United States and the United Kingdom. Cross-country studies further suggest that the relationship may be nonlinear and conditional on income levels and other country characteristics rather than following a universal pattern (Huang *et al.,* 2020; Acheampong *et al.,* 2021; Dogan *et al.,* 2022). These heterogeneous findings indicate that the energy implications of globalisation may depend on the channels through which globalisation operates and the specific dimensions of international integration considered.

This study revisits the globalisation–energy consumption nexus using a recent global panel dataset covering 170 countries from 2000 to 2023. It examines whether globalisation is associated with primary energy consumption per capita and whether this relationship differs across economic, social, and political dimensions of globalisation. Using the 2025 release of the KOF Globalisation Index (KOF Swiss Economic Institute, 2025) together with updated energy and socioeconomic indicators, the study provides updated cross-country evidence on how different aspects of globalisation relate to energy demand.

By distinguishing among the three dimensions of globalisation, this study examines whether different forms of international integration are associated differently with energy consumption. Focusing on primary energy consumption per capita complements related studies on renewable energy, energy intensity, and carbon emissions, which capture different aspects of energy and environmental outcomes. The findings provide further insight into whether deeper global integration primarily generates additional energy demand or facilitates efficiency improvements.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Early empirical research generally represented international integration using trade openness or trade-liberalisation measures. Cole (2006) examined whether trade liberalisation increases national energy use, while Ghani (2012) found that trade liberalisation alone did not significantly affect energy-consumption growth in developing countries; an energy-saving effect emerged only when trade liberalisation interacted with capital per worker above a certain threshold. This literature established a link between international openness and energy demand, but trade alone captures only one aspect of global integration and does not fully reflect capital flows, information exchange, migration, tourism, or international political cooperation.

The KOF Globalisation Index addresses this limitation by conceptualising globalisation as a multidimensional process. Dreher (2006) introduced the original index, and Gygli et al. (2019) revised it by distinguishing economic, social, and political globalisation as well as de facto flows and de jure conditions. Economic globalisation reflects trade and financial integration; social globalisationcaptures interpersonal, informational, and cultural connections; and political globalisation measures international cooperation and institutional participation. This broader measurement is particularly relevant for energy research because countries with similar levels of trade openness may differ substantially in technology diffusion, tourism activity, information exchange, and policy coordination.

Studies of trade and the environment provide a useful framework for understanding the channels through which globalisation may affect energy use (Antweiler *et al.,* 2001; Copeland & Taylor, 2004). On the one hand, deeper international integration expands markets, increases production, transport activities, business operations, and household purchasing power, which may raise energy demand (Cole, 2006). On the other hand, globalisation can promote structural transformation and facilitate technology transfer, imported capital goods, competition, and knowledge diffusion, thereby improving energy efficiency and reducing energy use (Cole, 2006; Ghani, 2012). The overall effect therefore depends on whether the energy-increasing effects associated with expanded economic activity outweigh the efficiency gains associated with structural change and technological improvement. These offsetting mechanisms also suggest that different dimensions of globalisation may have distinct implications for energy consumption.

Economic, social, and political globalisation may therefore affect energy demand through different channels. Economic globalisation directly influences trade, production networks, investment, and capital mobility. These activities may increase energy demand through expanded production and transport, although they may also facilitate access to more efficient technologies. Social globalisation affects information exchange, tourism, personal mobility, and consumption preferences. Greater connectivity may promote environmental awareness, but it may also contribute to higher travel activity, appliance ownership, and the diffusion of energy-intensive lifestyles. Political globalisation operates more indirectly. International organisations and cooperation mechanisms may facilitate environmental governance and policy coordination, while institutional integration may also support infrastructure development and cross-border economic activities that require energy inputs.

Previous empirical evidence suggests that the relationship between globalisation and energy consumption varies across countries and development contexts. Country-specific studies report both positive and negative effects, indicating that the relative importance of energy-expanding and efficiency-enhancing mechanisms differs across economies (Shahbaz *et al.,* 2016; Ahmed *et al.,* 2016; Shahbaz *et al.,* 2018a; Shahbaz *et al.,* 2018b; Danish & Ulucak, 2021). These differences may reflect variations in economic structure, technological capacity, institutional conditions, and stages of development.

Cross-country evidence further highlights the heterogeneous effects of globalisation. Huang et al. (2020), using data from 98 countries, identify an inverted U-shaped relationship between globalisation and energy consumption, suggesting that energy demand may initially increase before declining after a certain level of global integration is reached. Acheampong et al. (2021) find that the effects of different dimensions of globalisation are not uniform in emerging

economies, while Dogan et al. (2022) show that the relationship between economic globalisation and energy demand differs across income groups and time horizons. These findings suggest that the impact of globalisation cannot be fully captured by a single average effect and that different dimensions may have different implications for energy demand.

Related studies have also examined the links between globalisation, renewable energy, and energy efficiency. Gozgor et al. (2020) find that economic globalisation promotes renewable-energy consumption in OECD countries. Nan et al. (2022) show that globalisation affects the relationship between renewable energy and carbon emissions through nonlinear mechanisms. For African countries, Fotio et al. (2023) find that globalisation improves electricity access but has no statistically significant aggregate effects on renewable-energy consumption or energy intensity, with differences across globalisation dimensions. Although these outcomes are not equivalent to primary energy consumption, they further demonstrate the importance of examining different dimensions of globalisation separately.

Taken together, existing studies indicate competing mechanisms and substantial cross-country variation in the relationship between globalisation and energy consumption. This study examines the average relationship using a broad international panel updated through 2023. Because global integration may expand production activities, transport, and consumption patterns, the overall effect of globalisation is expected to increase energy demand. Therefore, the first hypothesis is proposed:

H1. Greater overall globalisation is associated with higher primary energy consumption per capita.

At the dimensional level, economic globalisation is expected to increase energy use when the expansion of trade, investment, production networks, and transport exceeds the energy-saving effects of technology diffusion:

H2a. Greater economic globalisation is associated with higher primary energy consumption per capita.

Social globalisation may increase energy demand through international mobility, information exchange, tourism, and the diffusion of consumption patterns across countries:

H2b. Greater social globalisation is associated with higher primary energy consumption per capita.

Political globalisation may also increase energy demand if international cooperation and institutional integration stimulate economic activities and infrastructure development that outweigh potential environmental governance effects:

H2c. Greater political globalisation is associated with higher primary energy consumption per capita.

3. DATA AND METHODOLOGY

3.1 Data and variables

The dataset is an unbalanced annual panel covering 170 countries from 2000 to 2023, with 3,761 observations in the baseline sample. The sample period ends in 2023, the latest year covered by the 2025 release of the KOF Globalisation Index.

Table 1: Variable definitions and sources

Variable	Symbol	Definition	Source
Energy consumption	Energy	Primary energy consumption per capita (kWh/person), log	Our World in Data
Globalisation	KOF	Overall KOF Globalisation Index, log	KOF Swiss Economic Institute
Income	GDP	GDP per capita, constant 2015 US$, log	World Development Indicators
Urbanisation	Urban	Urban population (% of total), log	World Development Indicators
Trade openness	Trade	Exports plus imports (% of GDP), log	World Development Indicators
Industrial structure	Structure	Services value added divided by industry value added, log	World Development Indicators

Notes: All continuous variables used in the regressions are transformed using natural logarithms.

The dependent variable is primary energy consumption per capita, measured in kilowatt-hours per person using the substitution method. The main explanatory variable is the overall KOF Globalisation Index. Additional regressions replace the overall index with its economic, social, and political dimensions. The controls follow the broader energy-demand literature and include GDP per capita, urbanisation, trade openness, and industrial structure (Sadorsky, 2014).

Table 2: Descriptive statistics

Variable	Obs.	Mean	Std. dev.	Min.	Max.
ln(Energy)	3,761	9.250	1.544	4.624	12.510
ln(KOF)	3,761	4.063	0.251	3.225	4.491
ln(GDP)	3,761	8.666	1.430	5.661	11.682

ln(Urban)	3,761	3.996	0.446	2.455	4.605
ln(Trade)	3,761	4.336	0.532	0.906	6.093
ln(Structure)	3,761	0.775	0.637	-2.055	3.613

Source: Authors' calculations from KOF, Our World in Data, and World Development Indicators.

3.2 Empirical model

The baseline specification is expressed as follows:

$$lnEnergy_{i,t} = \beta lnKOF_{i,t} + \gamma' X_{i,t} + \lambda_i + \mu_t + \varepsilon_{i,t} \quad (1)$$

where $Energy_{i,t}$ denotes primary energy consumption per capita in country i and year t, and $KOF_{i,t}$ denotes the overall KOF Globalisation Index. $X_{i,t}$ is a vector of control variables, including GDP per capita, urbanisation, trade openness, and industrial structure. λ_i and μ_t denote country and year fixed effects, respectively, while $\varepsilon_{i,t}$ is the error term. Country fixed effects absorb time-invariant characteristics such as geography and long-run institutional differences. Year fixed effects capture shocks common to all countries, including global energy-price movements and worldwide business cycles. Standard errors are clustered at the country level to allow for heteroskedasticity and serial correlation within countries. As a robustness check, the study also reports Driscoll-Kraay standard errors, which are robust to general forms of cross-sectional and temporal dependence in panels (Driscoll & Kraay, 1998; Hoechle, 2007).

4. RESULTS AND DISCUSSION

Table 3 reports the baseline estimates. Column (1) includes the globalisation index together with country and year fixed effects. Column (2) adds income and urbanisation, while Column (3) adds trade openness and industrial structure. The coefficient on globalisation remains positive and statistically significant in every specification. In the full model, the coefficient is 0.8798, indicating a positive association between globalisation and primary energy consumption per capita.

Table 3: Globalisation and primary energy consumption

Variable	(1) FE	(2) FE	(3) FE	(4) FE-DK
ln(KOF)	1.4761***	0.8577***	0.8798***	0.8798***
	(0.2805)	(0.2300)	(0.2458)	(0.1182)
ln(GDP)		0.4754***	0.4569***	0.4569***
		(0.0894)	(0.0919)	(0.0539)
ln(Urban)		0.8043***	0.7761***	0.7761***
		(0.1846)	(0.1818)	(0.0715)
ln(Trade)			-0.0364	-0.0364
			(0.0557)	(0.0289)
ln(Structure)			-0.0498	-0.0498**
			(0.0375)	(0.0211)
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	3,761	3,761	3,761	3,761
Within R-squared	0.255	0.414	0.417	0.417

*Notes: Country-clustered standard errors are in parentheses in Columns (1)-(3). Column (4) reports Driscoll-Kraay standard errors. * p<0.10, ** p<0.05, *** p<0.01.*

The coefficient on globalisation remains statistically significant when Driscoll-Kraay standard errors are used in Column (4), indicating that the statistical significance of the main finding is robust to an alternative treatment of cross-sectional and temporal dependence. Income and urbanisation are positively associated with energy consumption. Trade openness is statistically insignificant once overall globalisation and the other controls are included. Industrial structure has a negative coefficient, although it is statistically significant only when Driscoll-Kraay standard errors are used.

The positive coefficient on globalisation supports H1. One possible explanation is that the energy-demand effects associated with deeper international integration outweigh the energy savings generated by technology diffusion and efficiency improvements. Globalisation can expand markets, production, transport, cross-border mobility, and consumption opportunities, all of which may increase energy use. At the same time, greater international integration can facilitate access to more efficient technologies. The positive net association suggests that the former effects are stronger on average over the sample period.

Table 4 examines the three dimensions of globalisation separately. Economic globalisation has a positive coefficient of 0.1603 but is not statistically significant; therefore, H2a is not supported. Social globalisation has a positive and statistically significant coefficient of 1.1034, supporting H2b. Political globalisation also has a positive but statistically

insignificant coefficient, and H2c is therefore not supported. In the economic-globalisation specification, trade openness is omitted because it is already captured as part of the trade component of the KOF economic globalisation index. The insignificant coefficients for economic and political globalisation should not be interpreted as evidence that these dimensions have no effect, but rather as a lack of statistically significant evidence of a positive average within-country association in this sample.

Table 4: Globalisation dimensions and sample robustness

Variable	Economic	Social	Political	Pre-COVID
ln(KOF economic)	0.1603 (0.1088)			
ln(KOF social)		1.1034*** (0.1427)		
ln(KOF political)			0.1710 (0.1621)	
ln(KOF overall)				0.6919*** (0.2311)
ln(GDP)	0.5100*** (0.0924)	0.4294*** (0.0916)	0.5007*** (0.0941)	0.4579*** (0.1010)
ln(Urban)	0.8925*** (0.1853)	0.5061*** (0.1724)	0.8758*** (0.1831)	0.6989*** (0.1825)
ln(Trade)	—	0.0196 (0.0472)	0.0048 (0.0527)	0.0072 (0.0705)
ln(Structure)	-0.0441 (0.0385)	-0.0403 (0.0349)	-0.0488 (0.0382)	-0.0616* (0.0358)
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	3,721	3,761	3,761	3,110
Within R-squared	0.394	0.462	0.393	0.418

*Notes: Country-clustered standard errors are in parentheses. The pre-COVID sample ends in 2019. * p<0.10, ** p<0.05, *** p<0.01.*

The final column of Table 4 restricts the sample to 2000–2019. The coefficient on overall globalisation remains positive and statistically significant, indicating that the main result is robust to excluding observations after 2019.

The dimensional results are consistent with the mechanisms discussed in Section 2. Economic globalisation can increase energy use through greater production, trade, investment, and transport, while technology transfer and access to more efficient capital may work in the opposite direction. These countervailing effects may help explain the statistically insignificant coefficient. Political globalisation is likely to influence energy demand more indirectly through international institutions, cooperation, and policy coordination, and its effects may also take time to emerge. By contrast, social globalisation is more directly connected with tourism, personal mobility, information exchange, and the diffusion of consumption patterns, which may contribute to higher energy demand. These explanations should be regarded as possible interpretations rather than separately identified mechanisms.

The positive overall relationship is broadly consistent with previous studies reporting positive associations between globalisation and energy consumption (Shahbaz *et al.,* 2018a; Shahbaz *et al.,* 2018b; Danish & Ulucak, 2021). At the same time, negative and nonlinear relationships have also been reported (Shahbaz *et al.,* 2016; Huang *et al.,* 2020; Acheampong *et al.,* 2021). The present results therefore do not imply that globalisation increases energy consumption in every country or at every stage of development. Rather, the estimated coefficient represents an average within-country association over the sample period.

5. CONCLUSION AND IMPLICATIONS

Using data for 170 countries from 2000 to 2023, this study finds a positive association between globalisation and primary energy consumption per capita. The main finding remains robust to additional controls, an alternative standard-error estimator, and restricting the sample to the pre-2020 period. The dimensional analysis shows that social globalisation is positively and significantly associated with energy consumption, while the coefficients on economic and political globalisation are not statistically significant. Thus, H1 and H2b are supported, whereas H2a and H2c are not supported.

The findings suggest that deeper international integration may generate additional energy demand even though it can also facilitate technology diffusion and efficiency improvements. The stronger result for social globalisation indicates

that the energy implications of globalisation may differ across its dimensions, with international mobility, information exchange, tourism, and the diffusion of consumption patterns providing possible channels through which social integration is associated with energy demand.

These findings highlight the importance of considering the energy implications of international integration. Policies that promote energy efficiency, cleaner transport and logistics, and the international diffusion of energy-saving technologies may help mitigate the additional energy demand associated with deeper globalisation. International information and cultural networks may also provide channels for promoting energy conservation and less energy-intensive consumption practices.

This study has several limitations. First, the fixed-effects design identifies within-country associations but does not fully resolve reverse causality or omitted time-varying factors. Second, primary energy consumption does not distinguish among fossil, nuclear, and renewable energy sources. Third, the KOF dimensions combine several underlying components that may affect energy demand differently across countries. Future research could examine energy composition, nonlinear relationships, and heterogeneous effects across income and development levels.

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