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Assessing the Relationship Between Global Production Networks and Energy Intensity: Empirical Evidence

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This paper examines the relationship between global production networks (GPNs) and energy intensity across 60 countries from 2007 to 2022. The study incorporates various control factors such as high-technology exports, urbanization, and economic development. Utilizing a generalized method of moments estimator, the findings indicate that GPNs contribute to a reduction in energy intensity. Additionally, the research explores the differential impacts of various activities (upstream and downstream) and production networks (forward and backward) on energy intensity. The possibility of a nonlinear relationship between GPNs and energy intensity is also evaluated. The outcomes of this study highlight the importance of policy measures aimed at enhancing climate change mitigation efforts.

I. Introduction

Globalization has resulted in many goods and services being produced, consumed, and distributed across multiple countries rather than just one. The emergence of global production networks (GPNs) is a significant driver of this change (Constantinescu et al., 2019; Pahl & Timmer, 2020). Energy usage to produce output conveys the energy intensity (EI), which is fundamental in measuring efficiency and associated environmental emissions (Li et al., 2021; Sweidan & Alwaked, 2016). EI is influenced by a variety of factors, including technology, high-quality energy inputs, and structural factors such as changing trade patterns and the contribution of different sectors of an economy over time (Huang & Chen, 2020; P., 2015; Voigt et al., 2014). According to Chen et al. (2019), global trade accounts for 20% of total global energy consumption.

The channels by which GPNs influence EI are as follows: First, GPNs are associated with the transportation of intermediate components to final goods across borders, which increases EI (Peters & Hertwich, 2008; Vohringer et al., 2013). Second, because GPNs aim to improve production efficiency and economies of scale, they may result in lower EI (Escaith & Inomata, 2011). However, if the activities are energy-intensive, the EI may increase. Third, GPNs may facilitate the transfer of technologies and energy-efficient practices, resulting in reduced EI (Constantinescu et al., 2019; Criscuolo & Timmis, 2017). Nonetheless, the overall impact

is determined by the time required for technological diffusion.

The objective of this paper is to delve into the intricate interplay between GPNs and EI. Few attempts have been made in the literature towards examining the role of GPNs on EI (Liu et al., 2018; Wang et al., 2021). The results linked to GPNs may exhibit heterogeneity due to variations in technological advancements, industrial structures, and the degree of development within a given nation (Wang et al., 2021). The uniqueness of our research is as follows: First, we examine a group of 60 countries. Second, improved GPN measures are considered to address previous shortcomings such as inflated assessment of foreign value added, double counting, and underestimation of domestic value added (Borin et al., 2021). Third, the impact of price variations on GPN measurement has grown significantly, influencing our comprehension of GPN levels and trends. Consequently, it is no longer reasonable to examine GPN in nominal terms. Therefore, this study takes into account the constant GPN indicators. Finally, we examine the role of upstream/downstream activities in GPNs on EI.

The rest of the paper is structured as follows: Section II examines the data and methodology, whereas Section III discusses the empirical findings. Finally, Section IV discusses the conclusions.

II. Methodology and Data

To investigate the link between *GPN* and *EI*, we use the following model:

$$EI_{it} = \alpha_0 + \alpha_1 GPN_{it} + \alpha_2 X_{it} + \varphi_{it} \quad (1)$$

$$EI_{it} = \beta_0 + \beta_1 GPN_Position_{it} + \beta_2 X_{it} + \rho_{it} \quad (2)$$

$$EI_{it} = \gamma_0 + \gamma_1 GPN_{it} + \gamma_2 (GPN)_{it}^2 + \gamma_3 X_{it} + \theta_{it} \quad (3)$$

where *EI* and *GPN* represent the energy intensity and global production networks of country *i* at time *t*, respectively. This study covers a group of 60 countries for the period of 2007–2022.¹ To gain deeper insights, *GPN* is categorized into forward integrated networks (*FIN*) and backward integrated networks (*BIN*). *FIN* measures the domestically sourced value-added that is both exported and used by the trading partner to manufacture goods intended for other nations. Conversely, *BIN* assesses the proportion of foreign value-added within exports. The variable *X* encompasses control variables, where urbanization (*URBAN*), economic growth (*GDP*), and high-technology exports (*HTM*) are considered. *GPN_Position* is an index indicating the nature of activities. A rise in *GPN_Position* signifies engagement in upstream activities within the production process, while a decline in the index indicates involvement in downstream activities. All variables are expressed in logarithms. α , β , and γ are the coefficients to be estimated. φ , ρ , and θ are the error terms.

We apply a system generalised method of moments (GMM) estimator advocated by Blundell and Bond (1998) to empirically estimate equations (1–3). Using moment conditions, this estimator reduces small sample bias and lagged values are used as instruments. The study uses the autocorrelation test (AR (2)) statistic to evaluate serial correlations and the Sargan test statistic to justify the over-identifying constraints.

The data regarding *GPN*, *FIN*, and *BIN* are sourced from the Asian Development Bank. The proportion of total gross exports is used to calculate these measures. World Development Indicators are the source for both *EI* and all of the control variables. *URBAN* is computed as the urban population percentage of the total population. *HTM* is calculated as the percentage of high technology exports to manufactured exports. *GDP* is computed as the growth in gross domestic product per capita.

III. Empirical Findings

The results of Equation (1), estimated using the GMM, are presented in column (1) of [Table 1](#), revealing several key observations. Firstly, the positive and statistically significant coefficient of lagged *EI* indicates that the *EI* from previous years contributes to the current *EI*. Secondly, the study finds that the coefficient of *GPN* is negative and statistically significant, suggesting that a 1% increase in *GPN* leads to a 0.03% reduction in *EI*. This may be attributed to technology transfers or the dissemination of energy-efficient practices related to *GPN*.

Thirdly, the negative and significant coefficient of *URBAN* implies that a 1% increase in urbanisation reduces *EI* by 0.04%. This could be due to the widespread use of energy-efficient appliances in urban areas, a finding consistent with Lv et al. (2019). Fourthly, the negative and significant coefficient of *GDP* suggests that each 1% rise in economic growth reduces *EI* by 0.01%, aligning with the Environmental Kuznets Curve (EKC). Finally, the positive and significant coefficient of *HTM* indicates that a 1% increase in high-technology exports results in a 0.01% increase in *EI*, which could be linked to energy-intensive manufacturing processes.

The study examines two methods by which firms can engage in *GPN*, specifically looking at the effects of *FIN* and *BIN* on *EI*. According to the results in column (3), a 1% increase in *FIN* results in a 0.02% rise in *EI*. Column (4) indicates that a 1% increase in *BIN* leads to a 0.06% reduction in *EI*. This difference may occur because *BIN* might involve sustainable sourcing of raw materials, contributing to an overall decrease in *EI*. This necessitates further investigation into how different types of activities within *GPN* affect *EI*. The findings in column (5), using Equation (2), show that the coefficient of *GPN_Position* is negative and significant, indicating that a 1% increase in upstream activities corresponds to a 0.33% decrease in *EI*.

To explore the nonlinear relationship between *GPN* and *EI*, the study incorporates a quadratic term for *GPN*. The results presented in column (6) utilizing equation (3) indicate that the coefficient of *GPN* is negative and statistically significant, whereas the coefficient of the squared *GPN* term is positive and significant. These findings imply a U-shaped relationship between *GPN* and *EI*, where an initial increase in *GPN* leads to a decrease in *EI*, followed by an eventual increase.

A. Additional analysis

The research categorizes a panel of 60 countries into high- and middle-income groups. The results are shown in [Table 2](#). Most findings are consistent with those of the overall sample, but there are some differences in the effects of *GDP* and *URBAN* when compared to the overall sample. An increase in *GDP* elevates the *EI* in middle-income countries, which may be attributed to the EKC. On the other hand, *URBAN* has a positive impact on *EI* in high-income countries.

IV. Conclusion

Global Production Networks (*GPNs*) and energy efficiency play a crucial role in addressing climate change. An analysis of a 60-country panel from 2007 to 2022, utilizing the generalized method of moments, indicates that involvement in *GPNs* reduces energy intensity (*EI*). However, the effects differ based on the type of network integration, specific activities, and economic conditions. The study un-

¹ Appendix A contains the list of countries.

Table 1. Impact of global production networks on energy intensity

(1)	(2)	(3)	(4)	(5)	(6)
<i>lnEI</i> (-1)	1.03*** (0.00)	1.01*** (0.00)	1.01*** (0.00)	1.03*** (0.00)	1.04*** (0.00)
<i>lnURBAN</i>	-0.04*** (0.00)	-0.06*** (0.00)	-0.03*** (0.00)	-0.02*** (0.01)	-0.05*** (0.00)
<i>lnGDP</i>	-0.01*** (0.00)	-0.01*** (0.00)	-0.01*** (0.00)	-0.01*** (0.00)	-0.01*** (0.00)
<i>lnHTM</i>	0.01*** (0.00)	0.01*** (0.00)	0.01*** (0.00)	0.01*** (0.00)	0.01*** (0.00)
<i>lnGPN</i>	-0.03*** (0.00)				-1.75*** (0.00)
<i>lnFIN</i>		0.02*** (0.00)			
<i>lnBIN</i>			-0.06*** (0.00)		
<i>lnGPN_Activities</i>				-0.33*** (0.00)	
<i>lnGPN</i> ²					0.23*** (0.00)
Constant	0.21*** (0.00)	0.15*** (0.00)	0.27*** (0.00)	-0.01 (0.81)	3.42*** (0.00)
No of Obs.	638	638	638	638	638
No of Countries	60	60	60	60	60
Sargan	57.34	56.51	55.77	57.92	54.82
AR(2)	-0.164	-0.200	-0.257	-0.280	-0.0499

Note: The dependent variable is the energy intensity (*EI*). *URBAN* refers to urbanisation; *GDP* denotes economic growth; *HTM* signifies high-technology exports; *GPN* stands for global production networks; *FIN* indicates forward production networks; and *BIN* represents backward production networks. ***, ** and * indicate levels of statistical significance at 1%, 5%, and 10%, respectively.

derscores the importance of energy efficiency policies that consider the types of networks, their activities, and stages of economic development.

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Table 2. Impact of global production networks on energy intensity across high- and middle-income countries

(1)	High Income Countries					Middle Income Countries				
	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
<i>lnEI</i> (-1)	1.05*** (0.00)	1.02*** (0.00)	1.00*** (0.00)	1.04*** (0.00)	1.05*** (0.00)	0.99*** (0.00)	0.98*** (0.00)	0.96*** (0.00)	0.92*** (0.00)	0.95*** (0.00)
<i>lnURBAN</i>	0.16*** (0.00)	0.22*** (0.00)	0.17*** (0.00)	0.23*** (0.00)	0.16** (0.04)	-0.11*** (0.00)	-0.15** (0.02)	-0.12*** (0.01)	-0.05 (0.21)	-0.08* (0.08)
<i>lnGDP</i>	-0.01*** (0.00)	-0.01*** (0.00)	-0.01*** (0.00)	-0.01*** (0.00)	-0.01*** (0.00)	0.01*** (0.00)	0.01** (0.02)	0.01*** (0.00)	0.01 (0.63)	0.01 (0.14)
<i>lnHTM</i>	0.02*** (0.00)	0.03*** (0.00)	0.03*** (0.00)	0.02*** (0.00)	0.02*** (0.00)	0.01 (0.13)	0.01* (0.06)	0.01** (0.04)	0.01** (0.02)	0.01* (0.08)
<i>lnGPN</i>	0.08*** (0.00)				-1.59 (0.27)	-0.09*** (0.00)				-1.46*** (0.01)
<i>lnFIN</i>		0.06*** (0.00)					-0.01 (0.69)			
<i>lnBIN</i>			-0.07*** (0.00)					-0.04*** (0.00)		
<i>lnGPN_Activities</i>				-0.23*** (0.00)					-0.19* (0.08)	
<i>lnGVC</i> ²					0.21 (0.25)					0.19** (0.01)
Constant	-1.16*** (0.00)	-1.21*** (0.00)	-0.58** (0.03)	-1.11*** (0.00)	2.17 (0.47)	0.75*** (0.00)	0.58*** (0.00)	0.61*** (0.00)	0.27** (0.01)	3.14*** (0.00)
No of Obs.	375	375	375	375	375	263	263	263	263	263
No of Countries	35	35	35	35	35	25	25	25	25	25
Sargan	33.80	33.19	33.57	32.65	32.38	13.56	16.84	15.20	19.85	18.47
AR(2)	-0.0811	-0.102	-0.134	-0.171	-0.110	0.473	0.346	0.276	0.221	0.518

Note: The dependent variable is the energy intensity (*EI*). *URBAN* refers to urbanisation; *GDP* denotes economic growth; *HTM* signifies high-technology exports; *GPN* stands for global production networks; *FIN* indicates forward production networks; and *BIN* represents backward production networks. ***, ** and * indicate levels of statistical significance at 1%, 5%, and 10%, respectively.



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