



How Do International Trade Gains Affect Energy Prices? Evidence from the OECD Economies

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Abstract

This paper examines the influence of international trade gains (measured by the International Trade Potential Index) on real energy prices using panel data from 28 OECD economies from 1995 to 2015. The empirical models also control the role of gross domestic product per capita and total population. The paper utilises the Dynamic Common Correlated Effects, Cross-sectionally Augmented Distributed Lag and the Augmented Mean Group estimations. The findings suggest that higher gains from international trade are associated with increased energy prices. The evidence is critical because policymakers should understand the trade-offs between promoting international trade and managing energy costs. Since trade boosts drive up energy prices, governments should implement measures to mitigate the impact on consumers and industries, such as energy efficiency programs or investments in alternative energy sources.

Keywords: energy prices, international trade gains, international trade potential index, OECD countries, CS-ARDL estimations, augmented mean group estimations

JEL Classification: Q43, Q37, F18

1. Introduction

What drives energy prices? This question is a vital research exercise in the empirical literature since energy consumption is essential for economic performance. However, research in such directions continues to be scant. Several factors that can affect energy prices have been discussed in the literature, such as climate policy uncertainty (Fu *et al.*, 2024), geopolitical risks (Maneejuk *et al.*, 2024), and supply chain disruptions (Li, 2025). With the expansion of trade openness, the literature has included gains from international trade alongside economic growth as significant drivers of energy demand (Li and Shi, 2014; Pan *et al.*, 2019). Standard international trade models predict that policies that increase energy prices will put domestic firms at a disadvantage compared to foreign rivals. Such findings also test the validity of the PHH – Pollution Haven Hypothesis (Levinson and Taylor, 2008).

International trade can be regarded as a significant determinant of energy use and environmental degradation (Copeland and Taylor, 2004; Gozgor *et al.*, 2020). Advanced economies are adopting stringent regulations to mitigate the environmental degradation associated with higher levels of industrial production. Such behaviour lends credence to the PHH. According to the PHH, production processes tend to be transferred to regions with less stringent environmental laws (Wu *et al.*, 2022). Nonetheless, the gains from international trade can be essential in reducing ecological damage through technological sophistication and product specialisation, which support the PHAH – Pollution Halo Hypothesis (Ahmad *et al.*, 2021).

A strand in the literature has further calculated trade welfare gains in the domestic economy. To address the measurement challenges in identifying the gains from trade, Costinot and Rodríguez-Clare (2018) developed a new measure of international trade gains. Similarly, Shapiro (2021) discussed how domestic policies and economic performance often shape gains from global trade. Numerous studies have demonstrated that international trade influences domestic energy consumption in various ways. For example, Cole (2006) contended that an expansion of export demand is associated with economies of scale, resulting in varied energy use within the domestic economy. Shahbaz *et al.* (2014) argued that economic growth, economies of scale, and technical progress owing to trade openness significantly affect domestic energy use. Khan *et al.* (2017) deliberated that trade specialisation is a scope for technology transfer and the expansion of renewables.

Based on the above discussions, this paper uses the trade potential index to measure the welfare gains from international trade. We examine the impact of these gains (as a proxy for potential gains in technology development within the production structure) on econ-

omy-wide real energy prices. To better capture these nuanced gains, we employ the International Trade Potential Index (TPI). This innovative measure, derived from the Penn World Table (Feenstra *et al.*, 2015), estimates the potential welfare gains from trade based on a country's geographic and economic characteristics. Its value lies in its ability to proxy for the income and investment effects generated by more efficient resource allocation and access to larger markets, precisely the mechanisms that drive industrial expansion and, consequently, derived energy demand. This approach provides a distinct contribution to the literature on trade and energy dynamics. Whereas previous studies have often linked trade volumes to energy consumption or intensity, our use of the TPI allows us to specifically examine how the economic gains from trade influence energy prices through their effect on domestic industrial activity and energy demand. This offers a more precise test of the causal channel linking trade liberalisation to energy market outcomes.

In this paper, we focus on the panel dataset of 28 OECD countries spanning the period from 1995 to 2015. For this purpose, we utilise the DCCE CS-ARDL and the AMG methods to account for cross-sectional dependence and unobserved common factors. Our findings indicate that higher gains from international trade are associated with increased energy prices. Our results refine the Pollution Haven Hypothesis, which posits that trade efficiency relocates pollution-intensive production (Levinson and Taylor, 2008) and raises energy prices in high-demand OECD hubs, thereby complicating decarbonization efforts. The evidence is critical because policymakers should understand the trade-offs between promoting international trade and managing energy costs. Since trade increases energy prices, governments should implement measures to mitigate the impact on consumers and industries, such as energy efficiency programs or investments in alternative energy sources (Fu *et al.*, 2024).

Our study also advances the literature by addressing three critical gaps. First, this is the first empirical work to analyse the nexus between trade efficiency and energy prices for the panel dataset of OECD countries. Prior works have focused on trade volume or openness (*e.g.*, Chen *et al.*, 2022; Khan *et al.*, 2017), neglecting the impact of trade potential on energy prices. Second, we employ the DCCE CS-ARDL and the AMG methods to account for cross-sectional dependence and unobserved common factors, key limitations in earlier studies (*e.g.*, Shahbaz *et al.*, 2014). Third, while existing research prioritises emerging markets (*e.g.*, Wu *et al.*, 2022), we provide the first OECD-focused analysis, revealing a trade-off between trade potential and energy affordability.

This paper is organised as follows: Section 2 reviews the literature, providing a theoretical framework and empirical studies on the international trade-energy nexus, the economic

growth-energy nexus, and the determinants of energy prices. Section 3 explains the data, the empirical models, and the econometric methods. Section 4 discusses the empirical results, and Section 5 concludes with theoretical and policy implications.

2. Review of Literature

2.1 Theoretical Framework

The theoretical literature extensively documents the outcomes of asymmetrical environmental regulations. A primary focus of this discourse is the explanation of output-related emissions from polluting industries. Within a theoretical framework where two countries are identical except for their environmental policy stringency, the nation with less stringent laws will specialise in producing and exporting the polluting good to the country with stricter regulations.

This cost-competitiveness dilemma forms the core theoretical basis of the PHH (Levinson and Taylor, 2008). The mechanism is channelled through consumer prices: the ability of firms to pass increased energy costs onto consumers determines the subsequent level of energy-intensive production. A successful pass-through may dampen consumer demand for energy-intensive goods, potentially decreasing net exports. This shift in demand towards less energy-intensive products could, in theory, contribute to a reduction in overall energy prices (Hanna, 2010). However, this final step assumes a highly elastic energy supply, a condition often not met in the short run, revealing a potential limitation in the theoretical model.

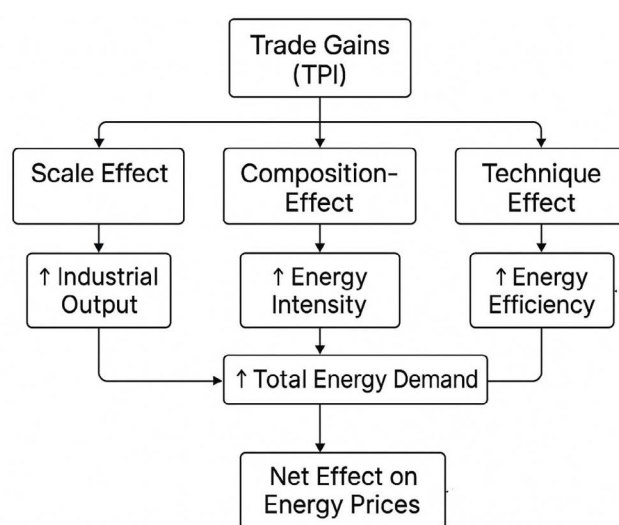
Nonetheless, it is acknowledged that many factors beyond energy prices and environmental laws, such as infrastructure quality, institutional strength, and geographical proximity to consumers, also significantly affect production location choices (Demailly and Quirion, 2008). Therefore, according to Copeland and Taylor (2003), the prediction that stringent environmental measures will lead to industrial relocation holds specifically if environmental compliance costs dominate these other determining factors.

In addition, the Porter Hypothesis offers a counterpoint, positing that stringent environmental regulations can stimulate innovation within firms, leading to the development of advanced pollution abatement technologies. This innovation may, in turn, enhance overall productivity, offsetting the initial costs of compliance and potentially improving a firm's international competitiveness (Porter, 1991; Porter and Linde, 1995). The effect of this dynamic on energy prices is nuanced and contingent. If the induced innovation leads to significant gains in energy efficiency, the demand for energy inputs could fall, exerting downward pressure on prices. Conversely, if the innovative response requires the installation of ma-

for new energy projects or capital-intensive clean technology, short-term energy demand and prices could see an increase. The net effect on energy prices is therefore an empirical question, determined by the balance between these opposing forces of efficiency gains and the energy costs of new technology adoption.

Finally, classical trade theories, such as the Heckscher-Ohlin model, provide a central mechanism: trade liberalisation enables a country to specialise and scale production in sectors where it possesses a comparative advantage. For numerous developed and developing economies, these sectors are frequently energy-intensive manufacturing industries, such as automotive, chemicals, and primary metals. Consequently, this export-induced industrial expansion creates a surge in the derived demand for energy, encompassing both electricity and thermal fuels, as an essential input for production, thereby exerting direct upward pressure on energy prices (Bernhofen and Brown, 2005). See the Flow Diagram in Figure 1, which summarises how trade gains affect energy prices.

Figure 1: Flow Diagram to Explain How Trade Gains Affect Energy Prices



Source: Authors' own elaboration

2.2 International Trade-Energy Nexus

The relationship between trade and energy has been researched in various contexts. Lin *et al.* (2012) empirically investigated the nexus between energy efficiency and international trade, aligning with production technology. These studies have deliberated that trade tends to increase energy and environmental efficiency. Li and Shi (2014) employed the input-output method to investigate the impact of international trade on energy consumption in China.

The authors concluded that trade openness does not help in energy conservation in China. Peng *et al.* (2021) employed the panel threshold models in 60 Belt and Road Initiative countries to explore the role of international trade on energy efficiency. The authors showed that trade enhances the convergence of total-factor energy efficiency. However, the impact is insignificant in countries with lower industrial shares. Similarly, Pan *et al.* (2019) utilised time series data from Bangladesh from 1976 to 2014, demonstrating that economic growth, technological innovations, and trade openness are crucial drivers in promoting energy efficiency.

Additionally, Chen *et al.* (2022) examined the influence of trade on energy intensity in 30 provinces of China from 2005 to 2018. Based on the dynamic panel data estimations, the results showed that international trade affects the energy intensity through the export conduit. In contrast, the import conduit is not essential. The authors concluded that the government's role is to promote trade openness to reduce energy intensity. Likewise, Tiwari *et al.* (2022) investigated the case of 16 Asian countries from 1990 to 2019, demonstrating how foreign direct investment, equity markets, and international trade influence the consumption of renewable energy sources. Their findings from the panel quantile regression methods indicated that global trade and economic growth significantly reduced energy consumption owing to technical effects. Sahu *et al.* (2022) analysed the impact of oil price fluctuations on renewable energy use in terms of controlling GDP, population density, and trade openness in the United States from 1970 to 2019. The authors employed an NARDL (Non-linear Autoregressive Distributed Lag) model. They found that a rise in oil prices, growth in population density, and GDP have a significant impact on renewable energy consumption.

Muhammad *et al.* (2022) also investigated the effect of carbon emissions, real oil prices, income inequality, economic growth, and trade openness on renewable energy consumption for the panel of 23 OECD economies. Based on the panel data estimation techniques, the study reported that trade openness, economic growth, and oil prices enhanced the use of renewables. The authors concluded that the governments of the OECD countries should consider trade openness to develop a demand for clean energy. Qi *et al.* (2022) focused on the Western African economies to explore the dynamic nexus between trade openness and energy development. Their findings suggest that economic growth and trade openness mutually reinforce the economies of Western Africa. The study concluded that Western African countries needed to integrate trade and energy development policies for sustainable economic growth. However, the literature on the nexus between international trade potential and energy prices is scarce, which is the focus of this study.

The relationship between trade and energy has been extensively researched, yet critical gaps remain, particularly regarding the interplay between international trade and en-

ergy prices (Peng *et al.*, 2021; Qi *et al.*, 2022). Existing studies have examined how trade influences energy efficiency, intensity, or renewable consumption, often through technological or structural channels (Lin *et al.*, 2012; Pan *et al.*, 2019). However, most literature focuses on energy quantity (consumption, intensity) or type (renewables), with scant attention to how trade potential, such as comparative advantage or trade barriers, interacts with energy price dynamics (Li and Shi, 2014; Muhammad *et al.*, 2022; Sahu *et al.*, 2022; Tiwari *et al.*, 2022). Furthermore, the channels through which trade influences energy prices remain underexplored in cross-country contexts (Chen *et al.*, 2022). At this stage, our study addresses these gaps by systematically analysing how trade potential modulates the energy prices.

2.3 Economic Growth and Energy Nexus

The seminal work by Kraft and Kraft (1978) first explored the energy-growth nexus. Nonetheless, the findings from the literature deliberations continue to be mixed. The lack of dominance of conclusions can be attributed to differences in data sets, the methodology applied, and the heterogeneity of the sample set of observations (Belke *et al.*, 2011; Saidi *et al.*, 2017; Shahbaz *et al.*, 2018).

The literature has explained the energy-growth nexus under the following four hypotheses (Apergis and Payne, 2009). First, the *Growth Hypothesis* posits that energy has a crucial impact on economic growth. Apergis and Payne (2010a and 2010b) found evidence of the causal relationship between energy and economic development in Eurasia and South American countries. Many studies have also obtained the unidirectional causality from energy consumption to economic growth. These include Gozgor *et al.* (2018) in OECD economies and Zafar *et al.* (2019) in the Asia-Pacific Economic Cooperation economies. Shahbaz *et al.* (2020) considered 38 countries that consume renewable energy.

Second, a noticeable number of studies in the energy economics literature provide evidence in support of the *Conservation Hypothesis*. This hypothesis explains a unidirectional linkage between economic growth and energy use. Chiou-Wei *et al.* (2008) observed this linkage in Singapore and the Philippines. In addition, Oh and Lee (2004) verified the Conservation Hypothesis in South Korea from 1981 to 2000. Sadorsky (2009) focused on 18 emerging countries from 1994 to 2003, verifying the validity of the Conservation Hypothesis. Considering 19 OECD countries from 1980 to 2008, Kula (2014) found evidence of unidirectional causality from economic growth towards renewable energy consumption. Mbarek *et al.* (2015) also utilised quarterly time-series data from France, spanning the period from 2001 to 2012. They obtained the evidence for the validity of the Conservation Hypothesis, *i.e.*, causality from economic growth to nuclear energy consumption. Rahman and Ve-

layutham (2020) examined five South Asian countries from 1990 to 2014, assessing the validity of the Conservation Hypothesis.

Third, according to the *Feedback Hypothesis*, a bidirectional causality exists between energy consumption and economic growth. This hypothesis posits that economic growth and energy consumption are interdependent; therefore, economic growth and energy policies should be implemented jointly. For instance, Mutascu (2016) focused on the G7 countries, Adams *et al.* (2016) considered Sub-Saharan African economies, and Saidi *et al.* (2017) focused on African and Middle Eastern countries; these papers found evidence supporting the validity of the Feedback Hypothesis. Ajmi and Inglesi-Lotz (2020) also examined the validity of the Feedback Hypothesis between biomass energy consumption and economic growth using a panel dataset of 26 OECD countries from 1980 to 2013. The authors concluded that OECD countries need to develop biomass energy infrastructure to promote economic growth and development.

Finally, the *Neutrality Hypothesis* implies that there are no causal links between energy and economic growth, meaning that energy and economic growth do not affect each other (Akinlo, 2008). For instance, Menegaki (2011) examined 27 European countries and found support for the Neutrality Hypothesis, which posits that energy consumption does not affect economic growth.

2.4 Determinants of Energy Prices

Energy prices and related policies have a significant impact on the energy transition. Existing studies have considered factors such as energy prices, financial systems, and trade that explain the transition to clean energy (Best and Burke, 2018). Asafu-Adjaye (2000) focused on India, Indonesia, Thailand, and the Philippines to investigate the causality nexus between economic growth and energy prices. The authors found that income and energy prices are mutually causal in the Philippines and Thailand. Berk and Yetkiner (2014) analysed the role of energy prices on economic growth for a panel dataset of 16 countries from 1978 to 2011. In the long run, energy prices negatively affected economic growth and energy consumption per capita. The authors emphasised the importance of renewable energy in mitigating the negative impacts of energy prices on economic growth. Similarly, Arshad *et al.* (2016) explored the effects of energy prices on economic growth in Pakistan. The authors indicated that the impact of energy prices on economic growth in Pakistan is adverse.

In addition, Dagoumas *et al.* (2020) studied the European Union to explore the long-run relationship between energy prices and economic growth. The authors concluded that a causal relationship exists. In particular, the Conservation Hypothesis holds between eco-

economic growth and electricity prices in the residential sector. Borzuei *et al.* (2022) considered a threshold regression model exploring the impact of energy prices on economic development and renewable energy consumption in Iran. They demonstrated the adverse effect of energy prices on renewable energy consumption during periods of high economic growth in Iran. Furthermore, the authors concluded that such a situation is due to the lack of proper resource management and reluctance to invest in affordable renewable energy.

The discussion above illustrates that researchers hold varying opinions regarding the role of international trade in influencing energy prices. Therefore, further studies with state-of-the-art methodology are still necessary. This study plays a crucial role in the debate on the role of international trade gains (potential) on energy prices. We position our research to examine the role of international trade in influencing energy prices. We utilise the international trade potential index to calculate the welfare gains from international trade, a novel strand in empirical research that enables the calculation of gains from trade across countries. We also use economy-wise real energy prices as the dependent variable, which is seldom used in the literature related to empirical energy economics.

3. Data and Econometric Methods

3.1 Data and Empirical Models

We investigate the impact of gains from international trade on real energy prices using panel data from 28 OECD countries from 1995 to 2015.¹ The sample's country dimension and the dates of its beginning and end are due to the availability of data on real energy prices across countries. The dependent variable is the *economy-wide energy price absolute index* collected from the data appendix in Liddle and Huntington (2020).² The authors provide these energy prices as constant prices (2005 = 100).

We also include log GDP per capita (in constant 2005 US dollars) as a proxy for a country's income level and log total population as a measure of country size, both as control variables. These data are obtained from the WB (2025).

1 Australia, Austria, Belgium, Canada, Chile, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea Republic, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Türkiye, the United Kingdom, and the United States.

2 See <https://journals.sagepub.com/doi/10.5547/01956574.41.3.blid?icid=int.sj-abstract.citing-articles.62> for details.

Furthermore, we consider the welfare gains of trade measures as a leading factor influencing energy prices. The *International Trade Potential Index* measures the welfare gains of international trade. The related data are obtained from the Penn World Table (PWT, version 10.01) of Feenstra *et al.* (2015).

Here, we follow Gozgor (2017), Lu *et al.* (2022), and Waugh and Ravikumar (2016) methods to define the Trade Potential Index (TPI) as:

$$TPI_{it} = \left(\frac{1 - M_{it}}{Y_{it}} \right)^{\frac{1}{1+\theta}} \quad (1)$$

Where M_{it} is the import share of the country³ i relative to its GDP (Y_{it}) in time t , calculated by the output-based real prices. θ denotes the trade elasticity, which is given as follows: Waugh and Ravikumar (2016).

The TPI data demonstrate that international trade (welfare) gains are lower in larger countries (measured by GDP).

3.2 Empirical Models

For testing the empirical validity of the effects of the international trade potential index, GDP per capita, and total population on real energy prices, the paper uses the following production function:

$$\ln ENPR = f(TRADE_POT, \ln GDP, \ln POP) \quad (2)$$

The production modelling framework in the natural logarithmic form, where the trade potential index is in the level form, can be written as follows:

$$\ln ENPR_{it} = \phi_0 + \delta_1 TRADE_POT_{it} + \delta_2 \ln GDP_{it} + \delta_3 \ln POP_{it} + \varphi_{it} \quad (3)$$

Where i represents the countries, t indicates the period, and φ_{it} is the error term, respectively. Moreover, $\ln ENPR_{it}$ is the log of economy-wide real energy prices, $TRADE_POT_{it}$ denotes the international trade potential index, which is a proxy for gains from international trade, $\ln GDP_{it}$ represents log real GDP per capita, which is a proxy of income level, and $\ln POP_{it}$ is the total population, respectively. ϕ_0 is the constant, and δ_1 , δ_2 , and δ_3 , are the slope coefficients with the respective variables.

³ The import share data is also based on the PWT 10.01 dataset.

3.3 Econometric Methods

3.3.1 The DCCE CS-ARDL Method

We utilise DCCE CS-ARDL estimations of Chudik and Pesaran (2015) and Ditzén (2018) to analyse the independent variables' long-run and short-run effects on log energy prices. The CS-ARDL method is more advanced than the Pooled Mean Group (PMG) and the Common Correlated Effects Mean Group (CCEMG) since it gives more efficient results in the presence of cross-sectional dependency. In addition, it captures the time-invariant heterogeneity across groups and unobserved common factors across the country (Chudik and Pesaran, 2015).

The DCCE CS-ARDL can be written in the following ways:

$$\begin{aligned} \Delta \ln ENPR_{it} = & \sum_{i=1}^p \delta_{1i} \ln ENPR_{it-1} + \sum_{i=1}^p \delta_{2i} TRADE_POT_{i,t} + \sum_{i=1}^p \delta_{3i} \ln GDP_{it} \\ & + \sum_{i=1}^p \delta_{4i} \ln POP_{it} + \sum_{i=0}^l \delta_{5l} \overline{CSA}_{i,t} + \varphi_{it} \end{aligned} \quad (4)$$

where, $\ln ENPR_{it-1}$ is the lagged log of real energy prices (adjustment variable), $TRADE_POT_{it}$ is the international trade potential index, $\ln GDP_{it}$ is the log GDP per capita, and $\ln POP_{it}$ is the log total population. $\overline{CSA}_{i,t}$ is the cross-sectional average of the variables (log real energy prices, international trade potential index, log GDP per capita, and log total population), and φ_{it} represents the error terms.

3.3.2 The AMG Method

We also conduct the AMG method for robustness purposes. This method is helpful for data with heterogeneity and cross-sectional dependency (Bond and Eberhardt, 2013; Eberhardt and Teal, 2013). The AMG gives good results for multiple unobservable common factors (Eberhardt, 2012). The AMG can be explained in the following ways:

$$\ln ENPR_{it} = \alpha_i + \beta'_i X_{it} + \vartheta_{it} \quad (5)$$

where α_i is constant and ϑ is the error term, respectively. The cross-sectional group-specific AMG estimated averages across groups can be expressed as $AMG = N^{-1} \sum \beta_i$; β'_i is the slope coefficient, and X_{it} represents the independent variables (international trade potential index, log GDP per capita, log total population, the common dynamic process effect, and the group-specific linear trend).

4. Empirical Results

4.1 Preliminary Results

We describe the summary statistics in Table 1 for log real energy prices, international trade potential index, log GDP per capita, and log total population. For the panel dataset of 28 OECD economies, log total population has the highest average, followed by log GDP per capita, real energy prices, and the international trade potential index. For the contest of standard deviation, the population has the highest value, followed by GDP per capita, energy prices, and the trade potential index.

Table 1: Summary Statistics

Variable	Definition	Data Source	Mean	Std. Dev.	Min.	Max.	Observation
ln ENPR	Log Energy Prices	Liddle and Huntington (2020)	4.485	0.181	3.814	4.927	588
TRADE_POT	Trade Potential Index	Authors' own calculations, based on the PWT dataset of Feenstra <i>et al.</i> (2015)	0.121	0.021	0.064	0.192	588
ln GDP	Log GDP per Capita	WB (2025)	10.332	0.624	8.787	11.424	588
ln POP	Log Total Population	WB (2025)	16.862	1.163	15.098	19.586	588

Source: Authors' own calculations

Table 2 illustrates the correlation matrix among the international trade potential index, log GDP per capita, log total population, and log real energy prices in the panel data set of 28 OECD countries. The findings indicate that log GDP per capita and total population have a positive correlation with real energy prices. Meanwhile, the international trade potential index negatively correlates with log real energy prices.

Table 2: Pairwise Correlations

Variable	$\ln ENPR$	TRADE-POT	$\ln GDP$	$\ln POP$
$\ln ENPR$	1.000	–	–	–
TRADE_POT	–0.410	1.000	–	–
$\ln GDP$	0.173	–0.853	1.000	–
$\ln POP$	0.082	0.323	–0.252	1.000

Source: Authors' own calculations

4.2 Results from the DCCE CS-ARDL Estimations

The DCCE CS-ARDL captures the short-run and long-run results with the adjustment term, presented in Table 3. Table 3 considers log real energy prices as the dependent variable, a function of the international trade potential index, GDP per capita, and log population.

Table 3: Results of the DCCE-CS-ARDL Estimations

Short run	Coefficient	Std. Err.	Z	$p > z$
$\ln ENPR_{t-1}$	–0.858***	0.040	–21.47	0.000
$TRADE-POT_t$	11.101**	5.349	2.08	0.038
$\ln GDP_t$	–0.388	0.288	–1.34	0.179
$\ln POP_t$	–1.563	1.128	–1.39	0.166
Adjust Term	Coefficient	Std. Err.	Z	$p > z$
(Long Run) $\ln ENPR_t$	–1.858***	0.040	–46.47	0.000
Long-run	Coefficient	Std. Err.	Z	$p > z$
$TRADE-POT_t$	5.653**	2.710	2.09	0.037
$\ln GDP_t$	–0.226	0.160	–1.41	0.158
$\ln POP_t$	–0.714	0.642	–1.11	0.266

Notes: The dependent variable is the $\Delta \log$ energy prices. Heterogeneous constant partialled out.

***, ** denote statistical significance at the 1%, and 5% levels, respectively.

Source: Authors' own calculations

The short-run coefficient and the long-run coefficient (adjustment term) of the lagged log real energy prices are -0.858 ($p < 0.01$) and -1.858 ($p < 0.01$). Moreover, log GDP per capita and log total population have negative but statistically insignificant impacts on real energy prices in the short and long run. It is noteworthy to note that our sample consists of 28 OECD countries at a similar stage of development or with comparable economic structures; the variation in GDP per capita may be insufficient to explain the variation in energy prices. The primary drivers would instead be policy differences or trade structures within this homogenous group.

The results also reveal that the international trade potential index has a significant impact on log real energy prices in both the long and short run. A one-unit rise in profits from the international trade potential index will lead to an increase in the real energy prices by 5.65% ($p < 0.05$) in the short run and 11.1% ($p < 0.05$) in the long run, respectively. Gains from international trade led to competitiveness and the expansion of industries. The direction of efforts to increase the scale of production at the industry level requires enough sources and energy for faster growth and significantly increased production output (Bouoiyour *et al.*, 2019). Similarly, a surplus from international trade will motivate new investors to expand production capacity by increasing raw materials capacity and adopting faster technologies that require substantial energy demand and higher energy prices.

We also observe that the potential gains from trade in the OECD countries increase energy prices. This evidence lends credence to the notion that trade enhances economic opportunities, leading to increased energy demand and, consequently, a price increase. It can be argued that gains from trade lead to the deployment of clean energies, the costs of which rise in the initial phases owing to high demand (Muhammad *et al.*, 2022; Tiwari *et al.*, 2022). Furthermore, the governments of OECD countries can utilise revenues from increased energy prices to support renewable energy deployments. Our findings align with Lin *et al.* (2012), who argued that gains from international trade may lead to technological sophistication.

From this point of view, policymakers in the OECD countries should be aware that the potential gains from international trade (a measure of economic globalisation) will likely increase the energy demand for the people of the OECD economies. These results suggest that people in OECD countries should adopt energy-efficient living methods. Otherwise, the demand for energy-intensive goods and services would increase the energy prices. These findings align with earlier studies by Asafu-Adjaye (2000) and Best and Burke (2018), which discussed that countries should implement energy conservation strategies to mitigate the increasing effects of foreign trade on energy demand.

4.3 Results from the AMG Estimations

We also use the AMG method to ensure the robustness of the CS-ARDL estimations. The results are provided in Table 4. They are in the context of earlier estimates of CS-ARDL estimations, *i.e.*, international trade potential index, log GDP per capita, and log total population affect log real energy prices. We also include the parameters for the common dynamic process and the group-specific linear trend.

Table 4: Results of the AMG Estimations

Variable	Coefficient	Std. Err.	Z	$p > z$
<i>TRADE_POT_t</i>	2.258*	1.247	1.81	0.070
<i>ln GDP_t</i>	−0.271*	0.146	−1.85	0.064
<i>ln POP_t</i>	−2.054	1.253	−1.64	0.101
Common Dynamic Process	0.995***	0.066	14.91	0.000
Group-Specific Linear Trend	−0.002	0.007	−0.32	0.749
Constant Term	39.427*	22.033	1.79	0.074

Notes: The dependent variable is log *energy prices*. Coefficient averages computed as outlier-robust means. ***, * denote statistical significance at the 1%, and 10% levels, respectively.

Source: Authors' own calculations

The coefficient of the common dynamic process is 0.995 ($p < 0.01$), and the coefficient of the group-specific linear trend is −0.002 (but statistically insignificant). Moreover, log GDP per capita ($p < 0.10$) and log total population harm real energy prices. However, the coefficient of the log total population is statistically insignificant.

The results also indicate that a one unit rise in the international trade potential index leads to a 2.258 per cent increase in real energy prices ($p < 0.10$) when we utilise the AMG estimations. Thus, the impact of the international trade potential index on the log energy price is robust across different estimation techniques.

5. Conclusion and Implications

This paper examines the impact of welfare gains from international trade on real energy prices using panel data from 28 OECD countries from 1995 to 2015, while controlling for GDP per capita and total population. To this end, the paper postulated a different meas-

ure of welfare gains from international trade. State-of-the-art estimation techniques were employed, including the DCCE CS-ARDL and the AMG methods. The findings showed that the welfare gains from international trade have a significant and positive effect on real energy prices in both the long and short run. It is essential to note that these results have both theoretical and policy implications, are subject to limitations, and provide several directions for future studies.

5.1 Theoretical Implications

The findings of higher gains from international trade led to increased real energy prices, revealing several critical theoretical implications for trade economics, energy markets, and environmental policy. For instance, the results align with the Heckscher–Ohlin model, which suggests that trade openness reallocates resources toward a country's comparative advantage (Bernhofen and Brown, 2005). If OECD economies specialise in energy-intensive manufacturing or services, trade expansion could increase energy demand, leading to higher prices (Marra *et al.*, 2024). In addition, the EKC hypothesis posits that trade initially worsens environmental pressures (scale effect) before cleaner technologies (technique effect) mitigate them (Wang *et al.*, 2022). Rising energy prices could reflect the dominance of the scale effect in the short-to-medium run (Fu *et al.*, 2024).

Furthermore, higher trade gains raise GDP per capita (a control variable), increasing energy consumption via income effects. If the energy supply is constrained, prices rise. This evidence suggests that the validity of the rebound effect (*i.e.*, efficiency gains leading to increased energy use) may partially offset the effectiveness of energy-saving policies (Gillingham *et al.*, 2016). This evidence also aligns with endogenous growth theory, which posits that innovation can mitigate resource constraints (Lemoine, 2024). In line with Acemoglu (1998 and 2002) and Acemoglu *et al.* (2012), directed technical change (*e.g.*, subsidies for economic growth) can influence the relationship between international trade and energy.

5.2 Policy Implications

The empirical results suggest that as trade openness in OECD countries increases, OECD economies should adopt technological sophistication and structural transformation strategies to reduce energy prices and encourage the development of energy-efficient products. Moreover, OECD countries should adopt innovative production methods to reduce energy consumption and lower energy prices. Policymakers in OECD economies should also be aware of the diversification of the energy mix. Their policy should aim to provide the proper direction for shifting from fossil fuels to renewables, which are more energy-efficient (Gozgor and Paramati, 2022).

Additionally, there is a need to reform energy policies that allocate funds towards energy-efficient techniques. Such steps lead to economic development while maintaining environmental sustainability. There is also a need to promote social awareness of the importance of technological sophistication and energy efficiency in the OECD economies. It is suggested that policies that incentivise innovation in energy efficiency should be adopted. Consequently, policies that encourage technological innovation to reduce production costs can enable the reaping of the benefits of foreign trade. Our results suggest a greater focus on innovation to mitigate rising energy prices in the context of trade openness. We recommend greater nuance in policy, aiming at technological sophistication to reap the benefits of the gains from international trade.

The interplay between industrial expansion, driven by global trade, and national energy systems presents a critical challenge for economic policymakers. History offers clear illustrations of this dynamic. Germany's export-powered model, reliant on energy-intensive manufacturing, led to high energy demand and a politically difficult burden-shifting of renewable energy costs to protect competitiveness. Japan's post-war export miracle created a profound vulnerability, as its dependence on imported oil sparked economic crisis during the 1970s price shocks, forcing a frantic pivot toward efficiency and diversification. Conversely, the United States shale boom functioned in reverse, where a domestic energy supply shock provided a potent trade advantage, fuelling a resurgence in energy-intensive industries like chemicals and metals by offering drastically lower input costs. These examples underscore that without strategic guidance, trade-led industrial growth can exacerbate energy insecurity, price volatility, and environmental externalities. Consequently, a toolkit of actionable policies is essential to steer this growth toward a sustainable and resilient future. Foremost among these is carbon pricing, which internalises the environmental cost of emissions and makes clean energy the most economically rational choice. This must be coupled with targeted investment incentives, such as tax credits for renewables and grants for efficiency, to accelerate the private sector's transition.

5.3 Limitations and Directions for Future Research

This study provides a foundational analysis of the relationship between trade-led industrial expansion and energy prices. While the present model offers significant insights, it simultaneously opens several productive pathways for future papers. For instance, future research would be markedly strengthened by incorporating advanced econometric techniques to establish the robustness of the core findings rigorously.

Secondly, the use of a broad Trade Policy Index (TPI), while practical, has inherent limitations. Its aggregate nature may mask the specific aspects of trade policy (*e.g.*, tariffs versus

non-tariff barriers, services versus goods trade agreements) that are most consequential for energy markets. Subsequent papers should seek to deconstruct this measure or employ alternative, more granular indices to pinpoint the precise mechanisms at play.

Finally, moving beyond linear and aggregate models promises to unlock a more sophisticated understanding of this complex relationship. The effects of trade on energy dynamics are unlikely to be uniform across all contexts. Investigating nonlinear relationships can also reveal important nuances. Similarly, disaggregating the analysis to explore sector-specific effects would be crucial. The energy price implications of expansion in a heavy manufacturing sector are likely profoundly different from those in a technology or services sector.

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