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The triangular relationship between energy consumption, trade openness and economic growth: new empirical evidence

Mandella Osei-Assibey Bonsu[1*] and Ying Wang[2]

Abstract: Our paper examines the triangular relationships between energy consumption, trade openness and economic growth of 45 countries from 1991 to 2014 using dynamic seemingly unrelated regression (DSUR) models. We confirm a bidirectional relationship among energy consumption and income, trade openness and income, trade openness and energy consumption for countries in the long run. Interestingly, the impact of energy consumption on economic growth is larger than the impact of trade openness, trade openness evidence larger impact on energy consumption than the impact of economic growth. However, the effect of economic growth on trade openness is the largest in the triangular relationships. We suggest that energy measures that aim to lessen energy usage in an economy will hinder economic growth. Our results provide insights for policymakers to understand and develop energy, trade, and environmental policies for sustainable development in the long run.

Subjects: Environment & Economics; Energy policy and economics; International Trade; incl; trade agreements & tariffs

Keywords: energy consumption; international trade; economic growth; DSUR model

JEL classification: Q43; Q48; F14; O13

1. Introduction

Global attention to the effects of energy use on the expansion of international trade and economic growth is growing. Policymakers and economists disagree on the virtues of excessive energy use, its detrimental impact on global development, and the environment. Evidence suggests that trade has a positive impact on growth through FDI (technology transfer), spillover effects, and increased productivity that build organisational expertise. Another strand examines the link among energy consumption and real income (a proxy of economic growth). Recently, the interaction amongst energy demand and income and the linkage amid trade and growth has attracted increased interests from energy economics and global scholars (Apergis & Payne, 2010; Arora & Shi, 2016; Belloumi, 2009; Shahbaz et al., 2018; Sun et al., 2019; Tiba et al., 2016).

The energy-growth hypotheses, the conservation hypothesis, the feedback hypothesis, and the neutrality hypothesis are generally considered to be the four main hypotheses in the literature on energy and growth. Energy-growth theories explain the importance of energy consumption in the production cycle. Because of unidirectional causation, energy conservation measures that aim to maximise energy consumption would reduce productivity (Tiba et al., 2016). Evidence of a unidirectional causality was found in OECD countries (Salim et al., 2014) and in Turkey (Ocal & Aslan, 2013).

However, Fang (2011) examined the energy-growth nexus and found positive impact of clean energy on economic growth in China over the period 1980 to 2010. According to the conservation hypothesis, increased energy consumption because of increased economic activity will drastically modify the production process and result in impairing economic performance (Squalli, 2007). The conservation hypothesis amid income, renewable and non-renewable energy consumption was supported using Germany data for a period of 29 years (Tugcu et al., 2012). However, the feedback hypothesis assumes that economic growth and energy use are linked in both directions. As such, policies aiming at maximising energy efficiency will have a detrimental effect on growth, and vice versa. Lastly, the neutrality hypothesis claims that there is no association between energy consumption and growth.

To date, evidence on the energy, trade and growth nexus, the reality and direction of causality between these variables are inclusive. Using the dynamic simultaneous equation panel data for 45 countries from 1991 to 2014, we examine the triagonal relations among energy consumption, trade openness, and economic growth through the dynamic seemingly unrelated regression (DSUR) model. In recent years, both developed and developing countries are important vehicles of global economic growth. Particularly, these economies have realistic chances to be catalysts for increasing co-investment opportunities, generating new global trade routes, and developing sustainable development and cross-country synergies.

Our results suggest stationarity and cointegration among variables for full panels in the long run with support from the unit root and panel cointegration test performed. We perform the long-run estimates using dynamic seemingly unrelated regression on the relationships among energy consumption and income, trade openness and income, and trade openness and energy consumption. Supporting the feedback hypothesis, our results indicate that there is bidirectional connection of energy consumption, trade openness, and income for countries in the long run. The three baselines sturdily complement each other; thus, energy consumption and trade openness are the utmost elements of economic growth in the long run. Our findings are consistent with (Amri, 2017; Tiba & Frikha, 2018; Tiba et al., 2016). In addition, we find positive significant elasticity of trade openness and energy consumption on economic growth in the long-run higher trade volumes and energy consumption gives rise to economic growth. Remarkably, the influence of energy consumption on economic growth is larger than the effect of trade openness; trade openness shows bigger impact on energy consumption than the impact of economic growth; the impact of economic growth shows the largest outcome on trade openness. Similar trends are identified for other income countries. However, for high-income countries, results show a larger impact of trade openness on economic growth and a smaller effect of economic growth on trade openness. The DSUR results, which outperform GMM, DOLS, and DOLs in terms of efficiency, are robust to cross-sectional dependency and heterogeneity, especially when the equilibrium errors are highly cross-sectional dependent.

We contribute to the energy-trade-and-output nexus literature in threefold. First, we respond to Amri (2017) suggestion that current research pays minimal attention to the triangular relations between energy use, trade openness, and economic growth in a single framework. Hence, we investigate such triangular relationships using panels data from 45 countries and provide new empirical evidence for these economies in a single framework, hence fill in this research gap. Second, we used dynamic seemingly unrelated regression (DSUR) following Mark et al. (2005) to estimates the long-run panel cointegration tests which is dissimilar to the literature. For example, previous studies used the generalized method of moments when analysing simultaneous equation models (Dogan & Aslan, 2017; Islam et al., 2013; Tiba et al., 2016). Further, we adopted a variety of cross-sectional dependence and heterogeneity-resistant panel cointegration methods. This allowed us to determine the variables' long-run cointegrating characteristics and select suitable panel data estimators. Finally, we use a streamlined Cobb-Douglas production function with total energy consumption and trade openness proxied using import and export as a proportion of GDP. This differs from prior studies (Ben Aïssa et al., 2014; Nasreen & Anwar, 2014), which used either export or import to measure trade and renewable energy as an energy source. Therefore, our results provide policymakers some insights to comprehend and develop energy, trade, and environmental policies.

The rest of the paper is divided into several sections. The relevant literature is reviewed in the second section. Section 3 discusses the method and models. In Section 4, the data is introduced. Section 5 analyses the results and discusses our findings. Section 6 concludes the research.

2. Literature review and hypothesis development

2.1. The nexus between energy and economic growth

Energy consumption and economic growth have been widely researched in energy economics literature (Arora & Shi, 2016; Shahbaz et al., 2018). Whilst most of the literature examine Western countries, some explore Middle Eastern country data. Evidence suggests a diverse set of findings for the relationship between energy and GDP (Shahbaz et al., 2018). The nexus suggests that increased economic growth necessitates increased energy use, and higher rates of economic growth are required for more productive energy usage. Under Granger causality tests, there are four major assumptions. The first causal association between energy and GDP is the Granger link. Second, in Granger, there is a causal association, followed by a feedback connection between energy and GDP, and finally, there is no causal relationship (neutrality). The discovery of unidirectional causality or neutrality between GDP and energy demonstrates that energy conservation measures can be undertaken deprived of potential economic growth. To date, studies did not reach any specific conclusions in the energy-growth research.

Scholars have adopted different approaches and validated different assumptions. Considering the absence of clarity about how to interpret the relationship amongst energy consumption and economic growth, the research reveals that energy is vivacious input factor in economic growth (Apergis & Payne, 2010). Whilst the various findings could be explained by different countries, time and econometric approaches, Granger's causality approach has evolved as widespread econometrics method for examining the association within energy use and economic growth. Belloumi (2009) utilised a VECM model to analyse the connection between energy consumption and economic growth in Tunisia between 1971 and 2004 and discovered causal association among energy consumption and income. Moreover, Omri (2013), employed simultaneous equation models to explore the link amid energy consumption and economic growth in MENA economies from 1990 to 2011. His findings discovered a bidirectional connecting link amongst energy usage and development. Additional set of empirical studies shows that these economic variables have a causal bidirectional relationship (Apergis & Payne, 2010). These researchers suggested that energy consumption fuels economic expansion, which in turn fuels energy use and emissions. However, Ouyang and Li (2018) support unidirectional causality (hypothesis of conservation) since economic growth to energy consumption, supporting hypothesis of neutrality. Aside from generic energy consumption, certain categories of energy consumption have also been extensively investigated and have been shown to have a significant impact on economic growth. For instance, electricity consumption and economic growth are cointegrated for the long-term connection in Japan, while natural gas consumption has an indirect impact on economic growth in Malaysia (Rafindadi & Ozturk, 2015, 2016). Studies on the relationship between energy consumption and economic growth, however, could not come to any definitive conclusions. However, the importance of energy consumption for economic development is greater because it is a key factor in a nation's economic development.

2.2. The association between trade and economic growth

The association between trade and economic growth has attracted attention from policymakers and academics around the world. The export-led growth hypothesis and growth led hypothesis are the two main strands of research. The Export Led Growth Hypothesis (ELG) has several theoretical justifications (Mark et al., 2005). First, increased exports stimulate a country's economic production and encourage specialisation in export production, which shall lead to economic growth and increased skill levels, resulting in improved overall productivity that benefits the economy. Second, increased exports may alleviate foreign exchange limits, making products, services, and foreign financial capital purchases more convenient. Finally, the expansion of exports is compatible with countries that have competitive advantage and benefit the economy from their specialism. The export-led growth hypothesis states that export growth is a result of greater demand for local output or commodities, which leads to higher domestic productivity (Rivera-Batiz & Romer, 1991). The import-led growth hypothesis, which emphasizes the importance of imports in promoting economic growth, is based on the growth-import link Foreign direct investment (FDI) in the financial development system, technical transfer from emerging economies, and international research and development (R&D) approaches are all examples of this. The other category of studies looks at the impact of international trade (the sum of imports and exports) on economic growth, determining whether it has a positive, negative, or neutral impact. Jin (2006), for example, discovered that international trade and real income have an inverse relationship.

Theoretical justification for the growth led export hypothesis proposes that economic growth, which offers an aggregate production mechanism based primarily on capital and labour, leads to the export growth. Improving economic growth requires expanding the capital-labour ratio and increasing technology throughout time to enhance productivity (Weil, 2008). Furthermore, economic growth generates additional skills and technology, which enable greater economic development that facilitates export growth.

On the other hand, the Neo-classic theory of trade supports the framework that global growth contributes to further exports. The hypothesis describes how higher economic growth is achieved by boosting export activities in the form of export industry innovation to improve output. As a result, economic expansion raises the level of innovation, giving countries a competitive advantage and boosting export growth. Trejos and Barboza (2015) and Menyah et al. (2014) unveils that there remains no impact amid real income and trade. Yanıkkaya (2003) inveterate a favourable association amongst trade and real income through transfer of technology, scale economies, and comparative returns. The above research on the connection between trade openness and economic growth share the common assumption that there is a stable, long-term relationship between the two. Moreover, these studies did not consider GDP that was proxied through import and export. Therefore, we build on streamlined Cobb-Douglas production with total trade openness using import and export as proportion of GDP to study the impact on economic growth.

2.3. The relationship between energy consumption and trade

Growing interest is now being paid to the connection between global trade and energy use. A unidirectional relation exists among trade and energy consumption indicating that international trade Granger causes energy consumption to rise because of increased economic activity. The existence of a bidirectional causality suggests that a reduction in energy consumption because of measures targeted at creating a low-carbon economy might have a negative impact on international trade and its environmental advantages. Those aimed at reducing energy consumption, particularly from conservative energy grounds, willpower offset policies intended on sponsoring economic growth. Trade liberalisation policies conflict with energy conservation regulations in this context. According to the neutrality hypothesis, there is no correlation amid the two variables. Lean and Smyth (2010) studied the relationship between international trade and energy use and found a variety of results. For instance, Narayan and Smyth (2009) used several panel estimating approaches on six oil-rich Middle Eastern countries. Their findings reveal a short-run causation between energy consumption and income, as well as income and exports. Furthermore, there was evidence of a long-term feedback nexus between power use and export. Similarly, Lean and Smyth (2010) discovered a causal association between commerce and power use in their research. Tiba and Frikha (2018) used both import and export indicators of international trade in a multivariate regression model to reduce the problem of omitted variables. Their findings back up the energy usage-import feedback concept. In the short run, they also uncover evidence of a causal relationship amongst export and energy use. Sebri and Ousama (2014) used data from the BRICS economies to look at the relationship between real income, international trade, CO2 emissions, and renewable energy use from 1971 to 2010. Their findings support a two-way theory that includes (output and trade), (renewable energy and output), and (renewable energy and output) (trade and renewable energy usage) while Amri (2017) demonstrates the existence of a one-way causality connecting trade to the consumption of renewable energy. The study examines data from 1990 to 2012 from industrialised and emerging economies. Similarly, Brini et al. (2017) study the relationship between the consumption of renewable energy, trade, oil prices, and economic growth in Tunisia between 1980 and 2011. The empirical finding establishes a one-way causal relationship between commerce and short-term consumption of renewable energy.

2.4. The dynamic nexus among energy, trade, and economic growth

Findings from the extant literature indicates mixed results of the dynamic nexus between the energy-trade-output in a multivariate environment. Ben Aïssa et al. (2014) used a panel cointegration estimation approach to explore trade openness, energy use and income in sampled African economies between 1980 and 2008 and found a bidirectional causality between output and trade in both short and long run. Sadorsky (2011) used data from seven economies in South America between 1980 and 2007 to explore the connection amongst economic growth, energy use, and international trade. Granger causality was established amid exports and energy consumption, in addition to bi-directional feedback link between imports and energy consumption.

Furthermore, Nasreen and Anwar (2014) used panel data from 15 Asian economies from 1980 to 2011 to observe the link amongst these three variables. In the long run, growth and trade had a positive influence on energy use. Sbia et al. (2014) used data from the UAE from 1975 to 2011 to explore the connection amongst output, trade, and energy use. They exposed that economic growth and renewable energy usage are mutually beneficial. For both developed and developing economies, Amri (2017) discovered a bidirectional relationship amongst (renewable energy use and output), (trade and renewable energy use), and income (trade and output).

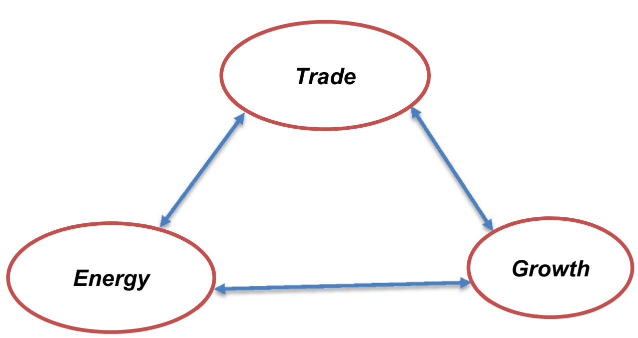
The preceding literature show that evidence on the relationship between trade, growth, and energy is inclusive of both reality and the direction of causality. Therefore, we hypothesize that there are triangular relationships between trade, energy, and growth. Figure 1 presents the theoretical research model developed in this paper.

3. Data and research methodology

3.1. Sample and data source

To investigate the triangular relationship among energy use, economic growth, and international trade, we used a balanced panel data for 45 countries collected from the World Bank database for the period from 1991 to 2014. Because the data for the chosen variables were not completely

Figure 1. Research model.



updated after 2014, we used the sample period of 1991–2014 as our time period with complete, useful, accessible, and manageable data.

The World Development Indicator (WDI) online database was used to obtain data for all the specified economic indicators from the World Bank. Data selected includes the following variables: Gross domestic product, energy consumption, international trade, gross capital formation utilised to signify physical capital stock, foreign direct investment, financial development, and total population. The 45 countries in the sample include: Korea Republic, Kenya, Jamaica, Italy, Indonesia, India, Hungary, Guatemala, Greece, Ghana, Gabon, Egypt, Ecuador, Dominican Republic, Cyprus, Costa Rica, Congo Republic, China, Chile, Bulgaria, Botswana, Bolivia, Benin, Malaysia, Malta, Mongolia, Morocco, Nigeria, Saudi Arabia, Senegal, Singapore, Sri Lanka, Sudan, Tanzania, Thailand, Togo, Tunisia, Turkey, Uruguay, Pakistan, Panama, Peru, Philippines, Portugal, Romania. Table 1 summarises the selected variables and sources.

3.2. Empirical model

We explore simultaneously the association between energy consumption, international trade, and economic growth using panel data. Previous studies focused on the relationships between several variables (Tiba et al., 2016). To investigate the triangular nexus, we used an extended Cobb-Douglas production framework (energy-trade-growth nexus) controlling for capital formation, FDI and labor force following previous studies (Omri, 2013; Tiba et al., 2016). Using an estimated study, we investigated the impact of two endogenous constructs on income including international trade and energy. This is how the extended Cobb-Douglas production framework is defined:

$$YE = A(ECS)^{\gamma 1} KC^{\gamma 2} LF^{\gamma 3} TRD^{\gamma 4} e^{\varepsilon} \quad (1)$$

Suppose that the output function has a fixed return to constant to scale, that is $\gamma_1 + \gamma_2 + \gamma_3 + \gamma_4 = 1$. By taking the natural log of equation (1), we were able to convert it to a log-linear form. This will assist us in determining the variables' growth rates as well as the linear version of the non-linear Cobb-Douglas production function. As a result, here is the time series equation of the paper:

$$lnYE_{it} = \gamma_0 + \gamma_1 lnECS_t + \gamma_2 lnKC_t + \gamma_3 lnLF_t + \gamma_4 lnTRD_t + \varepsilon_t \quad (2)$$

Because our research is focused on per capita, the study divided equation (2) by population, a proxy for labor force (L), while keeping the outcome on labor constant. As a result, the improved model is as follows:

Table 1. Descriptions of variables

Run	Description	Notes
YE	GDP	Proxy of economic growth, Current US$
ECS	Energy consumption	kg of oil equivalent
TRD	Trade	The sum of imports and exports
KC	Gross capital formation	Physical capital stock, Current US$
FDI	Foreign direct investment inflow	BoP, current US$
FDV	Financial Development	Liquid liability to GDP %
LF	Labor force	Total population, proxied for the labour force

Note: The data of the variables was obtained from World Development Indicators (WDI) from 1991–2014 .

$$lnYE_t = \gamma_0 + \gamma_1 lnECS_t + \gamma_2 lnKC_t + \gamma_3 lnTRD_t + \varepsilon_t \quad (3)$$

To generate our panel model, we revised equation (3) further, as shown beneath:

$$lnYE_{it} = \gamma_0 + \gamma_1 lnECS_{it} + \gamma_2 lnKC_{it} + \gamma_3 lnTRD_{it} + \varepsilon_{it} \quad (4)$$

Wherever $\gamma_0 = lnln(A_0)$, i signifies the amount of nations beneath explanations (i = 1,2,3, ……… N); t displays the time frame under study (1991–2014); YE stands for economic growth, which is the predicted output; ECS, KC, and TRD stand for energy consumption, real capita stock, and international trade, which are the explanatory variables.; wherever A_0 is the technological level and ε_t signifies the term for stochastic error which is presumed to normal distribution. $\gamma_1 - \gamma_4$ signifies the economic growth elasticity of energy consumption, real capita, labor, and international trade, correspondingly. Using the simultaneous equations listed below, the relationship between these three variables (trade, energy use, and output) is empirically studied.

$$lnYE_{it} = \gamma_0 + \gamma_1 lnECS_{it} + \gamma_2 lnTRD_{it} + \gamma_3 lnKC_{it} + \varepsilon_{it} \quad (5)$$

$$lnECS_{it} = \alpha_0 + \alpha_1 lnYE_{it} + \alpha_2 lnTRD_{it} + \alpha_3 lnFDV_{it} + \alpha_4 lnLF_{it} + \mu_{it} \quad (6)$$

$$lnTRD_{it} = \beta_0 + \beta_1 lnYE_{it} + \beta_2 lnECS_{it} + \beta_3 lnFDI_{it} + \pi_{it} \quad (7)$$

The influence of energy usage, trade, and capital stock on output had been observed via equation (5). For energy consumption, positive coefficient or elastic is expected, which is $\gamma_1 > 0$. This means that as economic activity rises, so does energy consumption, resulting in an increase in output. This implies that the two parameters are extremely intertwined. However, this result is influenced by domestic demand, international commerce, and investment. According to the literature, we should expect either positive or negative coefficient for γ_2. This is determined by the country's level of expansion. Likewise, Tiba and Frikha (2018) acknowledged that international trade can have a favourable impact on a country's growth and development. Capital stock (KC) is further controlled empowered by the works (Omri, 2013; Tiba et al., 2016). By including labor force (LF) a surrogate for population, and financial development (FDI), as contributory factors, the long-run impact of income and international trade on energy consumption was investigated using Equation (6). Similarly, utilizing equation (7), we expect strong positive income and energy consumption coefficients. This approves earlier research that has established the feedback concept (Zhang & Cheng, 2009). The body of knowledge on the association amongst trade and energy is vast and impressive, proving that trade has a positive impact on energy use (Narayan & Smyth, 2009; Tiba et al., 2016). According to the study of Islam et al. (2013), we also expect negative or positive elasticity for financial development (FDI). The simultaneous equations above show how the various independent variables can possibly influence the response variables.

The World Development Indicator (WDI) online database was used to obtain data for all the specified economic indicators. However, in accordance with Mensah et al. (2019) empirical research, we did an approximation on the physical capital stock (KC). Previous research that used gross capital formation used the physical capital stock (GCF). This is most referred to as investment in terms of physical capital stock. As a result, our research aims to assess the capital stocks of specific countries within the panel. The continuous inventory modus operandi established by the OECD (2009) could be used to assess a country's physical capital stock by accumulating its gross capital formation while maintaining the rate of depreciation constant (GCF). We assume that a country's physical capital stock (K_t) per year (t) consists of the sum of investment portfolios (I_t) in the same year (t) and accruing devalued stock in the preceding time (t-1), yielding the following relationship:

$$KC_t - (1 - \varphi)KC_{t-1} + I_t \tag{8}$$

Wherever φ symbolises the degree of depreciation for stationary capital stock. Existing investment and current capital stock (k) have an influence on physical capital stock growth rates, and the degree of depreciation, according to the previous computation.

According to the above equation, more investment will upshot in a higher physical capital stock if all other factors remain constant. On the other hand, the lower the present current capital stock of a country's current growth rate, the higher its value. The depreciation rate drives the growth of the physical capital assets. This suggests that through the evidence of the preceding capital stock (KC_{t-1}), assumed their current investment and depreciation rate, we can estimate each country's present physical capital stock.

Asafu-Adjaye et al. (2016) and Mensah et al. (2019) both used a 4% depreciation rate. Assume that the zero current capital stock (KC_b) is equivalent to the total of the opening investment and the recent investment post depreciation, resulting in a close approximation of the zero physical capital stock, denoted as KC_b with the following geometrical expression:

$$KC_b = I_b + (1 - \varphi)I_{b-2} + (1 - \varphi)^2 I_{b-2} \tag{9}$$

Furthermore, study assumed that the growth rate of investment is the same as the rate of long-run real GDP growth (ϑ), affirming it:

$$I_b = (1 + \vartheta)I_{b-1} \tag{10}$$

Factorising I_b from Equ. (9) we get:

$$KC_b = I_b\left[1 + \left(\frac{1-\varphi}{1+\vartheta}\right) + \left(\frac{1-\varphi}{1+\vartheta}\right)^2 + \dots\right] \tag{11}$$

The physical capital stock's expected original value is then computed using the equation below.:

$$KC_b = I_b\,\frac{1+\vartheta}{\vartheta+\varphi} \tag{12}$$

Lastly, the physical capital stock of a country is calculated using equation (8). Assuming we know the physical capital stock's initial value, long-run real GDP and the rate of depreciation.[1] Table 1 summarizes the definition of variables used in this study.

4. Research results

Our paper adopted the dynamic seemingly unrelated regression (DSUR) to estimate the long-run resistances of the factors and the long-term nexus between the variables on the predicted variable. The DSUR technique suggested by Mark et al. (2005) generates effective estimates in the evaluation of the cointegration vector in a cross-panel scenario albeit the widely used econometric models includes dynamic OLS (DOLS), the fully modified OLS (FMOLS) and generalized method of moment (GMM) in the literature.

The DSUR adopts the parametric method and uses seemingly unrelated regression (SUR) on various equation cointegration analysis to achieve asymptotically effective results. All framework equations' leads, and lagged distinctions govern the chance of serial correlation and endogeneity of errors. Furthermore, the dynamic SUR gives effective and efficient estimators with asymptotically normal distributions that are consistent even when T > N. The dynamic SUR estimator generates asymptotic efficiencies to other methods by introducing the long-run cross-sectional relationship of adjustment errors in the evaluation. However, by utilising the long-run cross-sectional association of the equilibrium errors in the estimates, the dynamic SUR estimator out-performs the other approaches in terms of asymptotic reliability.

The summary data aimed at the baseline series are presented in natural logarithmic form in Table 2. The largest mean value was foreign direct investment (20.5064), successive by labour force (proxy for total production) with a normal mean of (16.4548), economic growth (average mean = 7.9775), energy consumption (average mean of 7.3211), capital stock (average mean = 6.4926), and financial development (average mean = 3.4996). The anticipated Skewness and Kurtosis values of a sample data set must be zero and three, respectively, for it to be regularly distributed. The standard dispersal curves for income, energy consumption, capital stock, foreign direct investment inflow, and financial development are tilted to the left. The normal distribution curve shows that international trade and labor force tilted to be true. Except for international trade, skewness values are moreover fewer than zero or larger than zero (which is approximately equal to zero). Kurtosis estimations, on the other hand, are whichever fewer than three or larger than three. The findings demonstrate the existence of mesokurtic (kurtosis values around 3) leptokurtic (kurtosis values greater than 3) and platykurtic (kurtosis values greater than 3). Except for international trade, the designated variables are not normally distributed based on the criterion for normal distribution, leading us to adopt robust standard errors in the following analyses.

4.1. Cross-sectional dependence and heterogeneity

The study investigated for cross-sectional dependency and heterogeneity in our dataset and used the appropriate panel estimate methods. To assess the presence of homogeneity amongst the slope coefficients, we used the Pesaran and Yamagata (2008) approach. To test for heterogeneity, this method expands on Swamy (1970) technique by calculating the delta ($\tilde{\Delta}$) and the adjusted delta ($\tilde{\Delta}$). A null hypothesis of homogeneity; $H_o : \gamma_i = \gamma$ for all people in the sample, is compared to the substitute hypothesis of heterogeneousness, $H_1 : \gamma_i \neq \gamma_j$ for an encouraging fraction of the pairwise resistances $i \neq j$ by Pesaran and Yamagata (2008). This test provides robust results when $T > N$ (T is time dimension and N is numeral of cross-sections, and in small sample groups, it performs admirably. Since, the variables are varied among model countries, we will apply a variety of heterogeneous panel estimate approaches in which the variables fluctuate across cross-sections. Because there are individual variances among the selected variables, we additionally employ Pesaran's cross-sectional dependence (CD) test to seek for cross-sectional dependency within the designated panels. To give efficient empirical results, we also utilised a variety of robust to heterogeneity and cross-sectional dependency second-generation panel estimate models. The results of these tests are revealed in Tables 3 and 4, respectively.

4.2. Panel unit root test

Methods of first-generation panel unit root tests include the Levin-Lin-Chu (LLC) by Levin et al. (2002) and the Im Pesaran Shin (IPS) by Im et al. (2003). The second-generation test is grounded of cross-section independence and uses Pesaran's cross-sectionally augmented Dickey-Fuller (CADF), and cross-sectionally augmented IPS (CIPS) tests to estimate the cointegration features of the selected variables (not including for common time effects). The CADF and CIPS tests account for the dependency that may exist in various forms and degrees across the various components in the panel.

Multiple panel cointegration estimate systems that are robust to heterogeneousness and cross-sectional independence should be explored given the panels' cross-sectional dependence and heterogeneousness. This will limit the danger of biased estimate and deliver robust outcomes in the case of cross-sectional dependency and heterogeneity inside the panel. To explore the being of stationarity between the parameters, we used Pesaran's CADF and CIPS methods to cointegration.

Table 2. Descriptive statistics of the variables

Panel A: full Panel

Data	*lnYE*	*lnTRD*	*lnECS*	*lnKC*	*lnFDI*	*lnFDV*	*lnLF*
Mean.	7.9775	7.7766	7.3211	6.4926	20.506	3.4496	16.454
Median.	8.0197	7.7105	7.5501	6.6271	20.734	3.5628	16.136
Maximum.	10.950	12.236	9.4259	9.6896	26.396	5.5344	21.033
Minimum.	4.9271	3.9422	4.7491	2.3296	9.2103	−7.1026	13.141
Standard Deviation.	1.3755	1.6506	0.9879	1.4439	2.2712	1.0238	1.7628
Skewness.	−0.039	0.0529	−0.250	−0.229	−0.410	−3.2851	0.6106
Kurtosis.	2.0687	2.4314	2.3667	2.2725	3.4042	31.8848	2.8010
Jarque-Bera.	39.310	15.053	29.347	33.333	36.447	39,487.3	68.881
P-value.	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000
Obser vations	1080	1080	1080	1080	1080	1080	1080
Number of Countries	45	45	45	45	45	45	45

Panel B
High income countries

Data	*lnYE*	*lnTRD*	*lnECS*	*lnKC*	*lnFDI*	*lnFDV*	*lnLBF*
Mean	2.1275	2.0737	1.9522	1.7313	5.4683	0.9198	4.3879
Median	2.1385	2.0561	2.0133	1.7672	5.5292	0.9500	4.3031
Maximum	2.9200	3.2630	2.5135	2.5838	7.0390	1.4758	5.6090
Minimum	1.3138	1.0512	1.2664	0.6212	2.4560	1.8940	3.5044
Standard Deviation	0.3668	0.4401	0.2634	0.3850	0.6056	0.2730	0.4700
Number of Countries	12	12	12	12	12	12	12

Panel C
Other countries

Statistics	*lnYE*	*lnTRD*	*lnECS*	*lnKC*	*lnFDI*	*lnFDV*	*lnLBF*
Mean.	5.8500	5.7026	5.3685	4.7610	15.0378	2.5294	12.066
Median	5.8707	5.6542	5.5365	4.8598	15.2053	2.6125	11.833
Maximum	8.0300	8.9732	6.9121	7.1054	19.3572	4.0585	15.424
Minimum	3.6129	2.8908	3.4826	1.7083	6.75400	5.2085	9.6371
Standard Deviation	1.0087	1.2102	0.7243	1.0587	1.6654	0.7507	1.2925
Number of Countries	33	33	33	33	33	33	33

Note: *YE*, *TRD*, *ECS* represent economic growth, international trade, energy consumption respectively, *KC* represent real capita stock. The World Bank catalogs world's countries into income group: high, higher middle, lower middle and low income grounded on Gross National Income per capita (current US$) of countries. This study selected 12 high income countries including, Korea Republic, Italy, Hungary, Greece, Cyprus, Malta, Portugal, Romania, Saudi Arabia, Uruguay, Turkey, and Singapore, and combined 33 other countries under higher middle, lower middle and low: Kenya, Jamaica, Indonesia, India, Guatemala, Ghana, Gabon, Egypt, Ecuador, Dominican Republic, Costa Rica, Congo Republic, China, Chile, Bulgaria, Botswana, Bolivia, Benin, Malaysia, Mongolia, Morocco, Nigeria, Pakistan, Panama, Peru, Philippines, Senegal, Sri Lanka, Sudan, Tanzania, Thailand, Togo, and Tunisia.

Table 5 shows the outcomes of the CADF and the CIPS tests. We conclude that the variables are non-stationary at the level, but stationary at the first difference, based on the findings (1). This explains why the variables have a distinct order of cointegration, giving us confidence in our decision to use the panel technique to evaluates the long-run cointegration association amongst the zero constructs.

4.3. Results of panel cointegration test

Albeit the first-generation cointegration tests are widely employed in literature. Cross-sectional dependence is not a problem for them. When examining cointegration links, omitting to justify for cross-sectional independence between the variables provides false evidence. We thus use Westerlund and Edgerton (2007), LM boostrap cointegration test to see if there are any integrative features amongst the variables in the long run. The boostrap cointegration strategy will address problems related to cross-sectional reliance and homogeneity which is superior to other cointegration estimation. Likewise, the test adopts a null hypothesis of cointegration. The outcomes of the cointegration results are provided in Table 6. Based on the outcomes, our paper can conclude that the selected variables remain integrated in the long run for all panels. This concludes that, there is evidence of long-term association between the various parameters. In particular, the outcomes of the cointegration nexus between factors are right, effective, and robust.

5. Empirical findings and discussions

We used panels of simultaneous equations via the dynamic unrelated regression model estimator to explore the triangular relations between energy use, international trade, and income (Table 7–9). Our estimation test examines the nexus between variables in the long run. Since panel data are integrated, this test is efficient and resilient to cross-sectional dependency and homogeneity problems at the same order I (1). To lessen the problem of omitted variable bias, we thus added capital stock, financial development, foreign direct investment, and labor force as control factors to our model. Albeit working with cross-sectional panels, we employed series of second-generation data panel estimations that remain robust to cross-sectional dependency prior to estimating long-run panel cointegration estimates. This helps in selecting the best methods grounded on the variable's characteristics. The results of the Pesaran-Yamagata heterogeneity and Pesaran cross-sectional dependency (CDY) tests demonstrate signs of heterogeneity and cross-sectional independence which confirm with Sun et al. (2019), highlights the interconnection of numerous factors across countries. Furthermore, we employed two different second-generation unit root test approaches (CSADF and CSIPS) to study the integrating properties of the selected variables when all of them have a unique order of stationarity.

5.1. Results on the triangular association amongst energy consumption, trade openness and economic growth

Table 7 reports estimation highlights and empirical evidence from the various models for full sample. From model 1, energy consumption is positive and significant at 1% on economic growth. Positive effect confirms an upsurge in energy will significantly improve the economic growth of countries by about 0.7374. This result is consistent with Yıldırım et al. (2014). With respect to trade, there is evidence of positive and significant at 1% level on economic growth which suggest that trade openness increase the growth of countries as they extend their economies globally. The results, however, confirm the results of Menyah et al. (2014); and Nasreen and Anwar (2014).

From model 2, at 1%, economic growth has a large positive and significant impact on energy usage. The positive effects of economic growth show that rising economic growth leads to 0.0218 percent increase in energy consumption per capita. Similarly, trade has a greater impact on energy usage (1 percent significant level). This suggests that 1% upsurge in trade openness rises energy consumption per capita through 0.5395% in countries. Countries advanced by opening to the outside world as globalization is still expanding. Therefore, the upsurge in economic activities to meets the rising demands necessitates higher energy resources to power the numerous production sectors. Based on the results, energy use will increase significantly as countries

Table 3. Pesaran-yamagata homogeneity results

Model	Test	All countries Data/P-value	High Income Data/P-value	Other Income Data/P-value
Model1	$\tilde{\Delta}$	1860 (0.000) ***	290.5 (0.000) ***	740.5 (0.000) ***
	$\tilde{\Delta}_{Adj}$	41.77 (0.000) ***	20.44 (0.000) ***	28.46 (0.000) ***
Model2	$\tilde{\Delta}$	1817 (0.000) ***	275.3 (0.000) ***	735 (0.000) ***
	$\tilde{\Delta}_{Adj}$	35.3 (0.000) ***	16.81 (0.000) ***	25.05 (0.000) ***
Model3	$\tilde{\Delta}$	1972 (0.000) ***	352.2 (0.000) ***	716.9 (0.000) ***
	$\tilde{\Delta}_{Adj}$	31.02 (0.000) ***	22.4 (0.000) ***	16.12 (0.000) ***

Note: The table shows the results from Pesaran-Yamagata Homogeneity Test on the presence of homogeneity between the slope coefficients. We test for the P value (robust standard error) for all countries, High income, and other income respectively. ***, **, * indicate significance at 1%, 5% and 10% level, $\tilde{\Delta}$, and $\tilde{\Delta}_{Adj}$. Signify delta and adjusted delta correspondingly.

Table 4. Results of cross-sectional dependence test

		All countries		Higher Income		Other Income	
Test	**Run**	**Data**	**P-values**	**Data**	**p-values**	**Data**	**P-values**
CDY	$lnYE_{it}$	142.608	0.000***	53.838	0.000***	88.144	0.000***
	$lnTRD_{it}$	145.422	0.000***	53.755	0.000***	88.231	0.000***
	$lnECS_{it}$	24.787	0.000***	5.778	0.000***	21.126	0.000***
	$lnKC_{it}$	133.294	0.000***	50.55	0.000***	80.198	0.000***
	$lnFDI_{it}$	99.911	0.000***	34.635	0.000***	64.509	0.000***
	$lnFDV_{it}$	50.494	0.000***	24.545	0.000***	25.212	0.000***
	$lnLF_{it}$	16.582	0.000***	−1.135	0.256	18.723	0.000***

Note: The table shows results from the cross-sectional dependence test to inspect the presence of cross-sectional dependency within the selected panels. *YE*, *TRD*, *ECS* represent economic growth, international trade, energy consumption respectively, *KC* represent real capita stock. ***, **, * indicate significance at 1%, 5% and 10% level, CDY is cross-sectional dependency.

open. Results from model 3 found economic growth effect to be positive and designates that 1% increase in excess supply of domestic commodities increase trade openness by 1.0135% of countries. Likewise, energy consumption shows positive and significant influence on trade for all countries. The coefficient suggests that upsurge in energy demand will power to a rise in global trade. The results confirmed the findings of Lean and Smyth (2010).

In addition, 1% increase in capital stock expand economies of all countries. This suggests that increase to improve the capital stock of countries increase the economic performance of the coefficient, consistent to the literature (Omri, 2013; Thaddeus et al., 2021; Tiba & Frikha, 2018). Thaddeus et al. (2021) found gross capital formation is one of the most significant and powerful determinants of Cameroons economic growth.

However, financial development is positive and significantly related to energy consumption indicating that each rise in financial development across countries increases energy demand by 0.0313 percent of financial development. Similarly, the findings show that labour and energy use have a negative and significant association (significance level at 1 percent). All things being equal, a proportion surge in countries population leads to the reduction in energy demands for households and industries. In fact, the result is consistent with Omiri and Kahouli (2014). Furthermore, results from model 3 indicates negative impact of FDI on trade at 1% significant level. The coefficient magnitude specifies that, FDI increases will reduce international trade. Most foreign firms are moving towards cheaper labour and energy supply areas, hence foreign exchange outflows tend to surpass FDI inflow, all things being equal. The results support the outcomes of Sun et al. (2019).

Overall, our findings support indication of feedback hypothesis between trade and growth, energy, and growth (Ben Aïssa et al., 2014; Tiba et al., 2016). Evidence of bidirectional relationship between trade and energy consumption is also observed. Finally, evidence of significant association amongst energy and growth in the long run is observed. These outcomes suggest that trade liberation will make it conceivable for domestic firms to contend with far-off trades for market share thus generate rivalry among inland products. To gain the full benefits of trade and economic growth, effective utilization of energy resources is essential, to explore new and diverse energy sources.

5.2. Findings by income level

5.2.1. Results for high income countries

Table 8 reports estimation highlights and empirical evidence from high-income countries. With respect to model 1, results indicate larger influence of trade on economic growth by 1% significant level. The coefficient confirms the existence of positive elasticity amid trade and incomes, consistent with the results of Shabaz and Lean (2012). Likewise, energy is positive and significant on the growth of Korea Republic, Italy, Hungary, Greece, Cyprus, Malta, Portugal, Romania, Saudi Arabia, Uruguay, Turkey, and Singapore. The positive coefficient indicates 1% upsurge in energy consumption will promotes economic growth through 0.2747%. Our outcomes confirm the findings of Apergis and Payne (2010).

In model 2, the large and positive impact of growth on energy consumption reveals that a 1% upsurge in output leads to a 0.2726 percent upsurge in energy consumption similar to economic growth elasticity. The results corroborate those of Yildim, Sukruoglu and Aslan (2004) and Yilanci (20032003). Furthermore, we find trade to be beneficial to real energy use and significant at the 1% level. Increased trade openness results to a 0.5560 percent rise in energy consumption, according to the positive coefficient of trade.

In model 3, economic growth is significant and positive to trade suggesting that, developed countries increase input would resolve the problems of excess supply by exporting to further nations to receive foreign exchanges. However, a 1% rise in output results to a 0.5651% increase in trade according to the elasticity growth. The outcomes of Ben Aïssa et al. (2014) is confirmed. Similarly, energy usage has a greater favourable impact on growth. The effect is substantial at the 1% level, implying that a rise in energy consumption fallouts to an upsurge in trade volume of 0.6516 percent when all other factors are equal.

Furthermore, we find an opposite influence from financial development on energy consumption albeit 1% significant level. This suggests that as financial development, liquidity, and other rises, so does energy consumption ground on financial development coefficient. However, results (*model 2*) indicate labour force positively and significantly related to energy consumption. This suggests that a 1% rise in population will result in a 1% increase in energy consumption equivalent to the size of population elasticity. Finally, our findings from model 3 specifies negative and significant effect of FDI on trade. The negative coefficient confirms that, 1% increase in FDI leads to reduce trade by 0.067%.

5.2.2. Results for other countries

Table 9 displays the empirical results from the various equations for emerging countries. With respect to model 1, trade exerts positive and significant influence on income. Trade openness increase at 1% leads to an increase in income by 0.2332% of elasticity of trade. The outcome is in line with the outcomes of Shahbaz et al. (2018). Likewise, energy consumption is confident and

Table 5. Results of CADF and CIPS unit root test

Test	Run	All countries		Higher Income		Other Incomes	
		Level	First difference	Level	First difference	Level	First difference
CADF	$lnYE_{it}$	−2.369	−3.428 ***	−2.435	−2.792 ***	−2.183	−4. 513 ***
	$lnTRD_{it}$	−2.305	−3.569 ***	−2.143	−3.026 ***	−2.368	−4.781 ***
	$lnECS_{it}$	−2.435	−3.256 ***	−2.343	−3.047 ***	−2.411	−4.535 ***
	$lnKC_{it}$	−2.199	−3.456 ***	−2.400	−3.196 ***	−2.387	−3.116 ***
	$lnFDI_{it}$	−2.457	−3.539 ***	−1.063	−3.345 ***	−2.380	−4.563 ***
	$lnFDV_{it}$	−1.915	−3.367 ***	−2.242	−3.392 ***	−2.010	−4.330 ***
	$lnLF_{it}$	−1.476	−3.879 ***	−2.181	−3.242 ***	−1.704	−4.089 ***
CIPS	$lnYE_{it}$	−2.374	−4.240 ***	−2.248	−3.775 ***	−2.746	−4.513 ***
	$lnTRD_{it}$	−2.747	−4.563 ***	−2.491	−4.638 ***	−2.799	−4.781 ***
	$lnECS_{it}$	−2.680	−4.827 ***	−3.262	−5.104 ***	−2.411	−4.535 ***
	$lnKC_{it}$	−2.264	−4.125 ***	−2.224	−3.888 ***	−2.649	−4.422 ***
	$lnFDI_{it}$	−2.655	−4.751 ***	−3.973	−5.451 ***	−2.594	−4.563 ***
	$lnFDV_{it}$	−2.201	−4.243 ***	−1.887	−3.669 ***	−2.010	−4.330 ***
	$lnLF_{it.}$	−2.321	−3.336 ***	−2.564	−3.427 ***	−1.704	−2.857 ***

Note: *The table shows CADF and CIPS unit root test results. YE, TRD, ECS represent economic growth, international trade, energy consumption respectively, KC represent real capita stock. ***, **, * indicate significance at 1%, 5%, and 10% level. CSADF, and CSIPS are cross-sectional ADF and IPS, i.e., ADF- autoregressive Dickey-fuller and IPS- Im Pesaran Shin.*

Table 6. Bootstrap panel cointegration

Model	Panels	G_t	G_a	P_t	P_a
		Robust/ p-values	Robust/ p-values	Robust/ p-values	Robust/ p-values
Model1	All counties	−2.432(0.000) ***	−7.925(0.000) ***	−13.865 (0.010) ***	−6.848(0.010) ***
	Higher income	−2.301(0.010) ***	−7.428(0.020) ***	−8.807(0.010) ***	−6.509(0.020) **
	Other income	−2.171(0.000) ***	−5.339(0.000) ***	−9.608(0.010) ***	−4.152(0.010) ***
Model2	All countries	−2.847(0.000) ***	−6.053 (0.300)	−20.382 (0.000) ***	−7.732 (0.000) ***
	High income	−3.391(0.000) ***	−7.424 (0.090) *	−14.591 (0.000) ***	−9.385 (0.010) ***
	Other income	−2.517(0.000) ***	−5.221 (0.690)	−14.446 (0.000) ***	−6.772 (0.060) *
Model3	All countries	−2.271 (0.000) **	−6.555 (0.050) **	−14.619 (0.010)***	−6.720 (0.010) ***
	High income	−1.948 (0.076) *	−6.021 (0.118)	−11.462 (0.018)**	−8.222 (0.026) **
	Other income	−2.467(0.000) ***	−6. 879 (0.050) **	−10.360 (0.070)**	−6.132 (0.060) *

Note: The table shows Boostrap panel cointegration results to address problems related to cross-sectional reliance and homogeneity for all countries, High and Other income respectively. ***, **, * specify significance at 1%, 5% and 10% level. G_t and G_a represents group statistics, P_t and P_a represents panel statistics. Robust p-value represents robust standard error.

Table 7. DSUR results for full sample

	Dependent Variables		
	$lnYE_{it}$	$lnECS_{it}$	$lnTRD_{it}$
Independent Variables.	Model1	Model2	Model3
$lnYE_{it}$	-	0.0218 (0.00) ***	1.0135 (0.00) ***
$lnECS_{it}$	0.7374(0.00) ***	_	0.2492 (0.00) ***
$lnTRD_{it}$	0.3715(0.00) ***	0.5395 (0.00) ***	_
$lnKC_{it}$	0.0851(0.00) ***	-	_
$lnFDV_{it}$	_	0.0313(0.00) ***	_
$lnLF_{it}$	_	−0.0091(0.00) ***	_
$lnFDI_{it}$	_	-	−0.0102 (0.00) ***

Note: The table presents the DSUR results for 45 Countries sampled for the study. *YE*, *TRD*, *ECS* represent economic growth, international trade, energy consumption respectively, *KC* represent real capita stock. ***, **, * indicate significance at 1%, 5% and 10% level, p-value is provided in the parathesis.

Table 8. DSUR (high-income countries) results

	Dependent Variables		
	$lnYE_{it}$	$lnECS_{it}$	$lnTRD_{it}$
Independent Variable	Model1	Model2	Model3
$lnYE_{it}$	-	0.2726 (0.000) ***	0.5651 (0.000) ***
$lnTRD_{it}$	0.5134 0.000 ***	0.5560 (0.000) ***	-
$lnECS_{it}$	0.2747 0.000 ***	-	0.6516 (0.000) ***
$lnKC_{it}$	0.2173 0.000 ***	-	-
$lnFDV_{it}$	-	−0.0677(0.000) ***	-
$lnLF_{it}$	-	0.0361(0.000) ***	-
$lnFDI_{it}$	-	-	−0.0239 (0.000) ***

Note: The presents the DSUR results for high income countries. *YE*, *TRD*, *ECS* represent economic growth, international trade, energy consumption respectively, *KC* represent real capita stock. ***, **, * indicate significance at 1%, 5% and 10% level, p-value is provided in the parathesis.

Table 9. DSUR (other income countries)

	Dependent Variables		
	$lnYE_{it}$	$lnECS_{it}$	$lnTRD_{it}$
Independent Variables	Model1	Model2	Model3
$lnYE_{it}$	-	0.0162 (0.000) ***	0.9462 (0.000) ***
$lnTRD_{it}$	0.2332 (0.000) ***	0.7442 (0.000) ***	-
$lnECS_{it}$	0.3751 (0.000) ***	-	0.5802 (0.000) ***
$lnKC_{it}$	0.0700 (0.000) ***	-	-
$lnFDV_{it}$	_	0.0093 (0.000) ***	-
$lnLF_{it}$	_	−0.0090 (0.000) ***	-
$lnFDI_{it}$	_	-	0.0040 (0.000) ***

Note: The table presents the Dynamic seemingly unrelated regression results for other income countries. *YE*, *TRD*, *ECS* represent economic growth, international trade, energy consumption respectively, *KC* represent real capita stock. ***, **, * indicate significance at 1%, 5% and 10% level, p-value is provided in the parathesis significant on economic growth which suggests that 1% upsurge in energy of emerging countries leads to increase economic growth by 0.3751%. From model 2, economy growth positively and significantly affects energy consumption. Economy growth increase fallouts to upsurge in per capita energy consumption at coefficient of growth elasticity. Similarly, the effect of trade found to be positive and indicates significant increasing in economic actions to chance the demands in both domestics and foreign markets.

With respect model 3, we find economic activities positive and significant on trade at 1% significant level. This proposes that emerging countries growth increase leads to increase in international trade by large 0.9462%. Our findings further indicate energy consumption found to have larger impacts on trade for developing countries. This implies that, 1% rise in energy demand results to rise in trade volume via about 0.5802% in developing countries within the Belt and Road region. In addition, the results find financial development to be positive and significant on energy demands. Moreover, model 2 confirms the presence of inverse significant effect from labour force on energy consumption of developing nations. Interestingly, FDI has a big and favourable impact on trade. This suggests that, increasing FDI will promotes international trade of developing countries with the region. Ultimately, studies indicated signal significant positive link between capital stock and economic growth. Capital stock development will stimulate the growth of an economy, suggesting that, 1% level of capital stock will result in a proportional increase in actual GDP growth equal to the capital stock coefficient.

6. Conclusion

Using the dynamic seemingly unrelated regression in simultaneous equation framework, we examine the triangular association between energy use, trade openness, and economic growth for 45 countries during the period of 1991 and 2014. Our findings show the selected parameters (energy, trade, and growth) take a bidirectional link in the long run. However, interdependence occurs amongst the three variables. Energy policies that increase economic activity (output) while conserving energy drive favourable influence on economic growth. Therefore, countries should place a high priority on diversifying their present energy production path, focusing mostly on renewable energy sectors. This will aid in the preservation and maintenance of a green economy, as well as reduce concerns about price fluctuations in oil and natural gas on the international market because of demand and supply tremors. Household and business energy conservation efforts, on the contrary, will hinder economic growth. Our feedback linking amid economic growth, and energy consumption reveals that both variables are interrelated, meaning that greater effort should be placed into developing environmentally friendly industrial practices and lowering non-renewable energy use. This will increase economic growth while cutting carbon emissions.

When formulating energy consumption policies, policymakers should consider both sustainable growth and environmental quality. To ensure that energy consumption is efficient, and that the percentage of green energy consumed in their region increases. This will help to mitigate the long-term environmental consequences of a high reliance on traditional energy sources both inside their area and globally. Energy conservation measures aimed at ensuring optimal energy use will also have a detrimental influence on trade volume due to the feedback effect amongst energy consumption and foreign trade. Because of the bidirectional association amongst international trade and income, trade with the entire ecosphere is expected to increase the growth of an economy. The Country and world Trade Organization (WTO) has performed research that shows the advantages that countries gain by opening to the rest of the world. Innovation transfer, comparative advantages, and economies of scale assist emerging countries (poor and middle-income countries) the most. Developing countries can advance ecological industrial technology and the technical know-how to advance and succeed their renewable energy sectors with the help of advanced economies. In the long run, this will boost economic growth (all things being equal). In the same way, policies aimed at boosting economic growth will boost foreign trade. Countries should implement clean production technology and build their clean energy sectors in comparison to non-renewable energy in this circumstance. International trade will grow in the long run as energy consumption helps to link countries through trade. By providing fiscal incentives for green technology research and use, as well as stimulating investment in renewable energy businesses, international trade will grow.

We encountered some caveats creating avenues for further studies despite the achieved aims of our study. The current study used data from 1991 to 2014, hence calling for researchers to update the data from 2014 to 2022 when data is available to examine the dynamic nexus between energy consumption, trade and economic growth and could further extend the sample size of the economies used. Other economic variables, such as carbon emissions and urbanization, could be added in future studies to lessen omitted variable bias and the degree of international commerce when selecting trade data. Furthermore, determining whether the Environmental Kuznets Curve (EKC) exists will aid policymakers in developing successful environmental regulations.

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Endnotes

1. Concerns about heterogeneity and cross-sectional reliance are a major drawback of panel data analysis. Nonetheless, with small samples, panel data, as opposed to times series and cross-sectional data, gives a higher degree of freedom and lower volatility. Newly developed econometric approaches, on the other hand, recognize either heterogeneity or cross-sectional dependency, negating the previously mentioned drawbacks. We divide the economies into two income groups (high- (developed) and other- (developing) economies) for more rigorous empirical analysis.

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