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Trade and consumption of energy varieties: Empirical analysis of selected West Africa economies

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ABSTRACT

This paper examined the relationship between consumption of energy varieties (total, electricity and road transport) and trade (export and import) in selected West African countries. Data spanning 1971 to 2010 was used to estimate vector error correction models (VECM) for 6 countries based on data availability.

Empirical analysis showed that there is insignificant linkage between consumption of energy varieties and export of Benin. However, there is a one-way positive linkage running from energy varieties to import of the country. For Cote d'Ivoire, energy varieties have insignificant relationship with export and import. However, while inverse relationship runs from export to both electricity and road transport energy consumption positive (direct) association runs from import to total energy and transport energy consumption. With respect to Ghana, positive causality runs from electricity and road transport energy consumption to export. However, there is a significant positive feedback effect between import and electricity as well as road transport energy consumption. For Nigeria, there is a significant positive link running from both electricity and road transport energy consumption to export and import. Senegal's case suggests a bi-directional inverse linkage between export and total energy consumption. For Togo, both export and import are insignificantly linked with energy use.

These mixed findings generate different policy implications across the selected West African countries, which are well articulated in the paper.

Contents

1. Introduction

The role of trade and energy in economic growth and development cannot be overemphasized. Available data from the World Bank [1] revealed that, over the past 4 decades, many West African countries witnessed rapid growth in income and energy

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production/consumption as well as trade. However, the dynamic effects of trade and energy on economic development have led to some challenges in policy making and debates. The Challenges in policy making and debates arose from the need to expand trade and the quest for energy conservation due to the nonrenewable nature of some energy sources. This informs the need for research to unravel the link between the two important subjects.

The relationship between energy and trade is a significant area of research on many grounds. For instance, if energy consumption Granger causes exports or imports, it implies that any drops in energy use arising from government policy such as energy conservation polices, will bring about reduction in exports or imports flows and hence, dampens the gains from trade. Alternatively, promotion of economic growth through increased trade facilitated by trade liberalization policies will be jeopardized by energy conservation policies. However, a unidirectional causality from exports or imports to energy will not make energy conservation policies at odd with trade liberalization policies articulated to increase economic growth.

Despite the fact that there is a huge literature on the relationship between energy consumption and national output (GDP) as will be seen in the literature review section, and even much more texts focusing on the association between GDP and exports [2–4] very little has been explored on the connections between trade and energy. This important fact was first made by [5] and subsequently reechoed by [6,7]. The fact that very few studies [5–12] exist on this subject is another confirmation.

This present paper differs from the earlier ones in a numbers of respects. First, this paper focuses on West Africa where (to our knowledge) no such study exists and therefore there appears to be little or no empirical basis for policy. Second, since it is possible that consumption of different energy sources produce alternative impacts on export and import, therefore a more disaggregated analysis is better for policy analysis (use of different energy variables instead of only one variable employed in earlier studies). Energy required for export production (electricity which is majorly hydro power) may be different from that required for transportation to the markets (transport sector energy such as gasoline, diesel and charcoal). Similarly, different energy may be required for various import purposes, and besides the welfare effect of different energy sources is diverse. This leads to the use of total energy consumption, electricity consumption and the transportation sector energy consumption in this paper. Trade facilitation involves a well functioning banking system, airports and transportation network which consume energy. About 30% of global energy consumption is traced to the transportation sector [7,13].

Third, this paper is motivated by the idea that a good and policy oriented empirical analysis should be based on a solid and clear theoretical framework. This point was earlier made by [7] who stated that the earlier analyses were ad hoc. Thus, instead of approaching the issue from energy demand theory only, we improved upon the significant work of [6,7] by considering both energy demand and trade theories so as to see the clear energy consumption-trade nexus. We also account for the peculiarities of West African economies in terms of dependency on energy consumption and trade such that we use relative price (real exchange rate) instead of absolute energy price employed in earlier studies[2]. Fourth, we conducted individual country level analysis to see whether there is heterogeneity of the interactions of the variables of interest across West African countries. Heterogeneity issue is also addressed by ensuring that our sample covers the two main West Africa's economic sub-groups (WAEMU and WAMZ) as well as income groups[3]. This is necessary in order to see whether it will be advisable to harmonise policy at regional (such as ECOWS) and sub-regional levels (such as within WAEMU or WAMZ).

The rest of this paper is organized as follows; section II is on the background information (stylized facts) on trade and energy consumption in the Selected West African countries, while section III is on literature review. The theoretical framework and methodology are discussed in section IV, while section V presents and discusses the empirical results, and section VI is on policy analysis, and conclusions.

2. Energy consumption and West Africa's trade

2.1. Trend and composition of energy consumed in West Africa

Per capita energy consumption in West African countries for which data is available is displayed in Fig. 1a–c. In comparative terms, per capita total energy consumption was higher in Nigeria and lower in Senegal during the period. The level of total energy consumption reflects the size of the economies and their levels of industrialisation. However, in relative terms, per capita electricity consumption was higher in Ghana, followed by Cote d'Ivoire, and lower in Benin, followed by Nigeria. Comparatively, per capita road sector energy consumption in the 1970s and 1980s was higher in Cote d'Ivoire and lower in Nigeria and Senegal. But in the 1990s and 2000s, the reverse was the case, as it was lower in Cote d'Ivoire and higher in Benin.

2.2. Trend and structure of West Africa's trade

Figs. 2 and 3 present export and import of goods and services across the selected West African countries. In comparative terms, Nigeria's export was the highest among the countries (multiples), while Benin and Togo witnessed lower values. Similarly, in relative terms, Nigeria's import was the highest, while Togo and Benin also recorded lower values.

3. Literature review on the link between trade and energy

A review of literature reveals that there have been a number of studies on the economic related energy issues, which can be divided into four broad areas. The first of these broad areas focused on the relationship between energy consumption and output/income-GDP. The second group is on the link between energy consumption, foreign direct investment (FDI) as well as financial development, while the third category analyses the energy embodied in trade. The fourth covers the link between energy consumption and trade

With respect to the spread of studies reviewed across the globe, there are economic related energy studies at the global and regional levels as well as by income level [12,14–21]. There are also cross-country analysis among the studies reviewed [12,22–28]. A number of country specific studies which have been done include those for Taiwan [29,30], Lebanon [31], China and India [32–36]. Other studies include those on Malaysia [37,8,9], Russia [38], Brazil [39], Pakistan [40–42], Greece [43,44], Indonesia [45,46], USA [47], Turkey [10], and Canada [48]. Some studies have been done for some notable groups such as Middle East and North Africa—MENA [49], OECD [50,11],

[2] Some earlier studies used Consumer price index because energy price is not available.

[3] WAEMU mean West African Economic and Monetary Union; WAMZ mean West African Monetary Zone; ECOWAS mean Economic Community of West African States. In terms of income level, Nigeria, Cote d'ivoire and Ghana have higher income than other countries in the sample.

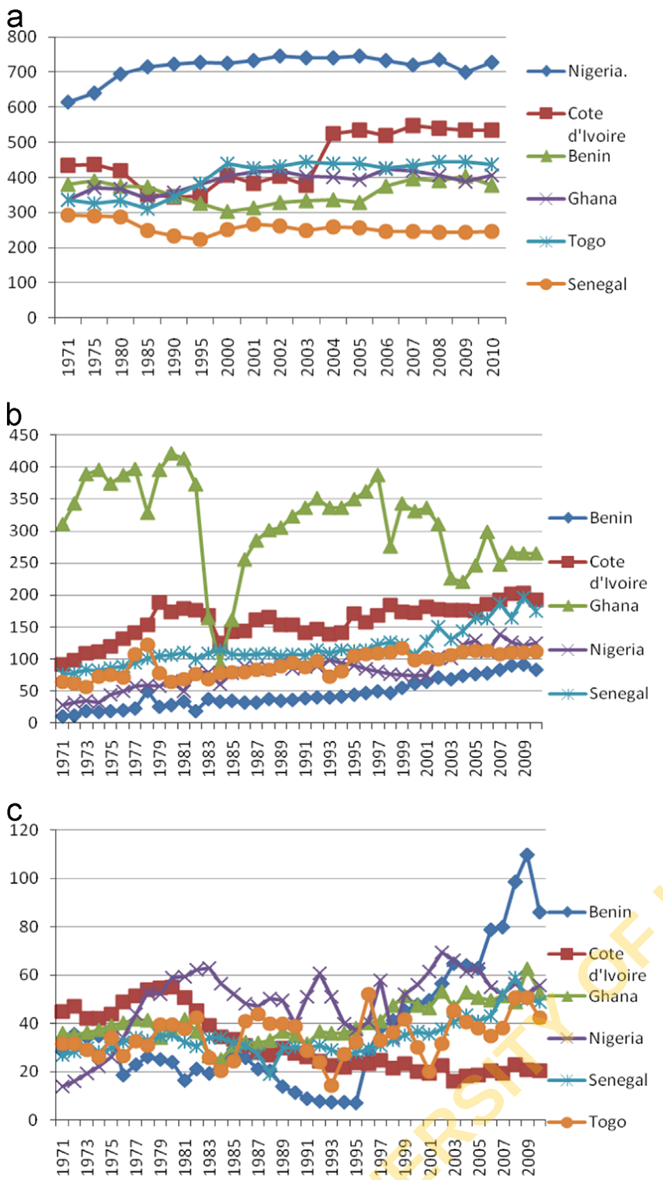

Fig. 1. (a) Total energy consumption by West African countries (kg/capita). (b) Electricity consumption by West African countries (kg/capita). (c) Road sector Energy consumption by West African countries (kg/capita).

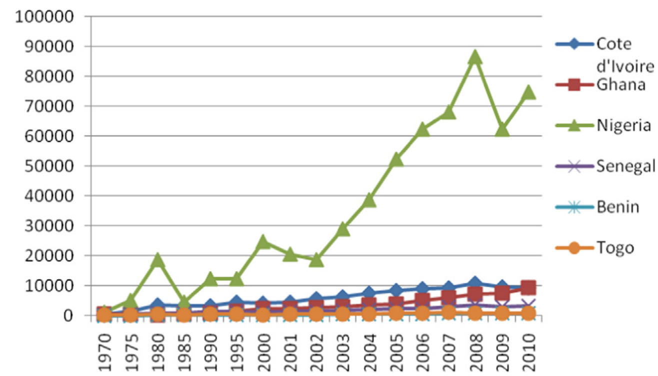

Fig. 2. Exports by West African Countries (US $ million).

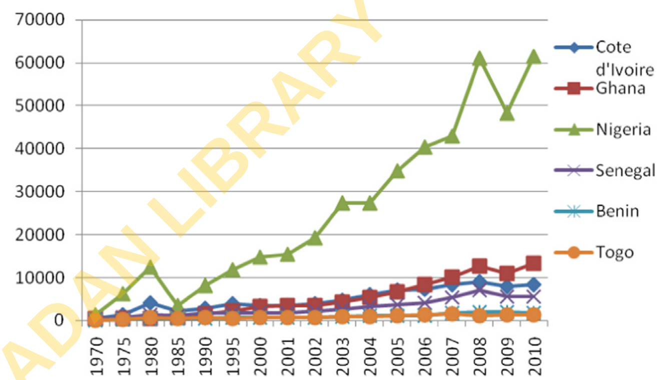

Fig. 3. Imports by West African Countries (US $ million).

Emerging European Countries—EEC [51], Golf Council Countries—GCC [52], and BRIC [53]. It is obvious that few studies exist for Africa, while little or no study focused on West African countries.

Although different types of energy were analysed, the literature is very huge on the link between energy and output (GDP) or economic growth (GDP growth)[4]. These studies employed different methodological approaches and obtained mixed findings. For instance, a unidirectional causality was found between GDP and energy consumption in GCC [52], USA [47], Lebanon [37] and Indonesia [46]. In the Middle Eastern countries, [25] found that, increase in energy consumption leads to significant positively impact on GDP, while [41] also reported similar findings for Pakistan. In contrast, a bi-directional causality was observed in the case of EEC [51]; OECD [50], Asian [18,29], G7 [14]. Other places in which a bi-directional link was reported include South America [17], China [34,35], Pakistan [42] and Central America [16]. In the case of MENA, [49] showed that there is no relationship between economic growth and energy consumption.

There is evidence that renewable energy and non-renewable energy have long run effect on economic growth in Latin American countries [54]. But [55,56] found that, while renewable energy (RE) and non renewable energy (NRE) in emerging market economies and Central America have a bi-causal link with economic growth in the long run, this is not the case for NRE in the short run. These inconsistent findings may be due to some reasons including different methodological approaches used in the various studies and different levels of energy consumption and economic activities in the different countries analysed. There is an indication that the link between GDP and energy consumption is independent of the cointegration method employed in the meta-analysis [57]. In a cross country panel analysis [22] showed that, in about 60% of the countries studied, energy consumption impact economic growth.

Some studies have established connections among energy consumption, FDI and financial development [38,39,20,40,45]. In a country specific analysis, [39,39] reported bi-directional causality between CO_2 emission and economic growth in both Brazil and Russia respectively, while obtaining a unidirectional link for Energy consumption and FDI among Brazil, Russia, India and China (BRIC). In the case of [20], estimates showed that FDI and Financial Development has a unidirectional relationship with energy consumption in both middle and high income countries, while in low income countries GDP and financial development produce positive impact on energy consumption. However, FDI and relative prices showed a negative relationship with energy consumption. In the same vein, [45] documented a unidirectional link between Energy consumption and financial development in Indonesia. The study

[4] Different types of energy analysed in the various studies include total energy, electricity production or consumption, natural gas, renewable energy, non-renewable energy, biomass, fuel wood, solar and wind.

also revealed a bi-directional causality between economic growth and CO_2; and between FDI and CO_2. Similarly, [40] indicated that financial development had significant positive effect on energy consumption via the channel of economic growth. Some studies have also analysed the energy embodied in trade, which include [58–60]; Amador, [61,62].

Since this current paper focuses on the causal link between energy consumption and trade, therefore the studies in the fourth group which made significant contributions to knowledge are reviewed in detail below.

The relationship between energy consumption, output and trade was examined by [5] in a panel of six Middle Eastern countries of Iran, Israel, Kuwait, Oman, Saudi Arabia, and Syria. They found that, in the short-run, Granger causality runs from electricity consumption to real GDP (income); and from real GDP to exports. In order to provide further results, the link between trade (export and import) and energy consumption was investigated by [6] in a sample of 8 Middle Eastern countries. Based on a short-run dynamic model, he revealed that Granger causality runs from exports to energy consumption; and existence of a bi-directional causality between imports and energy consumption. According to the author, the Fully Modified OLS estimated long run elasticities indicates that, a unit percentage rise in per capita exports raises per capita energy consumption by 0.11%, whereas a one percentage rise in per capita imports boosts per capita energy consumption by 0.04%. He concluded that, in both the short and long-run, increased trade impacts energy demand in the Middle East.

Similarly, [8] analysed the link between electricity generation and export in Malaysia. They reported that, Granger causality runs from electricity generation to exports. However, [9] reported no evidence that exports and electricity consumption have Granger causality relationship for the same country. This implies that causality between export and energy depends on whether analysis is conducted from supply side or demand side energy dimension.

The empirical links between national output, exports, energy consumption, and critical production inputs (capital and labour) was verified by [10] in Turkey. Three possible hypotheses with respect to the connection between aggregate output, exports and energy consumption are tested, and empirical results show a set of bidirectional causal relationship between income, energy consumption and exports. Specifically, he showed that there is bi-directional causality relationship between export and energy consumption in the long-run, while in short-run evidence of unidirectional relationship from export to energy consumption was obtained. In another contribution, [7] assessed the relationship between energy consumption, output and trade for a sample of 7 South American countries. Empirical results reveal that there exist a long-run relationship between output, capital, labor, energy, and exports; and output, capital, labor, energy, and imports. In the same vein, trade (exports or imports) and energy consumption have a causal relationship. The results also indicate a short-run bi-directional relationship between energy consumption and exports; output and exports; and output and imports. Further, a short-run causal relationship runs from energy consumption to imports.

Further, [11] found a bi-directional causal relationship between energy consumption, GDP, export and import for the OECD countries. In the same vein, [12] found that in all regions excluding Eastern Europe, trade components (export and import) have long run positive impact on energy consumption and CO_2 emission.

From the above review, it is clear that little studies exist for African countries where energy and trade are also important for economic growth and development as in the case of countries already analysed in the literature. Besides, the findings are mixed and inconclusive, while none of the studies reviewed focuses on West African countries. This important gap coupled with the need to consider the effect of different kinds of energy on trade motivates this study. To further buttress the key contributions of the present study, Table 1 provides an elaborate documentation of the empirical evidence so far.

Table 1
Summary of literature review.

S/N	Author & year	Country(s) & scope	Methodology		Findings
			Variables	Estimation methods	
36	Chang (2010)	China (1981–2006)	Y, ECC, NG, CO & EL	VECM and Granger causality	ECC in China produced efficiency gains over the period. ECC $\leftrightarrow$ Y
22	Narayan et al. (2010)	93 Countries, categorized under WE, LAC, MENA (1980–2006)	ECC & Y	FMOLS	60% of the countries considered showed ECC+Y
31	Abosedra (2009)	Lebanon, January 1995 to December 2005	M, EL, and TEM	Granger causality and a lagged ECM	EL $\rightarrow$ Y; absence of a long-term equilibrium relationship between EL & Y
23	Wolde-Rufael (2010)	India, Japan, China, South Africa, South Korea and United States (1965–2005)	CO & Y	Toda & Yomamoto Granger causality	CO $\rightarrow$ Y in India & Japan & Y $\rightarrow$ CO in China and South Korea. Y $\leftrightarrow$ CO South Africa and United States
49	Ozturk and Acaranci (2011)	11 MENA countries (1971–2006)	Y & EL	ARDL bound testing	No relationship between EL & Y in MENA
24	Abanda et al. (2012)	Africa, oil & non-oil producing block, West, East, North, Southern and Central Africa	RE & Y	OLS & correlation analysis	There exists a similar pattern in all the studied blocks in terms of mean, Standard deviation & correlation between RE & Y
50	Lee et al. (2008)	22 OECD countries (1960–2001)	ECC, K & Y	Panel co-integration & VECM	ECC $\leftrightarrow$ K $\leftrightarrow$ Y. K plays a critical role in realizing the dynamic relationship between ECC & Y
5	Narayan and Smyth (2009)	6 Middle Eastern countries (1974–2002).	EL, Y & X	FMOLS	The panel as a whole there are statistically significant feedback effects between these variable
32	Jayanthakumaran, et al. (2012)	China and India	RE, Y, trade, ECC, structural changes & CO_2	ARDL bound testing	In china, CO_2 were influenced by Y, structural changes & ECC. A similar causal connection cannot be established for India
15	Lee, and Chang (2008)	16 Asian countries (1971–2002)	ECC, Y, K & L	FMOLS	No short run causal relationship. Long-run ECC $\rightarrow$ Y
25	Sadorsky (2009)	18 emerging economies	RE, solar, wind & wood, waste electric power consumption	Panel co-integration techniques	Panel co-integration estimates show that increases in Y+significant impact on RE
52	Al-Iriani (2006)	6 Countries of the Gulf Cooperation Council (GCC)	ECC & Y	Panel VECM and GMM	Y $\rightarrow$ ECC in the GCC countries

Table 1 (*continued*)

S/N	Author & year	Country(s) & scope	Methodology		Findings
			Variables	Estimation methods	
37	Tang and Tan (2013)	Malaysia (1970–2009)	EL, EP & Y	ARDL	Income + affects EL, while EP & technology innovation – affect EL
8	Lean and Symth (2010a)	Malaysia (1971–2006)	Y, EL, X, L & K	VECM, Granger causality	In the short run Y↔EL, K↔Y & K→L; In the long run EL, X, K, L↔Y
55	Apergis and Payne (2011)	16 Emerging economies (1990–2007)	RE, NRE, EL, Y, K & L	Heterogenous panel cointegration test, panel error correction model	1. In the short-run, Y→RE & Y↔NRE 2. In the long-run, RE↔Y & NRE↔Y
26	Apergis and Payne (2010)	15 Emerging market economies (1980–2006)	Y, CO, K & L	Heterogenous panel cointegration	In the short-run and long run, CO↔Y
16	Apergis and Payne (2009)	6 Central American countries (1980–2006)	Y, ECC, K & L	Heterogenous panel co-integration and ECM	ECC↔Y in short run & long run
11	Dedeoglu and Kaya (2013)	OECD countries (1980–2010)	ECC, output, X & M	Granger causality and ECM	ECC↔Y, ECC↔X & ECC↔M. Long run + the pairs in the dynamic panel ECM
53	Pao and Tsai (2011)	Brazil, Russia, India and China (1980–2007)	CO_2, FDI, Y & ECC	Panel causality tests	CO_2↔FDI, Y→FDI; ECC→FDI
27	Acaravci and ozturk (2010)	Denmark, Germany, Greece, Iceland, Italy, Portugal and Switzerland (1960–2005)	CO_2, ECC & Y	ARDL bound testing approach	+ CO_2 & ECC in Denmark, Germany, Greece, Italy and Portugal
29	Lee and Chang (2007)	Taiwan (1955–2003)	Y, K, L, X & ECC	OLS and Threshold Autoregressive Model (TAR)	Changes in ECC contributed to Y, but the relationship is not linear
39	Pao and Tsai (2011)	Brazil (1980–2007)	CO_2, ECC & Y	Grey prediction and Granger causality	In the long run, CO_2 appears to be both ECC & Y inelastic. Y↔ECC↔CO_2
38	Pao et al. (2009)	Russia (1990–2007)	CO_2, ECC & Y	VECM	In the long run, CO_2 appears to be ECC elastic and Y inelastic. Y↔ECC↔CO_2
9	Lean and Smyth (2010b)	Malaysia (1970–2008)	Y, EL, X & EP	Multivariate Granger causality	Y→EL. No causality between EL & Y
12	Al-mulali and Sheau-Ting (2014)	189 Countries in 6 region (1990–2011)	Trade in goods and services, ECC & CO_2	FMOLS	All regions excluding Eastern Europe show a long run + trade variables & ECC & between trade variables & CO_2
54	Al-mulali et al. (2014)	18 LAC (1990–2011)	L, K, trade in goods & services, ECC & CO_2	Panel dynamic OLS (DOLS)	RE & NRE, L, K & total trades have long run + effect on Y
28	Chandran and Tang (2013)	China & Indian (1965–2009)	Y, CO & CO_2	Panel Co-integration and Granger causality	In China, Y & CO↔CO_2 in the short and long run. In India, only a short-run Y & CO↔CO_2
30	Pao 2009	Taiwan (1980–2007)	Y & EL	Co-integration and error-correction models	Short and long run Y EL but not vice versa
57	Menegaki (2014)	Meta-analysis of 51 studies published in the past 2 decades	ECC & Y	Meta-analysis based on OLS	The long run elasticity of Y with respect to ECC is independent of the method employed for the co-integration.
20	Khan et al. (2014)	Low income, middle income, high income, non-OECD, high income OECD, South Africa, MENA (1975–2011)	ECC, Y, FDI, relative prices and FD	FMOLS	Y + impact on ECC in low income, middle income, South Africa and MENA; FDI & FD→ECC in both middle & high income countries; in low income countries Y&FD→ECC(+); FDI & relative prices→ECC (−)
33	Fang (2011)	China (1978-2008)	RE, ECC & Y	OLS	+ RE & Y
51	Caraiani et al. (2015)	Emerging European countries (1980-2013)	ECC & Y	Granger causality	ECC↔Y
21	Al-mulal et al. (2013)	High income, upper middle income, lower middle income and low income (1980–2009)	RE, ECC & Y	FMOLS	79% of the countries have a + long run RE↔ECC↔Y, 19% showed no long run relationship and 2% showed a→
40	Komal and Abbas (2015)	Pakistan (1972–2012)	FD, UR, real Y and ECC	GMM	+ & significant impact of Y & UR on ECC. FD + affected ECC through Y
43	Arabatzis, et al. (2012)	Greece 2010	Fuel wood consumption and household size	Logistic regression	The supply of household with sufficient quantities of fuel wood in low prices is affected by environmental management
45	Shahbaz and Hye (2013)	Indonesia (1975Q1–2011Q4)	Y, ECC, FD, TO & CO_2	ADRL and VECM	ECC, Y, FD↔CO_2; Y & ECC→CO_2 (+); FD & TO→CO_2 (-). In the long run, ECC→FD
19	Ozturk and Bilgili (2015)	51 Sub-Sahara African Countries (1980–2009)	Y, biomass consumption, TO & POP	Dynamic panel OLS	Y is affected by biomass consumption, TO, & POP significantly & + in African countries.
50	Lee et al. (2008)	22 OECD countries (1960-2001)	Y, ECC & K	FMOLS	ECC↔K↔Y
7	Sadorsky (2012)	7 South American countries (1980–2007)	Y, K, L, ECC, X & M	Panel VECM and GMM	Long-run relationship Y, K, L, ECC & X & Y, K, L, ECC, & M. Short-run dynamics show a ECC↔X, Y↔X & Y↔M
44	Arabatzis and Malesios (2011)	11,106 Households in Northern Greece	Questionnaire Survey	multiple linear generalized regression model (GLM), Tobit & Heckman regression model	Household sociological and economical features & environmental issues are suitable to explain differences in fuel-wood consumption for space heating and cooking
6	Sadorsky (2011)	8 Middle Eastern countries (1980–2007)	X, M & ECC	FMOLS	In both short and long run X↔ECC & M↔ECC
41	Javid and Qayyum (2014)	Pakistan (1972–2012)	EL, Y, EP & ECC	Structural time series model	An upward slope relationship for electricity usage in commercial, agricultural and residential sectors
42	Shahbaz and Lean (2012)	Pakistan (1972–2009)	Y, ECC, L, K	ARDL and VECM	ECC↔Y

Table 1 (*continued*)

S/N	Author & year	Country(s) & scope	Methodology		Findings
			Variables	Estimation methods	
47	Warr and Ayres (2010)	US (1946–2000)	ECC, Y, K, L & energy efficiency	Granger causality and VECM	ECC→Y. No causality between Y, ECC & energy efficiency
46	Yoo and Kim (2006)	Indonesia (1971–2002)	EL & Y	Granger causality	Y→EL.
10	Halicioglu (2011)	Turkey (1968–2008)	Y,ECC, X, K & L	Bound Testing Co-integration	In the long-run, L↔K, X↔ECC↔Y. In the short-run, ECC↔Y, X↔Y & X→ECC
56	Apergis and Payne, (2011)	6 central American countries (1980–2006)	Y, RE, K, & L	The heterogeneous panel co-integration	RE↔Y in both the short and long-run.
34	Yuan et al., (2008)	China (1990–2006)	Y, ECC, EL & CO	Johansen co-integration and VEC	In the short-run, EL↔ECC↔Y, No causality between CO, ECC & Y. Also, Y↔ECC, CO↔ECC, but no causality between Y & EL
14	Narayan and Smyth (2008)	G7 countries	K, ECC, & Y	FMOLS	K, ECC, & Y are co-integrated with K & ECC↔Y+in the long run
35	Yuan et al. (2010)	China (1985–2007)	ECC, Y & CO	Grey incidence analysis	The degree of grey incidences between ECC & Y & Y & CO is larger
18	Chen et al. (2007)	10 Asian countries (1971–2001)	EL & Y	ECM and panel co-integration	In the Short-run, Y→EL & in the long-run, EL↔Y
48	Hamit-Haggar (2012)	Canada (1990–2007)	ECC, GH & Y	FMOLS	Short run, ECC→ GH. & Long run, weak ECC→GH
17	Apergis and Payne (2011)	9 South American countries (1980–2005)	ECC, T, K, L	FMOLS; and panel VECM	In the short-run and long-run causality runs from energy consumption to economic growth

Source: Compiled by the Authors; *Note*: GDP=Y; Energy Consumption of crude oil or energy use=ECC; Energy intensity=EIN; Industrial development=ID; Energy prices=EP; Natural gas=NG; Coal consumption=CO; Trade ratio=TR; Greenhouse gas emission=GH; Electricity consumption=EL; Temperature and humidity=TEM; positive relationship between=+; Fully modified OLS for heterogenous panel=FMOLS; Negative relationship between=−; X=energy Exports; Energy Import=M; Agricultural output=AGR; Population=POP; Labour=L; Investment=I; Real gross fixed Capital formation or Capital=K; Renewable energy=RE; Non-renewable energy=NRE; Urbanization=UR; CO2 emissions=CO2; Trade openness=TO; Bi-directional causality=↔; Uni-directional causality=→; Financial development=FD; Western Europe=WE, Asia, Latin America=LAC, Middle East and Africa=MENA.

4. Theoretical framework and methodology

The theoretical linkage between trade and energy consumption is analysed using the trade and energy demand theories. According to the classical and neo-classical trade theories (such as labour productivity theory of David Ricardo and resource endowment theory of Heckscher–Ohlin), export supply (EXP^s) is a function of domestic productive capacity or resource endowment (proxy by domestic GDP-GDP^d), and relative price (real exchange rate-RER).

$$EXP^s = f\left(GDP^d,\ RER\right) \tag{1}$$

However, production of output is a function of inputs (K, L, I), therefore we have aggregate output equation as follows;

$$GDP = f[K, L, I(ENE)] \tag{2}$$

where K=capital; L=labour and I=intermediate inputs particularly Energy (ENE).

Substituting for Eq. (2) in Eq. (1), we have:

$$EXP^s = f(K,\ L,\ ENE,\ RER) \tag{3}$$

Given that other inputs such as capital and labour also require energy to function, we focus on the role of energy and suppress other inputs; export supply function is as follows;

$$EXP^s = f\ (ENE,\ RER) \tag{4}$$

Similarly, export demand can be expressed as a function of foreign income (FINC), and relative price-RER [63,64].

$$EXP^d = f\ (FINC,\ RER) \tag{5}$$

Our general export (EX) equation that combined both supply and demand factors is specified as follows;

$$EXP = f\ (ENE,\ RER,\ FINC,) \tag{6}$$

On the energy demand side, according to the energy demand theory, total energy demand is a function of aggregate income (GDP) and energy price [7,65]. However, since in most of the sample countries some energy products are imported (refined oil and oil products), then we can use real exchange rate (RER) instead of energy price (data of which is not even available in most of the countries). We assume that demand and supply conditions in the countries from which energy products are imported (proxy by foreign income-GDP^f) influence a country energy demand. This is based on idea that productivity capacity of a country determines its ability to trade (production in a foreign country will influence export, and hence the partner country's import demand. Also, there could be home market effect that may be reflected by a negative link between foreign income and export (local preference for export goods will affect what is made available for the importing countries). Therefore, a country's energy demand is a function of both domestic output/income) and foreign output/income as well as the relative price.

$$ENE^d = f\ \left[GDP^d,\ RER,\ FINC,\right] \tag{7a}$$

However, since domestic output (GDP) is made up of export and non-export components, therefore either total output (GDP), or its components (export or non-export) could be used in the specification of the energy demand equation depending on the focus of the study. Hence, based on the focus of this study on trade, our energy demand equation is specified as follows;

$$ENE^d = f\ [EXP,\ RER,\ FINC,] \tag{7b}$$

Theoretically, energy demand can influence export, while export can also influence energy demand. In the first case, energy demand can influence export because energy is an important input into the production and transportation of goods destined for exports. The machinery and equipment used in the process of producing and transporting goods for export require energy to operate. Thus, the higher the production and transportation of goods for export, the more the energy demand. Consequently, a revision of energy policy (such as energy conservation policy) may require an examination of export promotion policy so s to ensure their consistency. In the second case, exports can affect energy consumption, because an increase in exports represents an increase in economic activities, which would increase the demand for energy.

In summary, there are three potential links between export and energy demand. It is possible that a feedback relationship exists between energy consumption and exports, whereby energy is important for explaining movements in exports and exports are important for explaining movements in energy demand (bi-directional). It is also possible for the relationship between energy consumption and exports to be either one-way (unidirectional) or neutral. It is one-way when either energy demand influences export or export affects energy demand but not both. The neutral case is that the correlation between energy and exports is so small that it does not show up as a statistically significant relationship at conventional tests levels.

For completeness, this present paper also investigates the relationship between energy consumption and imports. The standard import (IM) equation expresses import as a function of domestic income-GDP^d and relative price-RER [63,64]. However, changes in imports can affect energy consumption because the importation of goods into a country and the distribution of such imports require transportation equipment and network which is fueled by energy. Based on this, we modified this function to incorporate energy required for import facilitation. However, since data on energy required for import facilitation is not available, we use energy demand (ENE^d).

$$IMP = f\left(GDP^d,\ RER,\ ENE^d\right) \tag{8}$$

In the other way, energy consumption can be influenced by imports depending on the mix of imports. For instance, durable imported goods like automobiles, air conditioners, refrigerators, etc. are big users of energy and an increase in these types of imported goods will increase the demand for energy. Thus, apart from the energy demand theory which expresses energy demand (ENE^d) as a function of the income level or economic activities (GDP^d) and energy price (P), we consider import (IMP) as a driver of energy consumption. Since, our sample countries trade and consume energy simultaneously or depend not only on domestically produced energy products but also imported ones, then we use relative price (RER) instead of energy price.[5]

$$\mathbf{ENE^d = f\left(GDP^d,\ RER,\ IMP\right)} \tag{9}$$

All above are the theoretical explanations for the relationships that will show up in the vector error correction model (VECM) that we used.

The empirical (Vector Error Correction) models for subsequent analyses in this paper specified next. For each country in our sample, we bifurcate the equations into their export (EXP) and import (IMP) components, respectively. As stated earlier, three energy consumption (ENE) variables are adopted, which are total (TENE), Electricity (ELEC) and Road transport (ROAD). The export VECM specification derived from Eqs. (6) and (7b) is thus:

$$\Delta EXP_t = \gamma_{11} + \sum_{i=1}^{l} \tau_{11}\Delta(EXP)_{t-i} + \sum_{i=0}^{m} \tau_{12}\Delta(FINC)_{t-i} + \sum_{i=0}^{n} \tau_{13}\Delta(ENE)_{t-i} + \sum_{i=0}^{o} \tau_{14}\Delta(RER)_{t-i} + ECT_{t-1}$$

$$\Delta FINC_t = \gamma_{21} + \sum_{i=0}^{l} \tau_{21}\Delta(EXP)_{t-i} + \sum_{i=1}^{m} \tau_{22}\Delta(FINC)_{t-i} + \sum_{i=0}^{n} \tau_{23}\Delta(ENE)_{t-i} + \sum_{i=0}^{o} \tau_{24}\Delta(RER)_{t-i} + ECT_{t-1}$$

$$\Delta ENE_t = \gamma_{31} + \sum_{i=0}^{l} \tau_{31}\Delta(EXP)_{t-i} + \sum_{i=0}^{m} \tau_{32}\Delta(FINC)_{t-i} + \sum_{i=1}^{n} \tau_{33}\Delta(ENE)_{t-i} + \sum_{i=0}^{o} \tau_{34}\Delta(RER)_{t-i} + ECT_{t-1}$$

$$\Delta RER_t = \gamma_{41} + \sum_{i=0}^{l} \tau_{41}\Delta(EXP)_{t-i} + \sum_{i=0}^{m} \tau_{42}\Delta(FINC)_{t-i} + \sum_{i=0}^{n} \tau_{43}\Delta(ENE)_{t-i} + \sum_{i=1}^{o} \tau_{44}\Delta(RER)_{t-i} + ECT_{t-1}$$

In like fashion, the import VECM specification derived from Eqs. (8) and (9) is specified as:

$$\Delta IMP_t = \eta_{11} + \sum_{i=1}^{l} \phi_{11}\Delta(IMP)_{t-i} + \sum_{i=0}^{m} \phi_{12}\Delta(GDP)_{t-i} + \sum_{i=0}^{n} \phi_{13}\Delta(ENE)_{t-i} + \sum_{i=0}^{o} \phi_{14}\Delta(RER)_{t-i} + ECT_{t-1}$$

$$\Delta GDP_t = \eta_{21} + \sum_{i=0}^{l} \phi_{21}\Delta(IMP)_{t-i} + \sum_{i=1}^{m} \phi_{22}\Delta(GDP)_{t-i} + \sum_{i=0}^{n} \phi_{23}\Delta(ENE)_{t-i} + \sum_{i=0}^{o} \phi_{24}\Delta(RER)_{t-i} + ECT_{t-1}$$

$$\Delta ENE_t = \eta_{31} + \sum_{i=0}^{l} \phi_{31}\Delta(IMP)_{t-i} + \sum_{i=0}^{m} \phi_{32}\Delta(GDP)_{t-i} + \sum_{i=1}^{n} \phi_{33}\Delta(ENE)_{t-i} + \sum_{i=0}^{o} \phi_{34}\Delta(RER)_{t-i} + ECT_{t-1}$$

$$\Delta RER_t = \eta_{41} + \sum_{i=0}^{l} \phi_{41}\Delta(IMP)_{t-i} + \sum_{i=0}^{m} \phi_{42}\Delta(GDP)_{t-i} + \sum_{i=0}^{n} \phi_{43}\Delta(ENE)_{t-i} + \sum_{i=1}^{o} \phi_{44}\Delta(RER)_{t-i} + ECT_{t-1}$$

The methodological approach adopted here is straight forward. It begins with testing the time–series properties of the variables of interest via the Phillips–Perron unit root test. Following this, the Johansen–Juselius cointegration test is deployed to elicit information about long-run associations. Eventually, depending on the outcome of cointegration testing, the vector error correction models are estimated using the ordinary least squares (OLS) estimator. The data for the variables used in the estimation of the above equations were obtained from the World Bank [1]. As stated earlier, energy data covering 1971 to 2010 are available for the only the six sample countries out of the 15 ECOWAS member states: Nigeria, Ghana, (WAMZ countries), Cote d'Ivoire, Senegal,

[5] Note that import (IMP) is an element of foreign output or income (GDPf) used in the earlier energy demand Eqs. (7a) and (7b).

Table 2
Phillips–Perron unit root results.
Source: Compiled by the Authors' from the unit tests results.

Variables	Benin		Cote D'Ivoire		Ghana		Nigeria		Senegal		Togo	
	Level	1st Diff	Level	1st Diff	Level	1st Diff	Level	1st Diff	Level	1st Diff	Level	1st Diff
TENE	0.2081	**0.0000**	0.7818	**0.0000**	0.3734	**0.0000**	0.2566	**0.0000**	0.4577	**0.0000**	0.9064	**0.0000**
ELEC	0.2277	**0.0000**	0.6653	**0.0000**	0.1312	**0.0000**	0.1213	**0.0000**	0.8198	**0.0000**	0.1963	**0.0000**
ROAD	0.7308	**0.0000**	0.7604	**0.0000**	0.6418	**0.0000**	0.4265	**0.0000**	0.6252	**0.0000**	0.3345	**0.0000**
EXP	0.4055	**0.0000**	0.3301	**0.0007**	0.8918	**0.0058**	0.2358	**0.0000**	0.4118	**0.0000**	0.5633	**0.0000**
IMP	0.1645	**0.0000**	0.5494	**0.0061**	0.9140	**0.0003**	0.3007	**0.0005**	0.1858	**0.0001**	0.1022	**0.0002**
GDP	0.7999	**0.0001**	0.7820	**0.0034**	0.8123	**0.0016**	0.7695	**0.0000**	0.5516	**0.0000**	0.2545	**0.0000**
FINC	0.2404	**0.0000**	0.2404	**0.0000**	0.2404	**0.0000**	0.2404	**0.0000**	0.2404	**0.0000**	0.2404	**0.0000**
RER	0.2403	**0.0000**	0.2103	**0.0000**	0.8569	**0.0028**	0.9770	**0.0001**	0.1072	**0.0000**	0.6863	**0.0000**

Notes: The reported values are probability values. The bold print is indicative of the order of integration of the variables i.e $I(1)$.

Table 3
Johansen cointegration results.
Source: Compiled by the Authors'.

Cointegrating Equations	Benin		Cote D'Ivoire		Ghana		Nigeria		Senegal		Togo	
	Exp	Imp	Exp	Imp	Exp	Imp	Exp	Imp	Exp	Imp	Exp	Imp
Model with TENE (1)	**0**	**0**	**1**	**1**	**1**	**4**	**2**	**4**	**1**	**1**	**0**	**0**
Model with ELEC (2)	**1**	**1**	**1**	**0**	**2**	**4**	**4**	**1**	**0**	**1**	**0**	**0**
Model with ROAD (3)	**1**	**1**	**2**	**1**	**1**	**4**	**1**	**2**	**0**	**1**	**1**	**0**

Notes: The figures displayed in the table connote the number of cointegrating vectors on the basis of both maximum Eigen and trace statistics. These are, of course, at the 5% level of significance. TENE, ELEC and ROAD represent Total energy consumed; E electricity consumed and Road transport energy consumed, respectively.

Togo and Benin (WAEMU countries). Since data on energy consumption are expressed in per capita terms, all other variables are also used in like manner.

5. Empirical results and discussions

For the avoidance of spurious correlation and interpretation, time-series are typically pre-tested for unit roots. The intuition beneath this practice is that a firmer understanding of the underlying data generating process (DGP) not only makes for more meaningful estimation but also fosters drawing inferences appropriately. Therefore, the result for stationarity adopting the Phillip–Perron test is presented in Table 2. It is vivid from the reported probability statistics that all the series tested are integrated of order 1. This observation holds across all the countries in the sample. Arising from the foregoing, a formal testing of the existence or otherwise of long-run relationship (cointegration) becomes imperative since the behaviour of some linear combination of individually $I(1)$ series might possess a more predictable, i.e. $I(0)$, pattern. To gauge this possibility, Table 3 displays the results of the Johansen cointegration test. The resulting statistics, considering both maximum Eigen and trace tests, suggest a range of cointegrating vectors bounded by 0 (below) and 4 (above).

More precisely, there exists cointegration in both imports and export models for most of the countries save for Togo. Coming on the heels of answering the cointegration question in the affirmative, we proceed to estimating the regression equations for each of the selected West African countries. The results and discussion of the vector error correction model (VECM) is the preoccupation of the rest of this section.

Beginning with Benin, Table 4 indicates that electricity consumption negatively impacts exports but the statistical significance of the effect is nil (model 2). This is in line with the findings of [9] for Malaysia, who reported that the linkage between electricity consumption and export was considerably tenuous. Similarly, foreign income and real exchange rate (depreciation) produced insignificant positive effect on exports. The error correction term suggests that about 42.1% of adjustment takes place in a given year following a deviation from the equilibrium path. With respect to feedback effect, based on the electricity consumption specification[6], higher exports appear to be associated with greater electricity demand albeit with a low magnitude and statistically weightless coefficient. Also, an increase in foreign income leads to significantly reduced demand for electricity in the domestic economy. The adjustment speed in this model is trifling in relative terms. For the import model with electricity consumption, an increase of 1% in electricity consumption raises imports by some 0.2%. Both real exchange rate and domestic income effects on imports are muffled, although the model suggests 17% adjustment on an annual basis. Turning to the corresponding feedback, none of imports, domestic income and real exchange rate seem to have any influence on electricity consumption. This result is unlike that of [12] who found a positive and statistically significant relationship between imports and energy consumption. Nonetheless, this contrasting submission is in large part traceable to a number of factors especially estimation techniques and sample selection. They also went further to condition the energy consumption-trade nexus on the level of economic development of countries and obtained results that indicated that feedback association take place when the share of trade (both imports and exports) in GDP is high and the country has made remarkable improvements with respect to economic development. Conversely, these feedback effects peter out once the trade share and country level economic development become less important. We do note, notwithstanding, that our sample and study focus precludes the testing of the foregoing hypothesis. In the present study, the disaggregated trade-energy consumption nexus is viewed from the lens of a country-specific time series analysis on six ECOWAS countries for a

[6] To gauge possible feedback effects between trade – exports and imports – and energy (captured by three distinct indicators), all tables in the paper also report results for the models in which these measures of energy consumption are the dependent variable.

relatively long period, while [12] deployed panel econometric approaches to data spanning six regional groupings containing 189 countries for a shorter horizon.

The export model with the third type of energy consumption (Model 3 on Table 4), shows that road transport energy demand positively but insignificantly raises exports. In line with received wisdom, a real depreciation serves as exports booster, while exports is also quite elastic to foreign income. The speed of adjustment is somewhat slower than the export model with electricity consumption i.e. 32.4% as against 42.1% in the latter. With respect to feedbacks, exports are positively albeit insignificantly associated with road energy consumption. Other regressors are also not statistically important in the road energy consumption function. For imports model, foreign income, depreciation of the exchange rate and road energy consumption positively impacted on imports though these effects are only marginally significant at the 10.0% level. Moreover, about two-fifths of disequilibrium adjustment takes place per year. The analogous feedback energy demand model indicates that, increases in income abroad heighten the demand for road transport energy in Benin. Interestingly, real depreciation turns out to be a significant road energy consumption driver.

Turning to the results for Cote d'Ivoire in Table 5, Model 1 shows that exports respond negatively but insignificantly to total energy consumption. Contrary to this finding, a significant linkage between exports and energy consumption was found for Turkey in the short-run [10]. In the exports model, about 27.5% of deviations from the long-run trajectory are corrected per annum. This type of adjustment mechanism is scarcely obvious in the related model. The result of this model also shows insignificant effect for all predictors of total energy consumption. On the imports side, the response to total energy consumption is essentially synonymous to the case of exports. Real exchange rate depreciation also raises imports (a reflection of high import dependency of the economy). The corresponding estimated total energy consumption model revealed that both domestic income and imports are significant drivers of aggregate energy consumption. To gain some sense of the magnitude of this influence, an

Table 4
VECM results Benin.
Source: Computed by the Authors'.

Model	Variable	ΔEXP	ΔENE	ΔIMP	ΔENE
Model 2	ΔEXP		0.044(0.226)		
	ΔIMP				0.039(0.158)
	ΔGDP			0.470(0.339)	−1.037(−0.700)
	ΔFINC	1.006(1.114)	−2.177(−1.805)***		
	ΔRER	0.187(1.205)	−0.080(0.389)	0.011(0.039)	0.139(0.448)
With ELEC	ΔENE	−0.302(−1.409)		0.220(1.829)***	
	ECT	−0.421(−3.403)*	−0.009(−0.057)	−0.173(−1.667)***	−0.084(−0.528)
Model 3	ΔEXP		0.178(0.627)		
	ΔIMP				0.240(0.753)
	ΔGDP			1.148(1.671)***	1.105(1.697)***
	ΔFINC	1.997(2.032)**	2.512(1.524)		
	ΔRER	0.444(1.931)***	−0.189(−0.489)	0.555(1.736)***	1.173(2.640)***
With ROAD	ΔENE	0.053(0.550)		0.132(1.623)***	
	ECT	−0.324(−2.322)**	0.213(0.911)	−0.408(−2.542)**	0.191(0.856)

Notes: The figures in parenthesis are t-values. *,** and *** denote statistical significance at the 1%, 5% and 10% levels respectively.

Table 5
VECM Results for Cote d'Ivoire.
Source: Computed by the Authors'.

Model	Variable	ΔEXP	ΔENE	ΔIMP	ΔENE
Model 1	ΔEXP		0.048(0.520)		
	ΔIMP				0.273(2.755)**
	ΔGDP			0.887(1.395)	0.566(1.825)***
	ΔFINC	0.856(1.104)	−0.218(−0.505)		
	ΔRER	0.227(1.633)***	−0.097(−1.186)	0.562(3.214)*	−0.170(−1.573)
With TENE	ΔENE	−0.410(−1.213)		−0.207(0.600)	
	ECT	−0.275(−2.537)**	0.041(0.674)	−0.004(−0.049)	0.120(3.148)*
Model 2	ΔEXP		−0.232(−2.198)**		
	ΔIMP				
	ΔGDP				
	ΔFINC	−0.006(−0.008)	−0.265(−0.749)		
	ΔRER	0.268(1.637)***	0.104(1.468)		
With ELEC	ΔENE	0.360(1.006)			
	ECT	−0.027(0.169)	0.327(4.667)*		
Model 3	ΔEXP		−0.222(−1.629)**		
	ΔIMP				0.285(2.478)**
	ΔGDP			1.004(1.546)	0.022(0.056)
	ΔFINC	0.327(0.385)	0.427(0.828)		
	ΔRER	0.284(1.693)***	0.019(0.189)	0.563(3.040)*	0.406(3.546)*
With ROAD	ΔENE	−0.239(−0.759)		−0.158(−0.619)	
	ECT	0.118(0.677)	0.414(3.913)*	−0.019(−0.618)	0.072(3.793)*

Notes: The figures in parenthesis are t-values. *, ** and *** denote statistical significance at the 1%, 5% and 10% levels respectively.

Table 6
VECM Results for Ghana.
Source: Computed by the Authors'.

Model	Variable	ΔEXP	ΔENE	ΔIMP	ΔENE
Model 1	ΔEXP		−0.081(0.531)		
	ΔIMP				0.041(1.272)
	ΔGDP			−0.137(−0.124)	0.224(1.217)
	ΔFINC	0.248(0.164)	0.729(3.216)*		
	ΔRER	0.230(1.204)	0.009(0.311)	0.225(1.073)	−0.024(−0.679)
With TENE	ΔENE	0.237(0.195)		1.982(1.921)***	
	ECT	0.091(0.829)	−0.048(2.938)*	−0.548(−2.718)**	0.037(1.091)
Model 2	ΔEXP		0.006(0.033)		
	ΔIMP				0.3543(2.491)**
	ΔGDP			−0.861(−0.771)	1.582(1.979)***
	ΔFINC	0.346(0.327)	0.100(1.798)***		
	ΔRER	0.089(0.621)	−0.043(−0.275)	−0.122(−0.533)	−0.094(−0.577)
With ELEC	ΔENE	0.387(1.987)***		−0.033(−0.134)	
	ECT	−0.114(−4.087)*	−0.036(−1.220)	0.182(−2.610)**	0.031(0.626)
Model 3	ΔEXP		−0.111(−1.299)		
	ΔIMP				0.145(1.986)***
	ΔGDP			−0.365(−0.307)	0.465(1.290)
	ΔFINC	−1.285(−0.884)	0.999(1.839)***		
	ΔRER	0.276(1.686)	−0.059(−0.972)	0.251(1.244)	−0.194(−3.167)*
With ROAD	ΔENE	0.655(1.721)***		0.779(1.648)***	
	ECT	−0.055(−1.676)***	0.156(2.979)*	−0.228(−1.077)	0.132(2.059)**

Notes: The figures in parenthesis are t-values. *, ** and *** denote statistical significance at the 1%, 5% and 10% levels respectively.

increase, say 10%, in imports appears to result in slightly over 2.7% rise in total energy consumption. The adjustment is however slow at 12% per year.

The second broad model for Cote d'Ivoire is with electricity consumption, and Table 5 shows that only real exchange rate depreciation raises exports significantly. Electricity consumption evidently has a positive but statistically weightless association with exports. In the related energy model, increases in exports seem to imply lower electricity consumption. A plausible rationale for this queer outcome might be that the key exports of Cote d'Ivoire such as cocoa and other primary products are transferred to exports zones with little or no processing taking place domestically. The speed of adjustment is considerably high at 33%.

Finally, the results of road transport energy consumption models show that consumption of this kind of energy is not a significant driver of both exports and imports. However, higher exports lead to lower road transport energy demand, while increases in imports align with higher road transportation energy demand. On the part of imports, for example, a 1.0% surge in imports raises road transport energy consumption by almost 0.3%. Real exchange rate is a major positive driver of exports, imports and road transport energy demand.

The third country in the sample is Ghana, and the results for the energy consumption-trade nexus are presented next. Table 6 shows that exports do not respond to the stimulus from total energy consumption and the other baseline determinants. This result runs parallel to that of [6], who indicated that Granger causality[7] runs from exports to energy consumption, and drew implication that expansion of exports could be realized without any marked adverse consequences on energy conservation policies. It is pertinent to explicitly note that the preceding conclusion was reached for a panel of eight Middle East economies, implying a more nuanced consideration of direct comparison with our study findings. However, the total energy consumption elasticity of imports is about 1.98 suggesting that when energy use intensifies, imports are likely to rise more than proportionately, plausibly due to expansion in production activities and the implied increase in demand for imported inputs. Under this scenario, an adjustment in the neighbourhood of 50% per year is indicated. These submissions are in tandem with [6] albeit with a much lower elasticity coefficient. Specifically, a 1.0% increase in imports translated to a 0.04% rise in total energy consumption. On the feedback effects based on the energy demand model, in the case of exports, foreign income raises total energy consumption but the underlying adjustment is sluggish at a little less than 5% in a given year. In the case of import, result confirms the absence of causality from imports to total energy consumption.

Model 2 (with export and electricity consumption) is indicative of a positive and significant effect of electricity consumption on Ghana's exports. The traditional export determinants, namely foreign income and real exchange rate also impact positively although the elusive posture in terms of statistical importance is a snag. Imports are not significantly affected by electricity consumption, and the imports tend to adjust faster than exports following disequilibrium (18.2% against 11.4%). With respect to feedback effects, the picture implies that while exports show no tendency to affect electricity consumption on the one hand, a percentage point rise in imports raises electricity consumption by as much as 0.35%.

Ultimately, the road energy consumption models are succinctly discussed as follows. First, road energy consumption exerts positive influence on exports in Ghana with a statistically significant estimate at the 10% level. Second, the effect on import is similar in sign but larger in magnitude at 0.779. However, only the export model shows a significant adjustment coefficient which, of course, echoes a slow adjusted of a mere 5.5% towards equilibrium every year. Talking in terms of feedback effects, exports do not but imports do impact on road energy consumption. The adjustment coefficients are similar i.e. 15.6% for exports and 13.2% for imports.

[7] The concept of causality was initially defined by [66]. Broadly speaking, in a bivariate framework, a time series *P* Granger-causes another time series *Q* if series *Q* can be predicted with better accuracy by using past values of *P* rather than by not doing so, other information is being identical. Testing causal relations between two series *P* and *Q* can be tested within the vector error correction framework as we have attempted in the present study. Furthermore, it is worthy of note that three main types of causal relationships can emerge namely unidirectional causality from *P* to *Q* or from *Q* to *P* and bidirectional causality between *P* and *Q*. Finally, it is appropriate to state that the Granger causality test is highly sensitive to the choice of lag length (this can be decided using diverse criteria).

The narrative now drifts towards the fourth country in the sample, Nigeria. The discussion takes a slight twist at this juncture, as the focus is on interpreting the results on the basis of juxtaposing exports and imports models across the specifications involving the three energy consumption metrics. Thus, the figures reported in Table 7 suggest that only electricity consumption and road transport consumption had positive and significant impact on exports in Nigeria. Rather than this implicit picture of unidirectional causality, [7] took the position that feedback (bidirectional) effects existed between exports and energy consumption in his sample of seven South American countries. Accordingly, it was inferred that environmental policies articulated to minimize energy consumption may be incompatible with trade policies, thus, produce adverse effect on flows of trade [7].

In consonance with a priori expectation, real exchange rate depreciation boosted exports in all models but this influence was only statistically significant in the road energy consumption specification (Model 3). The error correction term is suggestive of some disequilibrium adjustment in the export model with electricity consumption (i.e. 11.4%). Looking at the import models across the board, it is conspicuous that imports are more responsive to total energy consumption than road energy consumption (1.98 as against 0.76) although both coefficients are significant. Domestic income effect on imports is not palpable in Model 3. There is evidence of some adjustment speed across the models, and the pace is about three times faster in the model with total energy consumption vis-à-vis the one with electricity consumption.

The results for the corresponding feedback models are highlighted next. On the side of exports, no clear indication emerges of any influence of exports on all three energy consumption indicators. The story is no different for imports. It is worthy of note that foreign income in the exports models and domestic income in the imports models are generally statistically significant. On the contrary, the impact of real exchange rate is insignificant regardless of specification. The exceptions, with opposing signs, are the exports Model 3 and the road energy consumption model in the last column of Table 7.

The results for Senegal are displayed in Table 8. Long-run co-movement was only supported in Model 1 for exports. This model suggests a more than proportionate fall in exports arising from an increase in total energy consumption. For imports, domestic income is positively but not significantly related to imports across specifications. Also, energy consumption seems to typically dampen exports. However, this effect is not statistically significant except for the import model with road transport energy consumption as a regressor. This result is inconsistent with both [7] who reported a significant positive relationship between imports and energy consumption in South America; and [11] who found the same results in the short- and long- runs for their sample of OECD countries. For the latter, for example, it was indicated that a 1.0% in exports and imports resulted in 0.21 and 0.16 % increases in energy consumption, respectively. We reckon that the seeming absence of such responsiveness in the present study may be driven, to some extent, by the level of economic development of the countries in our sample vis-à-vis industrialized (OECD) countries.

Adjustment coefficients are similar for Models 1 and 3 (20.8% and 23.1% in that order), while this speed is at its climax in the electricity consumption model (85.1%). Speaking briefly on the attendant feedback effects, these are weak and devoid of statistical significance in the main. Further to this, the adjustment coefficients are the lowest (averaging just about 3% per annum) compared to similar models estimated for the other countries in the sample.

Interestingly, there is only one cointegrating export equation for the final country in our sample, Togo. This is found when road transport energy consumption is the indicator included in the Johansen cointegration space. Turning to the specifics, as evident from Table 9, a host of the conventional determinants of exports reflected insignificant effect except foreign income which has a marginally significant positive effect. The speed of disequilibrium correction is moderate at 40% per annum. Finally, there is no evidence on any meaningful feedback influence in the case of Togo.

6. Summary, conclusion and policy analysis

This study sets out to investigate the energy consumption-trade nexus for a sample of West African countries. No previous study, as far as we are aware, has attempted to uncover the linkage

Table 7
VECM Results for Nigeria.
Source: Computed by the Authors'.

Model	variable	ΔEXP	ΔENE	ΔIMP	ΔENE
Model 1	ΔEXP		−0.018(−0.531)		
	ΔIMP				0.040(1.272)
	ΔGDP			−0.137(−0.124)	0.224(1.217)
	ΔFINC	−0.248(−0.164)	0.729(3.216)*		
	ΔRER	0.230(1.204)	0.009(0.311)	0.225(1.073)	−0.024(−0.679)
With TENE	ΔENE	−0.237(−0.195)		1.982(1.921)***	
	ECT	0.091(0.829)	0.048(2.938)*	−0.548(−2.718)**	0.037(1.091)
Model 2	ΔEXP		0.006(0.038)		
	ΔIMP				−0.007(−0.050)
	ΔGDP			0.861(0.771)	1.582(1.980)***
	ΔFINC	0.346(0.327)	0.101(1.798)***		
	ΔRER	0.089(0.621)	−0.043(−0.275)	−0.122(−0.534)	−0.094(−0.577)
With ELEC	ΔENE	0.387(1.987)***		−0.033(−0.135)	
	ECT	−0.114(−4.078)*	−0.036(−1.220)	−0.182(2.610)**	0.031(0.626)
Model 3	ΔEXP		−0.111(−1.299)		
	ΔIMP				0.038(0.587)
	ΔGDP			−2.985(−1.706)***	1.282(2.285)**
	ΔFINC	−1.285(−0.884)	0.998(1.839)***		
	ΔRER	0.276(1.686)***	−0.056(−0.972)	0.206(1.107)	−0.129(−2.157)**
With ROAD	ΔENE	0.655(1.721)***		0.758(1.647)***	
	ECT	−0.055(−0.391)	0.156(2.979)*	−0.044(−0.828)	0.053(3.069)*

Notes: The figures in parenthesis are t-values. *, ** and *** denote statistical significance at the 1%, 5% and 10% levels respectively.

Table 8
VECM results for Senegal.
Source: Computed by the Authors'.

Model	Variable	ΔEXP	ΔENE	ΔIMP	ΔENE
Model 1	ΔEXP		−0.024(−0.588)		
	ΔIMP				−0.015(−0.352)
	ΔGDP			−0.972(−1.403)	−0.117(−0.670)
	ΔFINC	−1.350(−2.070)**	−0.267(−1.227)		
	ΔRER	0.047(0.404)	0.025(0.629)	−0.096(−0.580)	−0.002(−0.042)
With TENE	ΔENE	−1.927(−3.333)*		−0.653(−0.917)	
	ECT	−0.636(−5.906)*	−0.052(−1.438)	−0.208(−3.346)*	−0.036(−2.312)**
Model 2	ΔEXP				
	ΔIMP				0.069(0.612)
	ΔGDP			0.149(0.264)	0.062(0.155)
	ΔFINC				
	ΔRER			0.337(2.178)**	0.033(0.295)
With ELEC	ΔENE			−0.415(−1.297)	
	ECT			−0.851(−4.409)*	0.013(0.093)
Model 3	ΔEXP				
	ΔIMP				0.054(0.306)
	ΔGDP			0.872(1.330)	0.047(0.078)
	ΔFINC				
	ΔRER			0.062(0.366)	0.055(0.351)
With ROAD	ΔENE			−0.158(−2.500)**	
	ECT			−0.231(−1.867)***	0.170(1.484)

Notes: The figures in parenthesis are t-values. *, ** and *** denote statistical significance at the 1%, 5% and 10% levels respectively.

Table 9
VECM results for Togo.
Source: Computed by the Authors'.

Model	variable	ΔEXP	ΔENE
Model 3	ΔEXP		0.065(0.309)
	ΔIMP		
	ΔGDP		
	ΔFINC	1.608(1.608)***	1.512(1.039)
	ΔRER	−0.058(−0.219)	−0.136(−0.495)
With ROAD	ΔENE	−0.066(−0.330)	
	ECT	−0.404(−2.114)*	0.602(3.051)*

Notes: The figures in parenthesis are t-values. *, ** and *** denote statistical significance at the 1%, 5% and 10% levels respectively.

between domestic energy use and export in West Africa. Disaggregated energy consumption (total, electricity and road transport) and trade (exports and imports) data spanning the period from 1971 to 2010 was deployed to estimate vector error correction models (VECM) for the countries in which data is available.

For Benin, neither electricity nor road transport energy consumption has significant linkage with exports. However, while energy varieties have significant positive relationship with imports, domestic income, import and real exchange rate had no palpable link with any energy type. In Cote d'Ivoire, energy varieties have insignificant effect on export and import. However, while export has significant negative impact on both electricity and road transport energy consumption, import has significant positive effect on total energy and road transport energy consumption.

Ghana's exports are positively and significantly affected by both electricity consumption and road transport energy consumption, with insignificant feedback effect from the energy types. However, imports raised both electricity consumption and road energy consumption, with significant positive feedback effect from both energy types. For Nigeria, the results also showed that both electricity and road transport energy consumption have significant positive link with exports and imports, with insignificant feedback effect from the energy varieties. Senegal's case suggested a unidirectional negative relationship running from total energy consumption to export. For Togo, both exports and imports are insignificantly linked with any form of energy used.

With pointed respect to policy implications on the imports side, a causal relationship transmitting from energy to imports implies that lowering energy consumption through conservation policies, for instance, will result in declines in imports. This reduction might have dire economic consequences particularly if imports are predominantly composed of equipment, new technology goods or other vital intermediate inputs. The resultant lackluster economic performance could become self-perpetuating since productivity typically receives less of a boost on one hand and wealth creation remains stunted on the other. Further, a reversal of the foregoing causal flow – namely from imports to energy – suggests that energy conservation policies can be effectual without hampering imports. Flipping briskly to the export side, both the energy-led export hypothesis and the export before energy proposition can be couched within a similar frame as the preceding discussion of imports. In other words, the influence of energy conservation policies on exports profiles follows a similar path to imports. In terms of specifics, energy conservation policies are likely to precipitate no effect on export but an adverse effect on imports for Benin. In Cote d'Ivoire's case, while trade may not be influenced by the energy conservation policies, trade policies may produce diverse effects on energy use in the country. The energy consumption policies will have adverse effects on exports and imports of Ghana and Nigeria. These policies appear to be innocuous for Senegal and Togo.

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