Energy consumption and sectoral trade in selected West African economies

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Abstract: This paper examines the impact of disaggregate energy consumption on sectoral trade in selected West African countries from 1971 to 2015. Panel data analysis indicates that the effect of fossil fuel consumption on agricultural, manufactured and services exports is negative, while that of fuel export is positive. However, electricity has positive effect on the exports of three sectors, while its impact on fuel export is insignificant. Further, fossil fuel generates negative impact on manufactured and services imports, but positive and insignificant effect on agricultural and fuel exports respectively. The effect of electricity on sectoral imports is positive except for agricultural products where it is insignificant. The country level analysis reveals diverse effects of fossil fuel and electricity consumption across sectoral trade structure and the selected West African countries. The foregoing findings inform the articulation of some policy implications including the following. Energy conservation policy is required to encourage production and exporting of commodities with energy saving techniques so as to save costs, conserve non-renewable energy, and foster export diversification in the selected countries. Liberal import policy should be accompanied with energy conservation policy especially where inefficiency of non-renewable energy use is prevalent.

Keywords: energy consumption; sectoral trade; West Africa; panel data analysis; ARDL approach.

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1 Introduction

1.1 Research issues and rationale of the paper

During 1971 to 2015, the upward trends of income, trade and energy consumption in many West African countries have posed a major issue of whether such trends support the pursuance of sustainable economic development. The challenge in policy making that could emanate from this issue is how to achieve energy conservation in the course of trade expansion and diversification due to the non-renewable nature of some energy sources, and carbon emission implication of energy use (Narayan and Smyth, 2009; Sadorsky, 2011a, 2011b). This necessitates research on energy-trade link.

Exploration of the energy-trade link is imperative because, if for instance, increased production of manufactured exports required higher energy consumption, it implies that any fall in energy use due to government policy, such as energy conservation policy, may cause a reduction in manufactured exports and hence, jeopardise export diversification[1] efforts and trade benefits. Also, since some imports such as production equipment and automobiles require energy to function, therefore liberal import policy may jeopardise energy conservation policy. Against this background, policy options depend on the elasticity of different kinds of exports and imports to energy consumption, which necessitate empirical research.

This article contains sufficient contributions to the new body of knowledge in this area, which include the following. First, although there is a huge literature on the link between energy consumption and output/income as shown in the literature review summarised in Table 1, this paper adds to a very few studies (Narayan and Smyth, 2009; Sadorsky, 2011a, 2011b; Lean and Smyth, 2010a, 2010b; Halicioglu, 2011; Dedeoglu and Kaya, 2013; Al-Mulali and Sheau-Ting, 2014; and Adewuyi and Adeniyi, 2015) on trade-energy link. Second, among the very few studies on trade-energy link listed above, only one is on West Africa (Adewuyi and Adeniyi, 2015) where energy also plays a major role in economic activities as in other regions such as Asia which features more in the literature. In the context of West Africa, the study of the link between energy consumption and trade becomes imperative so as to assess the energy conservation potential and environmental effects of export expansion and diversification programmes embarked upon. This current study differs from Adewuyi and Adeniyi (2015) in terms of sectoral analysis, methodological approach and findings which enrich policy analysis.

Third, this present paper introduced another dimension to the literature by analysing energy-trade link at a disaggregated (sectoral) trade level, which is not the case in the earlier studies reviewed. This approach is informed by the idea that production and consumption of various kinds of export and import require different energy contents, it is therefore expedient to disaggregate trade into various types and analyse the impact of energy on each of them. This disaggregated analysis, will inform better policy analysis than the typical aggregate analysis done by earlier studies. For instance, energy required

for production and marketing of manufactured exports is likely to be more than that of agricultural exports. Similarly, various imports require different energy contents to function. This leads to the analysis of the link between disaggregate energy consumption and sectoral exports and imports in this paper.

Fourth, this paper addresses the concerns of Sadorsky (2011b) and Adewuyi and Adeniyi (2015) on the need to recognise that meaningful economic analysis of energy related issues requires either articulating new economic models or blending the related existing standard economic models to serve as the basis of analysis. Thus, unlike most previous studies which adopted *ad hoc* methodological approaches, this study contributes to the literature by articulating energy augmented trade models derived from the standard neo-classical trade model as the basis of the methodology adopted to capture the role of energy in trade. Similarly, Pesaran et al. (2001) and Narayan and Smyth (2005) are concerned about the appropriateness of the methodological approaches adopted in the literature. They pointed out the benefits of the modified auto-regressive distributive lag (ARDL) approach over the traditional techniques such as Engel-Granger and Johansen cointegration and error correction model (ECM) techniques. According to Pesaran et al. (2001) and Narayan and Smyth (2005), the strengths of ARDL over the traditional approaches include the avoidance of endogeneity problem, the small sample properties, and the ability to handle models with single order of integration [(I(0) or I(1)] or mixed order of integration and to produce both short-run and long-run model estimates simultaneously. Despite this idea, majority of the studies reviewed in this paper on energy-trade link employed the traditional cointegration and causality/VECM methods even in the presence of the problems addressed with the use of ARDL method (see Table 2). However, application of the ARDL approach can be problematic if the lag length is long, while the sample size is small or when the integration order exceeds one (1). Since the maximum lag length in the application of the method in this study is one (1) and the sample is not small, therefore this paper contributes to the body of knowledge in the trade related energy literature by applying the ARDL bound testing cointegration and ECM methods to the analysis of the impact of energy consumption on sectoral trade because of its robustness in the presence of the small sample data available, possibility of endogeneity in the trade-energy model and its ability to generate (within the same framework) both short-run and long-run estimates, which enrich our policy analysis.

Fifth, by conducting individual country level analysis, this study examines existence of heterogeneity in the link between trade and energy, which only few studies did as reflected by the literature review. Thus, this paper explores the impact of energy consumption on sectoral trade in Benin, Côte d'Ivoire, Ghana, Nigeria, Senegal and Togo for which the required data sets are available.

On the remaining part of this paper; Section 2 embodies the stylised facts on energy consumption and sectoral composition of trade in the selected countries, while Section 3 contains literature review. The theoretical framework and methodology are discussed in Section 4, while Section 5 discusses the empirical results, and Section 6 concludes with policy lessons.

1.2 Energy consumption and sectoral composition of West Africa's trade

Available data from the World Bank (2013) reveals that, in comparative terms, Nigeria recorded the highest per capita energy consumption, while Senegal had the lowest during the period 1971–2015.

Nigeria's export and import were the highest among the countries, while Benin and Togo recorded lower values compared to others (World Bank, 2013). Sectoral analysis of exports and imports indicates some impressive performance and variations across the countries. Between 1970 and early 2000s, Côte d'Ivoire and Senegal recorded more manufactured exports than the rest, while by the late 2000s, Nigeria exported this product more than the other countries. Ghana recorded the lowest manufactured exports in the 1970s, while Benin had the lowest in the 2000s. Similarly, during the period, Nigeria was the highest importer of manufactured products, while Benin and Togo recorded lower values compared to others.

The major exporters of agricultural raw materials among the countries prior to the late 2000s were Côte d'Ivoire, Benin and Ghana. Subsequently, however, Nigeria became a major exporter of agricultural products. Export of agricultural product was lower in Senegal and Togo compared to the other countries during the period. Nigeria was a major importer of agricultural raw materials, while Togo was a minor importer. Services exports of Nigeria, Côte d'Ivoire and Ghana were higher during the period relative to that of other West African countries. Similarly, services import was highest in Nigeria compared to other countries, followed by Ghana, while Benin and Togo recorded lower values during the period. Figures in the appendix show the countries' trade structure and energy consumption in per capita terms.

1.3 Review of empirical literature on the link between energy and trade

A review of literature reveals that most of the earlier studies were done to analyse the relationship between energy consumption and output/income. Trade related energy literature is developing gradually and those on trade-energy link are few.

1.3.1 Energy consumption-output or economic growth nexus

The literature is extensive at single-country, multi-country and regional levels on the nexus between energy consumption/production and economic growth. However, the findings of the existing studies have largely remained inconclusive given the scope and dimension of issues addressed and methodological approaches adopted.

At the single-country level, Yuan et al. (2008) discovered short run bi-directional causality between total energy consumption and output in China, but no causality between electricity consumption and output This finding was supported by Chang (2010) who, in a similar study, found that energy consumption in China produced efficiency gains over the period with bi-directional causality between energy consumption and output. In the same vein, Pao et al. (2011) reported a bi-directional relationship for Russia, while, Pao and Tsai (2011a) equally indicated bi-directional causality for Brazil, and Shahbaz and Lean (2012) obtained similar result for Pakistan.

Some studies have also indicated unidirectional causality between energy consumption and output or economic growth. However, findings have been mixed, with evidences that causality either runs from energy to output or from output to energy. For instance, Abosedra et al. (2009) found that electricity consumption granger causes output without any long–run relationship between them in Lebanon. Also, Warr and Ayres (2010) studied the United States, and revealed that causality moved from energy consumption to economic growth while Fang (2011) showed that renewable energy consumption has positive effect on economic growth in the case of China. Alternatively, Pao (2009) submitted that, both in the short and long run, causality runs from economic

growth to electricity consumption in Taiwan. Similarly, Yoo and Kim (2006) indicated that the same result is valid for the case of Indonesia. Also, Komal and Abbas (2015) pointed out that economic growth has positive impact on energy consumption in Pakistan.

A number of studies were not able to establish any relationship between energy consumption and economic growth. For example, Lee and Chang (2007) revealed that there is no linear relationship between energy consumption and economic growth in Taiwan though their analysis showed that changes in energy consumption contribute to output growth. Similarly, Shahbaz et al. (2013) found that while economic growth and energy consumption granger cause CO_2 emissions, there exists no causality between economic growth and energy consumption in Indonesia. In the same vein, Javid and Qayyum (2014) revealed an upward sloping relationship for electricity usage in commercial, agricultural and residential sectors in Pakistan with no particular energy–output relationship. Also, Hamit-Haggar (2012) who analysed the case of Canada showed no evidence of causality between economic growth and energy consumption in the long run, though there seems to be weak unidirectional causality from economic growth to energy consumption in the short run.

The findings from multi-country investigations are similar to those of the single country. For example, Wolde-Rufael (2010) found that causality runs from coal consumption to output in India and Japan; and from output to coal consumption in China and South Korea; and bidirectional causality in South Africa and the United States. Analysing the case of 15 emerging market economies, Apergis and Payne (2010b) found bi-directional link between coal consumption and economic growth both in the short run and the long run. Similarly, Apergis and Payne (2011a) who investigated the link for 16 emerging economies revealed that causality runs from output to renewable energy consumption, while output and non-renewable energy have bi-directional causality in the short run. In the long run, both renewable and non-renewable energy reflects bi-directional causality.

In the same vein, Chandran and Tang (2013) found a bi-directional causality between output and coal consumption; output and CO_2 emissions for China both in the short run and the long run, while the same relationship exist for India only in the short run. For the G7 countries, Narayan and Smyth (2008) discovered that causality is positive and bi-directional between energy consumption and economic growth. Al-Mulali et al. (2013) who investigated the case of countries at various income levels reported that 79% of the countries have positive long run bi-directional causality between energy consumption and economic growth; 19% showed no long run relationship while only 2% revealed unidirectional causality from economic growth to renewable energy. However, Al-Iriani (2006) who examined the case of the 6 countries of the Gulf Cooperation Council (GCC) reported that causality runs from economic growth to energy consumption.

Further, Khan et al. (2014) showed that GDP per capita has positive impact on energy consumption in low income countries, middle income countries, South Africa and MENA. However, in high income OECD and non-OECD regions, no significant relationship was found. They also showed that FDI has significant impact on increased energy demand in middle income, high income OECD and non-OECD regions. According to Sadorsky (2009) who analysed the link for 18 emerging economies revealed that increase in output has positive and significant impact on renewable energy. In the same vein, Narayan et al. (2010) explored 93 countries categorised by regions and found that 60% of the countries showed positive relationship between energy consumption and economic growth. Similarly, Jayanthakumaran et al. (2012) revealed

that CO_2 emissions were influenced by economic growth, structural changes and energy consumption in China while similar causal connection cannot be established in the case of India. Their results however showed no evidence of causal relationship between energy consumption and economic growth.

Regional analysis has equally showed mixed results. For example, Caraiani et al. (2015) confirmed that the results for the Emerging European countries exhibited bi-directional causality between economic growth and energy consumption. A similar finding was reported by Apergis and Payne (2009) both in the short run and long run for six Central American countries. Also, Apergis and Payne (2011b) obtained similar result between renewable energy and economic growth for the six Central American countries. However, Lee et al. (2008) which investigates 22 OECD countries found a bi-directional relationship between energy consumption and real gross fixed capital formation, but no causality between energy consumption and output. For 6 South American countries, Apergis and Payne (2010a) showed that causality runs from energy consumption to economic growth, while Ozturk and Bilgili (2015) reported that output is affected by biomass consumption in the Sub-Saharan African countries. Al-Mulali et al. (2014) revealed that renewable energy and non-renewable energy have long run positive effect on economic growth in the 18 LACs considered. In contrast, Chen et al. (2007) who studied 10 Asian countries revealed that causality runs from output to electricity consumption in the short run but bi-directional in the long run. Lee and Chang (2008) explained that no short run, but long run, causal relationship exists between energy consumption and output in 16 Asian countries. Moreover, Abanda et al. (2012) examined the link in Africa and showed that while correlation between Renewable energy production and GDP was positive for all the blocks except the Southern Africa block, however, the direction of causality could not be determined. Similarly, the results reported by Pao and Tsai (2011b), Ozturk and Acaravci (2011), Acaravci and Ozturk (2010) and Tang and Tan (2013) for BRIC, MENA, Europe and Malaysia (respectively) are mixed.

1.3.2 Literature on energy-trade nexus

Empirical examination of the link between energy and trade has received little attention in the literature and the findings have been inconclusive. For instance, Halicioglu (2011) investigated the link between national output, export, energy consumption, labour and capital in Turkey. He revealed that there is bi-directional causal relationship between export and energy consumption in the long-run, while causality run from export to energy consumption in the short-run. In the same vein, Sadorsky (2011a) assessed the relationship between energy consumption, output and trade for a sample of seven South American countries using panel VECM and GMM. He found long-run relationships among output, labour, capital, energy consumption and export; and among output, capital, labour, energy and import. Also, he reported a short-run bi-directional relationship between energy consumption and exports; output and exports; and output and imports. He also found that short-run causality runs from energy consumption to imports. A bi-directional causality is equally reported by Dedeoglu and Kaya (2013) between energy consumption, GDP, export and import for the OECD countries.

Further, Lean and Smyth (2010a) employed multivariate Granger causality method to show that bidirectional causality occurred between aggregate output and electricity consumption in Malaysia, while causality runs from exports to aggregate output. Moreover, using FMOLS, Al-Mulali and Sheau-Ting (2014) showed that in all regions,

excluding Eastern Europe, trade components (exports and imports) have long run positive impact on energy consumption and CO_2 emission. In an examination of the relationship between energy consumption, output and trade, Narayan and Smyth (2009) found that short run causality runs from electricity consumption to real GDP and from real GDP to export for a panel of six Middle Eastern countries. However, Sadorsky (2011b), in a similar study of 8 Middle Eastern countries, reported that granger causality runs from export to energy consumption, though bi-directional causality exists between imports and energy consumption. Based on the FMOLS results, he concluded that increase in trade impacts energy demand in the Middle East both in the short run and long run.

In contrast to the above, Lean and Smyth (2010b) analysed the link between electricity generation, exports, prices and GDP in Malaysia using VECM and Granger causality and showed no evidence of causality between export and electricity generation both in the short-run and in the long-run, though their results indicated a unidirectional link running from economic growth to electricity generation.

Also, Adewuyi and Adeniyi (2015) evaluated the relationship between consumption of energy types and trade in selected West African countries using vector error correction models (VECM). They showed that insignificant linkage exists between Benin's exports and consumption of three types of energy (total, electricity, and transport). They also found a one-way positive linkage running from the various energy sources to import of the country. In the case of Côte d'Ivoire, all types of energy have insignificant link with export and import. For Ghana, they observed positive link moving from electricity and road transport energy consumption to export. But they found a significant positive reverse causality between imports and electricity as well as road transport energy consumption. Their results For Nigeria reveal a significant positive causal link extending from both electricity and road transport energy consumption to exports and imports. Their analysis of Senegal shows a bi-directional inverse connection between exports and total energy consumption, while Togo's result reflected insignificant link between energy consumption and both exports and imports

A number of gaps can be identified in the above literature, which necessitates this paper. These include dearth of studies focusing on African countries where energy and trade are crucial for economic growth and development. Besides, there is the need to consider the effect of energy consumption not only on aggregate export and import but also on sectoral trade; especially for policy purposes. Further, the commonly used estimation techniques in the studies reviewed on energy-trade link (Engel-Granger and Johansen, Toda Yamamoto based VECM) have some econometrics problems pointed out and addressed by Pesaran et al. (2001) and Narayan and Smyth (2005), which necessitates the use of ARDL approach in this paper.

2 Analytical framework and methodology

2.1 Analytical framework (Energy Augmented Trade Model)

The analytical basis of this study is the neo-classical trade model (resource endowment model of Heckscher-Ohlin). In this model, export supply (EXP^s) is a function of domestic productive capacity or resource endowment (proxy by domestic GDP), and relative price (real exchange rate – RER).

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

Since the production of output including export depends on inputs, then an expanded aggregate production function is used to reflect the role of energy in its production as follows:

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

where K = capital; L = labour and I = intermediate inputs which basically consist of energy (ENE).

Substituting equation (2) in equation (1), gives a modified export model:

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

Given the role of energy in facilitating the functioning of other inputs such as capital and labour, we suppressed other inputs, and focus on the role of energy in this paper. Thus, export supply function is written as follows:

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

Export demand can be stated as a function of foreign income (FY) and relative price-RER (Thirlwall and Santos-Paulino, 2004; Adewuyi and Akpokodje, 2010) as specified in equation (5).

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

Based on equations (4) and (5), export (EXP) equation that combined both supply and demand factors is specified as follows;

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

To consider the effect of energy consumption on imports, we adopt the simplified import equation derived from the imperfect substitution model developed by Goldstein and Khan (1985), which is commonly used in the literature. This equation expresses import (IMP) as a function of domestic income-GDP and relative price- RER (Thirlwall and Santos-Paulino, 2004; Adewuyi and Akpokodje, 2010). The argument for the inclusion of energy in the equation is that, importation of goods into a country and the distribution of such goods require transportation equipment and network which are run using energy. Besides, some imported products such as automobiles cannot work without energy. Based on these ideas, we modified the above import function to incorporate energy as follows:

$$IMP = f(GDP, RER, ENE) \tag{7}$$

It should be mentioned that energy consumption (fuel and electricity) should promote sectoral (agricultural, manufactured, fuel and services) exports and imports. Sectoral output or export (import) should increase per unit of energy consumption so as to achieve energy efficiency. Otherwise, there is need to encourage adoption of energy saving technologies among producers and exporters. In the absence of domestic production, fuel import should rise as its domestic consumption increases.

2.2 Methodology

Based on the above theoretical framework and adding a control variable (level of financial development which determines access of producers or exporters to domestic

credit: DC) the empirical models estimated in this study are expressed in logarithm and per capita terms as follows;

$$LEXP_{ijt} = \alpha_{1i} + \alpha_{2i}LFY_{it} + \alpha_{3i}LFF_{it} + \alpha_{4i}LEC_{it} + \alpha_{5i}LDC_{it} + \alpha_{6i}LRER_{it} + \varepsilon_{it} \quad (8)$$

$$LIMP_{ijt} = \alpha_{1i} + \alpha_{2i}LFY_{it} + \alpha_{3i}LFF_{it} + \alpha_{4i}LEC_{it} + \alpha_{5i}LDC_{it} + \alpha_{6i}LRER_{it} + \varepsilon_{it} \quad (9)$$

where EXP_{ij} and IMP_{ij} represent export and import of sector I respectively in country j, while other variables are defined in Table 1. Thus, the equations (8) and (9) are estimated for export and import of Manufacturing (ME & MI), Services (SE & SI) Oil or Fuel (FE & FI) and agricultural sectors. Equations (8) and (9) were estimated using Pool, fixed and random effects models The Haussmann specification test is used to select the best estimates between the fixed and random. Prior to the estimation, the variables were tested for stationarity using Fisher Unit-root test (ADF & PP) and Im, Pesaran and Shin test.[2]

For the purpose of robustness, individual country analysis ere also undertaken for each of the six (6) selected countries. This study adopts the Autoregressive Distributed Lag (ARDL model for this purpose. According to Pesaran et al. (2001), the ARDL co-integration technique (bound test), compared to other multivariate co-integration methods, enables the co-integration relationship to be estimated by the ordinary least square (OLS) after determining the lag order of the model. Also, the model can accommodate small sample data and regressors that are stationary at either levels I(0) or first difference I(1) or both as in the case of this study. In addition, the long run and short run parameters of the models can be simultaneously estimated (Pesaran et al., 2001; Narayan and Smyth, 2005).[3] Thus, the ARDL representations of the above equations are as follows:

$$\begin{aligned}\Delta LEXPij_t = {} & \beta_0 + \beta_1 LEXPij_{t-1} + \beta_2 LFY_t + \beta_3 LFF_t + \beta_4 LEC_t + \beta_5 LDC_t + \beta_6 LRER_t \\ & + \sum_{i=1}^{j} \beta_7 \Delta LEXPij_{t-i} + \sum_{i=1}^{j} \beta_8 \Delta LFY_{t-i} + \sum_{i=1}^{j} \beta_9 \Delta LFF_{t-i} + \sum_{i=1}^{j} \beta_{10} \Delta LEC_{t-i} \\ & + \sum_{i=1}^{j} \beta_{11} \Delta LDC_{t-i} + \sum_{i=1}^{j} \beta_{12} \Delta LRER_{t-i} + \mu_{1t}\end{aligned} \quad (10)$$

$$\begin{aligned}\Delta LIMPij_t = {} & \beta_0 + \beta_1 LIMPij_{t-1} + \beta_2 LDY_t + \beta_3 LFF_t + \beta_4 LEC_t + \beta_5 LDC_t + \beta_6 LRER_t \\ & + \sum_{i=1}^{j} \beta_7 \Delta LIMPij_{t-i} + \sum_{i=1}^{j} \beta_8 \Delta LFY_{t-i} + \sum_{i=1}^{j} \beta_9 \Delta LFF_{t-i} + \sum_{i=1}^{j} \beta_{10} \Delta LEC_{t-i} \\ & + \sum_{i=1}^{j} \beta_{11} \Delta LDC_{t-i} + \sum_{i=1}^{j} \beta_{12} \Delta LRER_{t-i} + \mu_{1t}\end{aligned} \quad (11)$$

Before the estimation of the ARDL model (equations 10 and 11) we tested for unit root using both the Augmented Dickey Fuller (ADF) and Philip Perron (PP) techniques.

The variables $e_1$and e_2 are error terms; and ecm_{t-1} is the error correction term lagged for one period; δ is the coefficient measuring speed of adjustment. Data used for the estimation of the above equations were gathered from the World Bank (2013) (online version). Energy data covering 1971 to 2015 are available for only six out of the 15 ECOWAS member states: Nigeria, Ghana, (WAMZ countries), Côte d'Ivoire, Senegal, Togo and Benin (WAEMU countries).[4] Given that data on energy consumption are expressed in per capita terms, all other variables are also used in this way. For the purpose of the model estimation, the variables were logged.

Table 1 Variable description and data sources

Variable	*Description*	*Measurement*	*Data sources*
AE	Agricultural raw materials exports	Agricultural raw materials exports per capita (current US$)	Computed using data from WDI
AI	Agricultural raw materials imports	Agricultural raw materials imports per capita (current US$)	Computed using data from WDI
ME	Manufactures exports	Manufactures exports per capita (current US$)	Computed using data from WDI
MI	Manufactures imports	Manufactures imports per capita (current US$)	Computed using data from WDI
SE	Service exports	Service exports per capita (BoP, current US$)	Computed using data from WDI
SI	Service imports	Service imports per capita (BoP, current US$)	Computed using data from WDI
FE	Fuel exports	Fuel exports per capita (current US$)	Computed using data from WDI
FI	Fuel imports	Fuel imports per capita (current US$)	Computed using data from WDI
DY	Domestic income	Domestic income per capita[a]	Computed using data from WDI
FY	Foreign income	Foreign income per capita[a]	Computed using data from WDI
FF	Fossil fuel energy consumption	Fossil fuel energy consumption per capita (kg of oil equivalent)	Computed using data from WDI
EC	Electric power consumption	Electric power consumption (kWh per capita)	Computed using data from WDI
DC	Financial development	Domestic credit to private sector (% of GDP)	WDI
RER	Exchange rate	Real exchange rate	Computed using data from WDI

Notes: Côte d'Ivoire data on service exports and imports commences from 2005 to 2015 and WDI = World Development Indicators.

[a]Foreign income is defined as world income minus the respective country income.

3 Empirical results and discussions

3.1 Descriptive statistics, stationarity (unit root) and cointegration tests

The descriptive statistics are shown in Table 2. The results of the unit root tests for the panel of countries and individual countries are presented in Tables 3 and 4. The results show that all the variables across the countries attain stationarity after first differencing. Since the variables are characterised by mixed order of integration I(0) and I(1), it is pertinent to further test for the existence or otherwise of long-run association among them. We deployed the bounds test with a view to detecting any such co-integrating vector(s). The cointegration test results for both exports and imports models for the countries are displayed among the results in Tables 5 to 8. Given the existence of cointegration across countries, we estimated both the short-run and long-run models.

3.2 Panel data analysis of impact of disaggregate (electricity and fossil fuel) energy consumption on sectoral trade

Results of the panel data analysis of the impact of electricity and fossil fuel use on *agricultural export and import* of the selected West African countries are reported in Table 5. The results show that fossil fuel and electricity consumption exert significant negative and positive influence on agricultural (raw material) export respectively. Hence, 1.0% rise in fossil fuel use caused 1.20% decline in agricultural export, while a similar increase in electricity consumption yielded positive effect of 0.49% on the export. This suggests that increased use of fossil fuel could be detrimental to agricultural production and export. This finding may be a reflection of the non-affordability of prices of petroleum products (high cost) to the peasant farmers in the rural areas which dominates the agricultural sector of the West African countries. However, electricity use appears to promote agricultural export in these economies. Thus, the result suggests that electricity is affordable and accessible to the farmers. Foreign income has significant positive impact on agricultural export with elasticity of 2.22. Thus, income of importing countries (majority of which are industrialised) is critical to the export of agricultural raw materials in the West African countries. Real exchange rate and domestic credit do not exert significant influence on agricultural export. In terms of import of agricultural commodities (raw materials), while the effect of electricity consumption is insignificant, that of fossil fuel consumption is significant positive. This may portray the fact that fossil fuel is required for the functioning of agricultural machineries and equipment use during cultivation of land for production and processing of local and imported agricultural raw materials. Moreover, the coefficient of domestic income is negative and significant, with income elasticity of agricultural import of –0.44. This may suggest that, as income rises, domestic producers tend to shift attention away from the demand and use of foreign agricultural raw materials in favour of local ones. This result may be a reflection of the effectiveness of local content policy in the countries. The significant positive influence of domestic credit on agricultural raw material import implies access of producers (farmers and manufacturers) to credit to finance import of agricultural goods. Like the case of export, exchange rate does not influence import of agricultural commodities.

Table 2 Individual country descriptive analysis

Country	*Statistic*	*LAE*	*LAI*	*LDC*	*LEC*	*LEU*	*LFE*	*LFF*	*LFI*	*LFY*	*LME*	*LMI*	*LRE*	*LSE*	*LSI*	*LY*
Benin	Mean	–1.271	–3.059	2.753	3.738	5.868	–5.177	3.901	–1.926	8.810	–2.473	0.008	5.759	–1.145	–0.677	6.484
	Maximum	0.008	–2.354	3.461	4.607	6.033	–1.963	5.160	–0.687	9.145	–0.786	0.834	6.550	–0.805	–0.198	6.726
	Minimum	–4.068	–4.595	1.689	2.375	5.666	–10.064	2.470	–6.383	8.450	–4.189	–0.704	4.906	–1.775	–1.158	6.301
	Std. Dev.	0.950	0.568	0.489	0.596	0.087	2.219	0.847	1.212	0.200	0.851	0.382	0.543	0.219	0.257	0.119
CIV	Mean	–0.346	–3.668	3.146	5.106	6.069	–0.637	4.835	–0.346	8.644	–0.567	0.773	5.700	NA	NA	7.327
	Maximum	0.949	–2.806	3.744	5.621	6.423	0.714	5.210	0.392	9.074	0.360	2.027	6.563	NA	NA	7.780
	Minimum	–1.163	–4.358	2.277	4.547	5.863	–3.719	4.407	–1.668	8.090	–1.393	–0.130	4.588	NA	NA	7.038
	Std. Dev.	0.591	0.361	0.470	0.218	0.164	0.804	0.212	0.486	0.307	0.403	0.551	0.628	NA	NA	0.216
Ghana	Mean	–2.088	–3.259	1.922	5.733	5.837	–2.452	4.482	–1.077	8.755	–2.602	0.432	–6.889	–1.233	–0.450	6.901
	Maximum	–0.319	–2.412	3.018	6.054	6.030	1.008	5.188	–0.305	9.049	–0.188	1.662	1.800	0.723	0.897	7.430
	Minimum	–3.795	–4.428	0.433	4.538	5.595	–7.167	3.572	–3.129	8.323	–5.304	–0.679	–18.197	–2.804	–1.395	6.553
	Std. Dev.	0.786	0.481	0.736	0.284	0.114	1.520	0.359	0.570	0.203	1.581	0.582	6.696	0.855	0.603	0.223
Nigeria	Mean	–4.580	–3.959	2.516	4.420	6.543	1.021	4.786	–3.426	8.635	–4.151	0.346	0.026	–1.893	–0.339	7.413
	Maximum	–0.754	–1.971	3.648	5.055	6.682	2.162	5.106	–0.491	8.940	–1.043	1.674	5.640	–0.639	1.203	7.849
	Minimum	–9.125	–5.139	1.547	3.352	6.361	0.090	3.543	–5.618	8.141	–8.140	–0.622	–5.528	–3.691	–1.996	7.048
	Std. Dev.	1.883	0.660	0.414	0.428	0.079	0.580	0.366	1.341	0.246	1.754	0.677	4.245	0.806	0.913	0.245
Senegal	Mean	–2.857	–2.932	3.147	4.782	5.536	–1.566	4.736	–0.559	8.768	–0.736	0.475	5.904	–0.087	0.040	6.816
	Maximum	–1.798	–1.880	3.626	5.409	5.720	–0.243	4.976	0.405	9.120	–0.143	1.174	6.638	0.503	0.729	6.959
	Minimum	–4.026	–3.712	2.615	4.302	5.332	–8.039	4.512	–1.776	8.363	–1.495	–0.217	5.073	–0.725	–0.685	6.673
	Std. Dev.	0.526	0.380	0.302	0.303	0.106	1.448	0.140	0.634	0.218	0.345	0.339	0.486	0.333	0.359	0.074
Togo	Mean	–2.159	–3.531	3.009	4.519	5.912	–6.028	3.961	–1.203	8.824	–1.460	0.338	6.033	–0.881	–0.338	6.283
	Maximum	–0.583	–2.618	3.629	5.029	6.199	–0.159	4.776	0.199	9.175	0.089	1.461	6.793	–0.189	0.554	6.527
	Minimum	–3.890	–4.913	2.156	4.018	5.714	–12.839	3.028	–3.014	8.450	–3.270	–0.832	5.122	–1.830	–1.185	6.019
	Std. Dev.	0.887	0.507	0.346	0.253	0.149	3.017	0.341	0.771	0.213	0.964	0.488	0.612	0.425	0.442	0.105
	Observations	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45

Source: Authors computation from underlying data from World Development Indicator, 2017 (WDI) and International Financial Statistics (IFS database)

Table 3 Panel unit root tests

	ADF Fisher chi-square		*PP Fisher chi-square*		*Im, Pesaran and Shin t-bar*		
Variable	*Level*	*First difference*	*Level*	*First difference*	*Level*	*First difference*	*Decision*
LAE	4.751***	72.087*	4.751***	72.087*	–2.600	–10.479*	I(0)
LAI	7.878**	67.037*	7.878**	67.036*	–3.209**	–9.145*	I(0)
LDC	0.286	27.049*	0.286	27.049*	–0.620	–5.589**	I(1)
LEC	5.330***	23.977*	5.330***	23.977*	–2.726***	–5.273*	I(0)
LEU	1.472	31.245*	1.471	31.245*	–1.609	–6.002*	I(1)
LFE	11.416*	72.087*	11.415**	72.087*	–3.762**	–9.981*	I(0)
LFF	0.946	64.430*	0.945*	64.430*	–1.313	–8.924*	I(1)
LFI	19.223*	59.572*	19.223*	59.572*	–4.752**	–8.512*	I(0)
LFY	5.826***	29.024*	5.826***	29.024*	–2.828***	–**5.786***	I(0)
LME	0.952	72.087*	0.951	72.087*	–1.317	–10.243*	I(1)
LMI	1.899	72.087*	1.899	72.087*	–1.787	–9.944*	I(1)
LRE	1.987	13.305*	1.987	13.305**	–1.820	–4.023***	I(1)
LSE	0.156	25.490*	0.156	25.490*	–0.303	–5.430**	I(1)
LSI	0.108	18.248*	0.108	18.248*	–0.123	–4.639**	I(1)
LY	0.006	15.239*	0.006	15.239*	1.392	–4.275**	I(1)

Notes: *, **, *** represent 1%, 5% and 10% significant levels respectively.

Table 4 Unit root tests results (individual country)

		ADF			*PP*			
		Level	*First difference*	*Order of stationarity*	*Level*	*First difference*	*Order of stationarity*	*Decision*
Benin	LAE	–1.428	–6.569*	I(1)	–1.429	–6.548*	I(1)	I(1)
	LAI	–3.109**	–7.938*	I(0)	–3.091**	–14.565*	I(0)	I(0)
	LDC	–1.524	–6.325*	I(1)	–1.738	–6.335*	I(1)	I(1)
	LEC	–1.462	–5.444*	I(1)	–2.077	–13.378*	I(1)	I(1)
	LEU	–1.409	–6.621*	I(1)	–1.452	–6.621*	I(1)	I(1)
	LFE	–3.374**	–3.212**	I(0)	–3.355**	–7.799*	I(0)	I(0)
	LFF	–0.527	–5.961*	I(1)	–0.698	–5.961*	I(1)	I(1)
	LFI	–2.347	–6.124*	I(1)	–2.479	–6.456*	I(1)	I(1)
	LFY	–0.691	–5.243*	I(1)	–0.710	–5.243*	I(1)	I(1)
	LME	–1.944	–8.619*	I(1)	–1.909	–8.607*	I(1)	I(1)
	LMI	–2.341	–6.766*	I(1)	–2.201	–8.489*	I(1)	I(1)
	LRE	–1.188	–5.450*	I(1)	–1.300	–5.451*	I(1)	I(1)
	LSE	–3.813*	–6.869*	I(0)	–3.820*	–9.481*	I(0)	I(0)
	LSI	–2.184	–6.371*	I(1)	–2.146	–6.586*	I(1)	I(1)
	LY	–0.171	–6.379*	I(1)	0.526	–6.674*	I(1)	I(1)
CIV	LAE	–1.316	–7.108*	I(1)	–1.115	–7.466*	I(1)	I(1)
	LAI	–3.182**	–8.486*	I(0)	–3.196**	–8.824*	I(0)	I(0)
	LDC	–0.779	–2.763***	I(1)	–1.009	–5.354*	I(1)	I(1)
	LEC	–2.303	–7.927*	I(1)	–2.303	–7.913*	I(1)	I(1)
	LEU	–0.905	–7.143*	I(1)	–0.781	–7.143*	I(1)	I(1)
	LFE	–4.917*	–5.973*	I(0)	–4.455*	–6.217*	I(0)	I(0)
	LFF	–2.397	–7.772*	I(1)	–2.374	–7.813*	I(1)	I(1)
	LFI	–3.253**	–6.358*	I(0)	–3.261**	–6.292*	I(0)	I(0)
	LFY	–1.087	–3.193**	I(1)	–1.736	–5.099*	I(1)	I(1)
	LME	–3.230**	–5.855*	I(0)	–3.334**	–7.822*	I(0)	I(0)
	LMI	–1.373	–6.261*	I(1)	–1.462	–6.257*	I(1)	I(1)
	LRE	–1.146	–5.664*	I(1)	–1.184	–5.662*	I(1)	I(1)
	LY	–1.219	–4.038*	I(1)	–1.322	–4.088*	I(1)	I(1)

Table 4 Unit root tests results (individual country) (continued)

		ADF			PP			
		Level	*First difference*	*Order of stationarity*	*Level*	*First difference*	*Order of stationarity*	*Decision*
Ghana	LAE	−1.770	−10.479*	I(1)	−2.380	−11.077*	I(1)	I(1)
	LAI	−3.209**	−9.146*	I(0)	−3.151**	−10.536*	I(0)	I(0)
	LDC	−0.620	−5.589*	I(1)	−0.818	−5.545*	I(1)	I(1)
	LEC	−3.806*	−5.558*	I(0)	−2.636***	−7.358*	I(0)	I(0)
	LEU	−1.609	−6.003*	I(1)	−1.801	−6.002*	I(1)	I(1)
	LFE	−3.762*	−9.981*	I(0)	−3.699*	−13.415*	I(0)	I(0)
	LFF	0.117	−7.237*	I(1)	−1.036	−10.136*	I(1)	I(1)
	LFI	−4.753*	−6.243*	I(0)	−4.668*	−15.178*	I(0)	I(0)
	LFY	−2.829***	−5.787*	I(0)	−2.848***	−5.787*	I(0)	I(0)
	LME	−0.577	−10.244*	I(1)	−0.972	−10.371*	I(1)	I(1)
	LMI	−0.906	−9.944*	I(1)	−1.579	−10.135*	I(1)	I(1)
	LRE	−1.821	−4.024*	I(1)	−1.500	−4.035*	I(1)	I(1)
	LSE	−0.304	−5.431*	I(1)	−0.334	−5.431*	I(1)	I(1)
	LSI	−0.123	−4.639*	I(1)	−0.524	−4.639*	I(1)	I(1)
	LY	0.462	−4.275*	I(1)	0.722	−4.235*	I(1)	I(1)
Nigeria	LAE	−2.420	−9.031*	I(1)	−2.404	−9.218*	I(1)	I(1)
	LAI	−2.694**	−7.006*	I(0)	−4.847*	−14.961*	I(0)	I(0)
	LDC	−2.632***	−5.338*	I(0)	−2.538***	−7.218*	I(0)	I(0)
	LEC	−2.186	−6.362*	I(1)	−2.385	−9.177*	I(1)	I(1)
	LEU	−1.935	−5.838*	I(1)	−2.194	−5.941*	I(1)	I(1)
	LFE	−2.285	−5.971*	I(0)	−2.362	−5.926*	I(0)	I(0)
	LFF	−4.872*	−4.872*	I(0)	−5.387*	−4.872*	I(0)	I(0)
	LFI	−1.031	−9.707*	I(1)	−1.978	−9.399*	I(1)	I(1)
	LFY	−2.408	−6.754*	I(1)	−2.531	−6.749*	I(1)	I(1)
	LME	−1.779	−8.487*	I(1)	−1.754	−6.068*	I(1)	I(1)
	LMI	−0.131	−4.842*	I(1)	−0.258	−4.871*	I(1)	I(1)
	LRE	−0.131	−4.842*	I(1)	−0.258	−4.871*	I(1)	I(1)
	LSE	−2.586	−4.970*	I(1)	−2.306	−4.975*	I(1)	I(1)
	LSI	−1.766	−5.791*	I(1)	−1.837	−5.805*	I(1)	I(1)
	LY	−0.076	−5.474*	I(1)	−0.498	−5.586*	I(1)	I(1)

Table 4 Unit root tests results (individual country) (continued)

		ADF			*PP*			
		Level	*First difference*	*Order of stationarity*	*Level*	*First difference*	*Order of stationarity*	*Decision*
Senegal	LAE	–2.367	–5.551*	I(1)	–2.191	–14.136*	I(1)	I(1)
	LAI	–2.134	–6.019*	I(1)	–2.134	–6.867*	I(1)	I(1)
	LDC	–1.722	–5.322*	I(1)	–1.905	–5.322*	I(1)	I(1)
	LEC	0.555	–7.136*	I(1)	–0.570	–9.302*	I(1)	I(1)
	LEU	–1.314	–6.179*	I(1)	–1.416	–6.178*	I(1)	I(1)
	LFE	–6.357*	–9.276*	I(0)	–6.354*	–21.996*	I(0)	I(0)
	LFF	–1.526	–7.899*	I(1)	–1.446	–7.932*	I(1)	I(1)
	LFI	–2.705***	–6.969*	I(0)	–2.663***	–7.044*	I(0)	I(0)
	LFY	–1.101	–5.551*	I(1)	–1.952	–9.472*	I(1)	I(1)
	LME	–3.353**	–7.760*	I(0)	–3.418**	–9.559*	I(0)	I(0)
	LMI	–1.704	–7.712*	I(1)	–1.675	–7.768*	I(1)	I(1)
	LRE	–1.500	–5.420*	I(1)	–1.614	–5.410*	I(1)	I(1)
	LSE	–1.809	–6.166*	I(1)	–1.862	–6.162*	I(1)	I(1)
	LSI	–1.536	–6.807*	I(1)	–1.563	–6.805*	I(1)	I(1)
	LY	–0.979	–7.686*	I(1)	–0.763	–7.725*	I(1)	I(1)
Togo	LAE	–2.529	–8.215*	I(1)	–2.368	–9.529*	I(1)	I(1)
	LAI	–2.959**	–5.179*	I(0)	–2.443	–7.785*	I(0)	I(0)
	LDC	–1.814	–7.679*	I(1)	–1.820	–7.633*	I(1)	I(1)
	LEC	–1.792	–6.763*	I(1)	–1.582	–7.017*	I(1)	I(1)
	LEU	–0.443	–6.969*	I(1)	–0.252	–7.056*	I(1)	I(1)
	LFE	–3.744*	–9.398*	I(0)	–3.807*	–9.575*	I(0)	I(0)
	LFF	–2.363	–8.063*	I(1)	–2.216	–8.554*	I(1)	I(1)
	LFI	–2.927**	–6.678*	I(0)	–2.963**	–6.723*	I(0)	I(0)
	LFY	–0.668	–6.323*	I(1)	–0.695	–6.388*	I(1)	I(1)
	LME	–0.729	–11.186*	I(1)	–1.064	–10.562*	I(1)	I(1)
	LMI	–1.681	–5.585*	I(1)	–1.938	–5.576*	I(1)	I(1)
	LRE	–1.147	–5.665*	I(1)	–1.211	–5.659*	I(1)	I(1)
	LSE	–1.496	–6.302*	I(0)	–1.638	–6.303*	I(0)	I(0)
	LSI	–1.475	–4.387*	I(1)	–1.518	–5.032*	I(1)	I(1)
	LY	–1.788	–6.580*	I(1)	–1.884	–6.582*	I(1)	I(1)

Source: Author's compilation from World Bank World Development Indicators (WDI, 2017).

Notes: *, **, *** represent 1%, 5% and 10% significant levels respectively. Lag lengths for ADF are selected using the Schwarz Info Criterion while bandwidths for PP are selected using Newey-West automatic selection with Bartlett kernel spectral estimation method.

Table 5 Static panel data analyses of agriculture trade

Variables	*AED-OLS*	*AED-FE*	*AED-RE*	*AID-OLS*	*AID-FE*	*AID-RE*
LFY	2.239 (0.690)***	–1.604 (0.728)**	**2.239 (0.690)*****	–	–	–
LFF	–1.204 (0.186)***	–0.0371 (0.201)	**–1.204 (0.186)*****	0.263 (0.107)**	0.330 (0.082)***	**0.263 (0.107)****
LEC	0.487 (0.217)**	1.314 (0.318)***	**0.487 (0.217)****	0.023 (0.073)	–0.112 (0.094)	**0.023 (0.073)**
LDC	–0.157 (0.216)	–0.185 (0.167)	**–0.157 (0.216)**	0.153 (0.092)*	–0.0485 (0.069)	**0.153 (0.092)***
LRE	0.026 (0.033)	0.038 (0.033)	**0.026 (0.033)**	–0.010 (0.011)	–0.0400 (0.009)***	**–0.010 (0.011)**
LY	–	–	–	–0.436 (0.134)***	1.627 (0.192)***	**–0.436 (0.134)*****
Constant	–18.76 (5.509)***	5.995 (5.312)	**–18.76 (5.509)*****	–2.051 (0.802)**	–15.13 (1.222)***	**–2.051 (0.802)****
Observations	236	236	**236**	236	236	**236**
R-squared	0.234	0.092	–	0.077	0.344	
Country effect	NO	YES	**YES**	NO	YES	**YES**
Year effect	NO	NO	**NO**	NO	NO	**NO**
F-test	14.08	4.534	–	3.847	23.62	–
Prob > *F*	0.000	0.000586		0.00229	0.000	–
No. of country	–	6	**6**	–	6	**6**
Wald-chi^2	–	–	**70.41**	–	–	**19.23**
Prob > chi^2	–	–	**0.000**	–	–	**0.00174**
Hausman Test		264.21 (0.000)			153.59 (0.000)	

Notes: All variables are in log form and standard errors in parentheses; ***, **, * are 1%, 5% and 10% significant levels.

AED = Agriculture Exports and Disaggregate Energy; AEA = Agriculture Exports and aggregate Energy; AID = Agriculture Imports and Disaggregate Energy;

AIA = Agriculture Imports and aggregated Energy; OLS = Ordinary Least Square; FE = Panel Fixed Effect; and RE = Panel Random Effect.

Estimates of the panel data analysis of the effect of electricity and fossil fuel on *manufactured export and import* are presented in Table 6. Fossil fuel consumption has significant negative effect on manufactured export, while the impact of electricity consumption on it is significant positive. The elasticity of manufactured export with respect to fossil fuel and electricity consumption is –0.64 and 1.61 respectively. Thus, non-affordability of the price (high cost) of fossil fuel (petroleum products) to the manufacturers harms export of the goods. However, the use of electricity in powering industrial plants and machineries boosts output and export of the West African countries. Further, domestic credit and real exchange rate exert positive effect on manufactured export, as a percentage rise in these variables engenders 0.54% and 0.20% (respectively) increase in this export. This confirms the positive role of access to domestic credit and foreign exchange in promoting manufacturing activities, and the elastic nature of demand for manufactures (produced in West Africa) in the world market. The impact of foreign income on West Africa's manufactured export is negligible. Similar to the estimates for export, fossil fuel use produce significant negative impact on import of manufactures, while electricity consumption generated positive effect. This finding could be related to the continuous concerns for the shift to fossil fuel-efficient production technologies which are largely imported from abroad. Moreover, domestic credit and income have significant positive impact on import of manufactured products with elasticity coefficients of 0.57 and 0.49 respectively. This is an indication that increased income (economic growth) and access to credit in West Africa is critical to demand for manufactured import. In addition, the significant negative coefficient of real exchange rate reveals its adverse effect on import of this product.

The results of the panel data analysis of the role of electricity and fossil fuel in *service export and import* are shown in Table 7. Consumption of fossil fuel and electricity has significant negative and positive influence on service export, with elasticity coefficients of –0.21 and 0.63 respectively. In essence, the influence of these energy types on service export is similar to those observed for agricultural and manufactured exports. The coefficient of foreign income is statistically significant and negative, thus 1.0% increase in foreign income reduced service export of the West African countries by about 1.57%. This suggests that, as incomes of trading partners increase, they tend to reduce their export of services from the West African countries and seek alternatives elsewhere (service export of West Africa becomes an inferior good). Furthermore, domestic credit and real exchange rate exert significant positive effect on service export, as 1.0% increase in these variables raise service export by 0.58% and 0.60% respectively. Thus, these variables appear to play important role in financing the provision and export of services by West African countries. Results for the import of service also reveal that fossil fuel and electricity consumption have negative and positive impact on the import respectively. Thus, 1.0% increase in the use of the fossil fuel (electricity) reduces (raises) service imports by about 0.39% (0.13%). This implies that as the use of electricity (unlike fossil fuel) rises in the West African countries, service output is enhanced which in turn reduces the consumption and dependence on foreign services providers. The influence of domestic credit and income is positive, as the response of service import to 1.0% increase in these variables stood at 0.55% and 0.85% respectively, underscoring their critical role in financing such import. The real exchange rate elasticity of service import is found to be –0.02, suggesting that exchange rate has adverse effect on service import. Thus, the deprecation of exchange rate in West African countries hinders import of services.

Table 6 Static panel data analyses of manufacturing trade

Variables	*MED-OLS*	*MED-FE*	*MED-RE*	*MID-OLS*	*MID-FE*	*MID-RE*
LFY	–0.256 (0.527)	0.915 (0.642)	**–0.256** **(0.527)**	–	–	–
LFF	–0.639 (0.142)***	–0.041 (0.178)	**–0.639** **(0.142)****	–0.157 (0.075)**	0.098 (0.063)	**–0.157** **(0.075)****
LEC	1.610 (0.166)***	0.420 (0.281)	**1.610** **(0.166)****	0.123 (0.051)**	–0.415 (0.073)***	**0.123** **(0.051)****
LDC	0.540 (0.165)***	0.466 (0.147)***	**0.540** **(0.165)****	0.569 (0.064)***	0.412 (0.053) ***	**0.569** **(0.064)****
LRE	0.198 (0.026)***	0.120 (0.030)***	**0.198** **(0.026)****	–0.033 (0.007)***	–0.051 (0.007)***	**–0.033** **(0.007)****
LY	–	–	–	0.491 (0.094)***	1.895 (0.147)***	**0.491** **(0.094)****
Constant	–6.568 (4.211)	–13.53 (4.687)***	**–6.568** **(4.211)**	–4.328 (0.560)***	–12.02 (0.939)***	**–4.328** **(0.560)****
Observations	236	236	**236**	236	236	**236**
R-squared	0.607	0.411	–	0.354	0.586	–
Country effect	NO	YES	**YES**	NO	YES	**YES**
Year effect	NO	NO	**NO**	NO	NO	**NO**
F-test	71.06	31.38	–	25.24	63.65	–
Prob > *F*	0.000	0.000	–	0.000	0.000	–
No. of country		6	**6**	–	6	**6**
Wald-chi^2	–	–	**355.3**	–	–	**126.2**
Prob > chi^2	–	–	**0.000**	–	–	**0.000**
Hausman Test		57.70 (0.000)			1.43 (0.6978)	

Notes: All variables are in log form and standard errors in parentheses; ***, **, * are 1%, 5% and 10% significant level.

MED = Manufacturing Exports and Disaggregate Energy; MEA = Manufacturing Exports and aggregate Energy; MID = Manufacturing Imports and Disaggregate Energy; MIA = Manufacturing Imports and aggregated Energy; OLS = Ordinary Least Square; FE = Panel Fixed Effect; and RE = Panel Random Effect.

Table 7 Static panel data analyses of services trade

Variables	*SED-OLS*	*SED-FE*	*SED-RE*	*SID-OLS*	*SID-FE*	*SID-RE*
LFY	–1.566 (0.328)***	–0.748 (0.360)**	**–1.566** **(0.328)****	–	–	–
LFF	–0.210 (0.088)**	0.201 (0.100)**	**–0.210** **(0.088)****	–0.390 (0.088)***	–0.146 (0.051)***	**–0.390** **(0.088)****
LEC	0.629 (0.103)***	–0.129 (0.158)	**0.629** **(0.103)****	0.132 (0.060)**	–0.482 (0.058)***	**0.132** **(0.060)****
LDC	0.584 (0.103)***	0.509 (0.083)***	**0.584** **(0.103)****	0.549 (0.075)***	0.249 (0.043)***	**0.549** **(0.075)****
LRE	0.0593 (0.016)***	–0.002 (0.017)	**0.059** **(0.016)****	–0.015 (0.009)*	–0.061 (0.006)***	**–0.015** **(0.009)***
LY	–	–	–	0.846 (0.110)***	2.876 (0.120)***	**0.846** **(0.110)****
Constant	8.989 (2.617)***	3.899 (2.630)	**8.989** **(2.617)****	–6.410 (0.657)***	–17.49 (0.763)***	**–6.410** **(0.657)****
Observations	236	236	**236**	236	236	**236**
R-squared	0.344	0.207	–	0.335	0.775	–
Country effect	NO	YES	**YES**	NO	YES	**YES**
Year effect	NO	NO	**NO**	NO	NO	**NO**
F-test	24.15	11.74	–	23.16	154.6	–
Prob > *F*	0.000	4.23e-10	–	0.000	0.000	–
No. of country	–	6	**6**	–	6	**6**
Wald-chi^2	–	–	**120.8**	–	–	**115.8**
Prob > chi^2	–	–	**0.000**	–	–	**0.000**
Hausman Test		136.93 (0.000)			704.04 (0.000)	

Notes: All variables are in log form and standard errors in parentheses; ***, **, * are 1%, 5% and 10% significant level.

SED = Service Exports and Disaggregate Energy; SEA = Service Exports and aggregate Energy; SID = Service Imports and Disaggregate Energy; SIA = Service Imports and aggregated Energy; OLS = Ordinary Least Square; FE = Panel Fixed Effect; and RE = Panel Random Effect.

Table 8 Static panel data analyses of fuel trade

Variables	*FED-OLS*	*FED-FE*	*FED-RE*	*FID-OLS*	*FID-FE*	*FID-RE*
LFY	–4.566 (1.369)***	0.789 (1.268)	**–4.566 (1.369)*****	–	–	–
LFF	2.501 (0.369)***	–1.566 (0.351)***	**2.501 (0.369)*****	0.287 (0.193)	0.591 (0.155)***	**0.287 (0.193)**
LEC	0.423 (0.430)	0.770 (0.554)	**0.423 (0.430)**	1.055 (0.132)***	0.252 (0.178)	**1.055 (0.132)*****
LDC	–0.074 (0.429)	0.726 (0.291)**	**–0.074 (0.429)**	0.225 (0.166)	–0.153 (0.131)	**0.225 (0.166)**
LRE	0.005 (0.066)	0.0097 (0.058)	**0.005 (0.066)**	0.041 (0.019)**	–0.047 (0.018)***	**0.041 (0.019)****
LY	–	–	–	1.335 (0.242)***	1.977 (0.364)***	**1.335 (0.242)*****
Constant	24.57 (10.94)**	–8.293 (9.256)	**24.57 (10.94)****	0.627 (1.447)	–18.25 (2.321)***	**0.627 (1.447)**
Observations	236	236	**236**	236	236	**236**
R-squared	0.259	0.098	–	0.387	0.279	
Country effect	NO	YES	**YES**	NO	YES	**YES**
Year effect	NO	NO	**NO**	NO	NO	**NO**
F-test	16.11	4.886	–	28.99	17.44	–
Prob > *F*	0	0.000290	–	0	0	–
No. of country	–	6	**6**	–	6	**6**
Wald-chi^2	–	–	**80.53**	–	–	**145**
Prob > chi^2	–	–	**0**	–	–	**0**
Hausman Test		308.48 (0.000)			82.91 (0.000)	

Notes: FED = Fuel Exports and Disaggregate Energy; FEA = Fuel Exports and aggregate Energy; FID = Fuel Imports and Disaggregate Energy; FIA = Fuel Imports and aggregated Energy; OLS = Ordinary Least Square; FE = Panel Fixed Effect; and RE = Panel Random Effect.

Panel data results for *export and import of fuel* (Oil) are presented in Table 8. The coefficient of fossil fuel consumption is positive and statistically significant; with fossil fuel elasticity of fuel export of 2.50%. This underscores the role of refined fossil fuel (petroleum products) in facilitating the functioning of machines and equipment used in the production and export of crude oil in West Africa. However, the results reveal that the impact of electricity on fuel (crude oil) export is negligible. The results indicate the relative importance of the two types or sources of energy in fuel (crude oil) production and export in the West African countries. The effect of foreign income on export of fuel is negative and significant. The results suggest that, as income increased in the partner countries (particularly the developed countries, which form the main market for fuel originating from West African countries) there is a shift to renewable energy sources following increased campaign against global warming. Other factors such as domestic credit and exchange rate do not exhibit any significant effect on fuel (crude oil) export. Contrary to the estimates for fuel export, while the effect of fossil fuel is insignificant, electricity consumption exerts significant positive effect on fuel import, as 1.06% increase in the later resulted from a percentage rise in the former. Thus, electricity consumption compliments refined fossil fuel (petroleum products) consumption in these countries (which largely comes from abroad). Also, fuel import elasticity of real exchange rate and domestic income is 0.04 and 1.34 respectively. This suggests that both increased incomes and exchange rate affordability encourage fuel import. Results further reveal that domestic credit does not have significant influence on fuel import.

3.3 Country level analysis of impact of disaggregate energy consumption on trade

3.3.1 Trade in agricultural commodities and disaggregate energy consumption

The results on the effect of disaggregated energy consumption on agricultural exports of the selected West African countries are presented in Table 9. ARDL-bounds test reveal that the F statistics is higher than the upper bound critical value at 10% except for Togo where F statistics falls within the upper and lower bound critical values. Thus, the null hypothesis of no co-integration is rejected in these countries and long-run co-integration relationship is confirmed among the variables. The diagnostic tests confirm the appropriateness of the models. Results reveal that *in the short-run*, foreign income (both current period and previous) has significant positive impact on agricultural exports of Benin, while it produces insignificant effect in Côte d'Ivoire, Ghana, Nigeria, Senegal and Togo. These results suggest that an increase in foreign income promoted agricultural exports of only Benin. The impact of fossil fuel consumption on agricultural export is negative and significant in Benin, Côte d'Ivoire and Senegal, but insignificant in the remaining three countries (Nigeria, Ghana and Senegal). This result implies that an increase in fossil fuel use reduces agricultural export of Benin, Côte d'Ivoire and Senegal. The impact of electricity consumption on agricultural export is also negative and significant in Benin but positive and significant in Côte d'Ivoire and Senegal. With respect to domestic credit, the results show a significant positive impact on agricultural export of Benin but significant negative impact on the export of Côte d'Ivoire and Nigeria, while producing insignificant impact in the remaining countries. A significant negative impact of real exchange rate on agricultural export is shown in Benin, Nigeria

and Senegal. Also, the previous (lag) value of real exchange rate has a significant positive impact on agricultural export in only Côte d'Ivoire, but insignificant impact in the remaining countries. Moreover, the error correction term (ECM) which reflects the speed of adjustment to equilibrium when disequilibrium occurs varies from 22% in Togo to 85% in Benin.

In the long-run, the results on the impact of foreign income on agricultural export reveal a significant positive impact in only Benin, and significant negative impact in only Senegal. This indicates that an increase in foreign income enhances agricultural export in only Benin, but reduces agricultural export of only Senegal. Further, in Benin, Côte d'Ivoire and Senegal, the results show a significant negative impact of fossil fuel on agricultural export, while indicating insignificant effect in the remaining countries. Electricity consumption does not have significant impact on agricultural exports in all the countries except Benin where the impact is negative. Moreover, the results indicate a significant negative impact of domestic credit on agricultural export of Côte d'Ivoire and Nigeria, but significant positive effect in Benin. Finally, the results showed a significant negative impact of real exchange rate on agricultural export of Benin, Côte d'Ivoire, Nigeria and Senegal, but insignificant effect on the export of the remaining countries.

The results in respect of the relationship between agricultural imports and disaggregated energy are also presented in Table 9. The ARDL-bounds test reveals that the F statistics is higher than the upper bound critical value at 10% except for Senegal and Togo where F statistics falls within the upper and lower bound critical values. Thus, the null hypothesis of no co-integration is rejected in these countries and long-run co-integration relationship is confirmed among the variables. The diagnostic tests validate the specified models. *In the short-run*, the results show a significant positive impact of domestic income on agricultural import of Benin and Côte d'Ivoire. However, a significant negative effect is revealed on export of Senegal, while insignificant impact is shown in the remaining countries. Moreover, the results indicate a significant positive impact of fossil fuel on agricultural import of only Benin; and significant negative effect in only Senegal, while insignificant influence is revealed in the remaining countries. Also, a significant negative impact of electricity consumption on agricultural import is shown in only Benin and Senegal, while the effect is insignificant in the remaining countries. Similarly, Benin and Senegal are the only countries where a significant positive impact of domestic credit on agricultural imports is revealed. Moreover, the impact of real exchange rate on agricultural import is negative and significant in Benin, Côte d'Ivoire, Nigeria and Senegal, while its impact is insignificant in the remaining two countries. In the same vein, the previous (lag) value of real exchange rate has a significant positive impact on agricultural import of Ghana; significant negative impact on export of Benin, but insignificant impact in the remaining countries. In addition, the error correction term (ECM) which indicates the speed of adjustment ranges from 22% in Togo to 85% in Benin.

In the long-run, the results reveal a significant positive impact of domestic income (on agricultural import of Benin, Côte d'Ivoire, Ghana and Nigeria, while significant negative impact is shown for Senegal, and insignificant effect for Togo. This implies that, while an increase in domestic income raises agricultural import of Benin, Côte d'Ivoire, Ghana and Nigeria, it reduces agricultural import of Senegal, and produces insignificant impact in Togo. For the impact of fossil fuel on agricultural import, the results also reveal a significant positive impact in only Benin, but a significant negative

impact in only Senegal. Electricity consumption shows insignificant impact on agricultural import of four out of the six countries except Benin and Senegal. The results further show that an increase in electricity consumption raises agricultural import of Senegal, but reduces that of Benin. Furthermore, the results indicate a significant positive impact of domestic credit on agricultural import of only Benin and Senegal. Finally, the impact of real exchange rate on agricultural import is negative and significant in Côte d'Ivoire, Ghana, Nigeria and Senegal, but positive and significant in only Benin.

3.3.2 Trade in fuel products and disaggregate energy consumption

Short-run and long-run results of the impact of fossil fuel and electricity use on export of fuel products are reported in Table 10. The results of the ARDL-bounds test show that the F statistics is higher than the upper bound critical value at 10% suggesting that null hypothesis of no co-integration is rejected for Benin, Côte d'Ivoire, Ghana and Senegal, and long-run co-integration relationship is established among the variables. However, for Nigeria and Togo, the F-statistics, which fall within the lower and upper bounds at 10%, suggests inconclusive decision. Diagnostics tests employed supports the correctness of the models estimated. *Short-run* impact of fossil fuel consumption on fuel export is observed to be significant (positive) only in the case of Côte d'Ivoire with elasticity of 1.05, while the impact of electricity consumption is negligible in all the countries. This result may be due to the fact that fuel takes a negligible fraction of total exports of these countries (except Nigeria) or because, the cost of energy is negligible in the total production cost of the export. Also, while short-run effect of domestic credit on fuel export is significant in Benin and Nigeria, negative influence is discovered in the case of Nigeria. This follows the nature of oil production and export in developing economies (including West Africa) where foreign investment dominates and domestic credit plays little role. Foreign income and real exchange rate do not exert significant effect on fuel export of all the countries. The error correction terms which show the speed of adjustment of any deviation in fuel exports to long-run equilibrium range from 22% in Togo to 85% in Benin.

In the long-run, the impact of fossil fuel consumption on fuel export is significant and positive in only Côte d'Ivoire, but significant negative in Benin and Senegal. Also, electricity consumption has significant (negative) influence on fuel export in only Nigeria. Estimates show that the responsiveness of fuel export to changes in the consumption of these energy types is very elastic. Most of the countries are passive players in the world fuel market and therefore, an increased consumption of energy (fossil fuel or electricity) may not boost their production and export of fuel appreciably. Long-run coefficient of foreign income is significant and positive in Benin and Côte d'Ivoire, with 1.0% increase in foreign income resulting to a significant rise in fuel export. The impact of domestic credit on fuel export is significant and negative in only Nigeria, while real exchange rate exert significant negative influence on export of Côte d'Ivoire and Ghana ,with inelastic and highly elastic responses of fuel export respectively.

Table 9 Agricultural trade and disaggregated energy

Variable	*Benin*		*Cote D'Ivore*		*Ghana*		*Nigeria*		*Senegal*		*Togo*	
	Exports	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*
						Short-run						
D(LY)		22.202 (12.35) *		1.343* (2.606)		1.204 (1.124)		1.879 (1.478)		–3.104 (–5.083)*		1.209 (1.592)
D(LY(-1))												–0.285 (–0.343)
D(LFY)	22.20 (5.049)*		1.343 (0.983)		1.204 (0.234)		1.879 (0.322)		–3.104 (–0.828)		1.209 (0.196)	
D(LFY(-1))	22.00 (5.224)*								4.758 (0.198)			
D(LFF)	–1.730 (–8.613)*	9.390 (49.443)*	–0.562 (–2.315)**	0.406 (1.159)	–0.232 (–0.427)	–0.232 (–0.701)	0.407 (0.192)	–0.583 (–1.036)	–1.165 (–2.042)**	–2.468 (–5.895)*	0.285 (0.780)	–0.201 (–1.068)
D(LFF(-1))							0.525 (0.246)					
D(LEC)	–2.114 (–6.111)*	–22.00 (–68.84)*	1.047 (2.992)*	–0.562 (–1.249)	–0.130 (–0.486)	–0.130 (–0.737)	0.056 (0.039)	–0.525 (–0.875)	1.647 (2.210)**	–1.165 (–3.579)*	–0.201 (–0.306)	–0.138 (–0.399)
D(LEC(-1))			0.536 (1.496)				0.218 (0.149)		1.639 (2.047)**			
D(LDC)	4.214 (25.497)*	0.978 (5.599)*	–0.424 (–2.431)**	0.027 (0.056)	0.151 (0.405)	0.151 (0.661)	–11.375 (–13.72)*	0.056 (0.159)	–0.408 (–1.058)	0.754 (6.166)*	–0.138 (–0.467)	0.161 (1.044)
D(LDC(-1))					–0.052 (–0.161)			0.218 (0.644)				

Table 9 Agricultural trade and disaggregated energy (continued)

Variable	*Benin*		*Cote D'Ivore*		*Ghana*		*Nigeria*		*Senegal*		*Togo*	
	Exports	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*
					Short-run							
D(LRE)	−3.217 (−12.52)*	−2.114 (−5.598)*	0.074 (0.419)	−0.424 (−2.23)**	−0.019 (−0.245)	0.052 (0.358)	−8.414 (−13.822)*	−11.38 (−10.86)*	−0.414 (−.863)***	−1.639 (−14.71)*	0.201 (0.361)	−0.238 (−0.888)
D(LRE(-1))		−4.214 (−10.58)*	8.521 (44.314)*			7.796 (55.173)*	−0.233 (−0.351)					−0.238 (−0.882)
D(Trend)	−78.54 (1003.9)*		0.081 (2.603)**		−2.291 (−5.397)*		12.118 (88.821)*		0.153 (1.719)***		−0.424 (−3.672)*	
ECM	−0.849 (−7.123)*	−0.850 (−4.998)*	−0.684 (−5.787)*	−0.684 (−4.529)*	−0.397 (−.386)**	−0.396 (−.626)**	−0.473 (−2.929)*	−0.473 (−3.003)*	−0.603 (−4.617)*	−0.603 (−6.637)*	−0.219 (−1.78)***	−0.219 (−1.913)
					Long-run							
LY		26.135 (4.243)*		1.964 (2.366)**		3.728 (2.128)**		4.831 (3.319)*		−5.151 (−3.457)*		2.454 (0.964)
LFY	11.29 (1.711)***		2.558 (1.323)		3.728 (0.387)		3.972 (0.306)		−17.140 (−.987)**		1.154 (0.039)	
LFF	−0.885 (−4.738)*	11.053 (5.34)*	−0.822 (−.941)***	0.594 (1.244)	−0.586 (−0.405)	−0.586 (−0.629)	−1.483 (−0.488)	−1.23 (−0.997)	−1.934 (−2.095)**	−11.989 (−6.19)*	1.300 (0.633)	−0.918 (−0.831)
LEC	−4.087 (−5.239)*	−27.93 (−4.907)*	0.787 (1.425)	0.709 (1.453)	−0.328 (−0.480)	−0.328 (−0.685)	0.198 (0.043)	−1.110 (−0.788)	1.263 (0.761)	0.799 (2.808)*	−0.918 (−0.296)	0.287 (0.172)
LDC	4.961 (5.928)*	1.151 (3.071)*	−0.620 (−2.090)**	−0.744 (−1.619)	−0.029 (−0.044)	−0.161 (−0.341)	−51.384 (−2.943)*	0.198 (0.301)	−0.678 (−1.128)	1.251 (3.741)*	−0.631 (−0.448)	0.736 (0.989)
LRE	−3.786 (−7.098)*	0.874 (2.091)**	−12.815 (−5.915)*	−0.620 (−1.99)**	−0.050 (−0.252)	−19.576 (−.638)**	−19.378 (−2.983)*	−24.037 (−3.013)*	−0.686 (−.798)***	−2.720 (−7.637)*	1.653 (0.775)	−1.938 (−1.593)

Table 9 Agricultural trade and disaggregated energy (continued)

Variable	Benin		Cote D'Ivore		Ghana		Nigeria		Senegal		Togo	
	Exports	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*
						Long-run						
Constant	0.519 (0.010)	–3.786 (–0.309)	17.894 (1.019)	0.109 (0.019)	–19.657 (–0.249)	–5.776 (–0.915)	2.158 (0.023)	–27.347 (–3.214)*	150.750 (2.013)**	–0.678 (–0.123)	–1.087 (–0.004)	1.085 (0.045)
Trend	–92.45 (–7.106)*		0.118 (2.349)**		–5.776 (–.329)**		25.607 (2.965)*		0.254 (1.576)		–1.935 (–1.451)	
R-Square	0.930	0.631	0.949	0.638	0.781	0.812	0.826	0.568	0.774	0.879	0.736	0.847
Bound Test (K)[a]	5.265 (5)*	3.797 (5)**	5.255 (5)*	3.351 (5)***	6.468 (5)[b]	10.659 (5)*	4.696 (5)**	11.162 (5)*	4.153 (5)***	3.690 (5)	3.507 (5)	2.821 (5)
LM Test	0.414 (0.525)	3.037 (0.091)***	0.068 (0.796)	0.273 (0.604)	0.732 (0.399)	0.022 (0.882)	1.396 (0.248)	4.384 (0.044)**	2.182 (0.150)	0.799 (0.378)	0.511 (0.479)	0.034 (0.855)
ARCH	0.437 (0.512)	22.248 (0.000)*	0.699 (0.408)	1.484 (0.230)	1.310 (0.259)	1.252 (0.269)	2.515 (0.121)	0.506 (0.481)	0.992 (0.325)	0.036 (0.851)	0.684 (0.413)	0.093 (0.762)
JaqueBera	6.269 (0.044)**	0.501 (0.779)	1.276 (0.528)	1.739 (0.419)	0.115 (0.944)	0.890 (0.641)	1.151 (0.562)	0.192 (0.909)	1.266 (0.531)	11.125 (0.004)	1.233 (0.539)	0.922 (0.631)
RR Test	0.958 (0.336)	1.650 (0.208)	0.400 (0.532)	1.139 (0.293)	2.063 (0.161)	0.294 (0.592)	0.284 (0.599)	2.889 (0.099)	0.102 (0.751)	0.027 (0.869)	0.028 (0.868)	1.449 (0.238)

Source: Estimated regression model using ARDL Co-integration techniques.

Notes: *, **,*** represent 1%, 5% and 10% significant levels respectively and figure in parenthesis refers to the t-statistic value; Test = Ramsey Reset Test.

[a]The critical Value Bound at 1% = (3.41 – 4.68); 5% = (2.62 – 3.79) and 10% = (2.26 – 3.35) for lower and upper bound.

[b]The critical Value Bound at 1% = (3.93 – 5.23); 5% = (3.12 – 4.25) and 10% = (2.75 – 3.79) for lower and upper bound.

Regarding fuel import, the appropriateness of the model is validated by the diagnostic statistics. ARDL-bounds test suggests that the F statistics is higher than the upper bound critical value at 10%, suggesting that null hypothesis of no co-integration is rejected for Ghana, Nigeria and Togo and long-run co-integration relationship is confirmed among the variables. However, for Benin, Côte d'Ivoire and Senegal, the F-statistics, which fall within the lower and upper bounds at 10%, suggests inconclusive decision. *In the short-run*, while fossil fuel and electricity consumption exert significant impact on fuel import of Benin and Senegal, the influence of electricity on the import is positive in only Benin. Thus, the results suggest that increased use of electricity is complemented with increased import of fuel for consumption in only Benin, while consumption of fossil fuel is hardly met by increased fuel import. In addition, domestic income has short-run significant impact on fuel import of Benin, Côte d'Ivoire and Senegal (although the effect is negative in Senegal). This suggests that increased domestic income (economic growth) contributes immensely to fuel import in the case of only Benin and Côte d'Ivoire. Moreover, domestic credit has significant positive effect on fuel import in Côte d'Ivoire and Senegal, but significant negative impact in Benin and Nigeria. Similarly, real exchange rate elasticity of fuel import is –1.36, 0.15, 1.02 and –1.64 in Benin, Ghana, Nigeria and Senegal respectively. This indicates diverse influence of domestic credit and real exchange rate across the countries. The error correction terms which show the speed of adjustment of any deviation in fuel imports from long-run equilibrium vary from 22% in Togo to 85% in Benin.

Long-run results reveal that the effect of fossil fuel use on fuel import is significant (negative) in only Benin and Senegal, while electricity consumption exert significant impact on fuel import of Benin (positive), Nigeria (negative) and Senegal (negative). While the influence of these energy types is elastic in all the three countries, responses of fuel import vary from country to country. The negative effect of fossil fuel consumption on (official) fuel import suggests that either domestic production of fuel has increased or informal fuel import is growing. This is because, in the absence (or inadequacy) of domestic production, fuel import should increase as domestic fuel consumption increases. There is also substitutability and complementarity in the use of fuel and electricity in the countries. Domestic income is found to have significant positive impact on fuel import of Benin, Côte d'Ivoire and Nigeria but significant negative effect in Senegal with elastic responses of fuel import in all cases. These results therefore support the important role of domestic income in fuel import. Mixed findings are observed for domestic credit and real exchange rate. Thus, domestic credit exert significant positive impact on fuel import of Côte d'Ivoire and Senegal with elasticity of 1.53 and 3.98 respectively, but its effect is significant negative in Benin and Nigeria with elasticity of –2.49 and –9.38 respectively. Fuel import response to real exchange rate is positive and significant in Ghana and Nigeria but significant negative in Senegal, as 1.0% increase in this variable caused fuel import to rise by 0.38% and 2.16% in Ghana and Nigeria respectively but fall by 3.40% in Senegal.

Table 10 Individual country analysis of fuel trade and disaggregated energy

Variable	*Benin*		*Côte d'Ivoire*		*Ghana*		*Nigeria*		*Senegal*		*Togo*	
	Exports	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*
						Short-run						
D(LY)	–	22.202 (6.397)*	–	1.343 (2.461)**	–	1.204 (1.270)	–	1.880 (1.043)	–	–3.104 (–2.317)**	–	1.210 (0.849)
D(LY(-1))	–	–	–	–	–	–	–	0.583 (0.344)	–	–	–	–
D(LFY)	22.202 (1.176)	–	1.343 (0.765)	–	1.204 (0.150)		1.880 (0.842)	–	–3.104 (–0.650)	–	1.210 (0.036)	–
D(LFY(-1))	22.000 (1.195)	–	0.562 (0.325)	–	–	–	0.583 (0.284)	–	–	–	–	–
D(LFF)	–1.730 (–1.358)	–22.000 (–45.849)*	1.047 (3.622)*	0.406 (1.163)	0.274 (0.165)	0.274 (0.449)	–0.525 (–0.887)	–0.525 (–0.410)	–2.468 (–0.700)	–2.468 (–2.502)**	0.285 (0.158)	0.285 (0.852)
D(LFF(-1)	2.114 (1.662)	–	–	–	–	–	–0.256 (–0.441)	–0.256 (–0.178)	1.165 (0.300)	–	–	–
D(LEC)	–1.358 (–0.740)	0.978 (2.179)**	–0.536 (–1.127)	–0.562 (–1.302)	–0.232 (–0.178)	–0.232 (–0.717)	–0.218 (–0.599)	–0.218 (–0.255)	1.647 (0.531)	–1.165 (–3.172)*	–0.201 (–0.054)	–0.201 (–0.308)
D(LEC(-1))	–	–	–	–	–	–	–	12.941 (14.412)*	1.639 (0.487)	–	–	–
D(LDC)	4.214 (2.335)**	–2.114 (–7.315)*	–0.424 (–0.868)	1.047 (3.875)*	0.151 (0.124)	–0.130 (–0.519)	–12.941 (–50.126)*	–8.414 (–16.667)*	–0.408 (–0.261)	1.647 (2.563)**	0.201 (0.072)	0.201 (0.444)

Table 10 Individual country analysis of fuel trade and disaggregated energy (continued)

Variable	*Benin*		*Côte d'Ivoire*		*Ghana*		*Nigeria*		*Senegal*		*Togo*	
	Exports	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*
Short-run												
D(LDC(-1))	–	–	–	–	–	–	0.989 (4.829)*	–0.233 (–0.499)	–	–	0.238 (0.095)	0.238 (0.589)
D(LRE)	0.441 (0.468)	–1.358 (–2.331)**	–0.316 (–1.141)	0.027 (0.148)	0.052 (0.056)	0.151 (7.597)*	0.233 (1.201)	1.021 (18.011)*	–0.414 (–0.504)	–1.639 (–4.071)*	–0.424 (–0.244)	–0.424 (–0.777)
D(LRE(-1))	–	3.217 (5.061)*	–	–	7.796 (9.389)*	–	–	–	–	–	–	1.008 (2.000)**
ECM (-1)	–0.850 (–4.982)*	–0.850 (–4.796)*	–0.684 (–6.483)*	–0.684 (–5.118)*	–0.397 (–2.408)**	–0.397 (–2.382)**	–0.473 (–3.370)*	–0.473 (–2.810)*	–0.603 (–3.805)*	–0.603 (–3.816)*	–0.219 (–1.467)	–0.219 (–1.455)
Long-run												
LY	–	37.188 (4.059)*	–	1.964 (2.296)**	–	3.036 (0.996)	–	3.600 (1.987)***	–	–5.151 (–1.768)***	–	1.154 (0.203)
LFY	11.292 (1.759)***	–	1.736 (2.737)*	–	3.036 (0.150)	–	3.600 (0.875)	–	–5.151 (–0.648)	–	1.154 (0.047)	–
LFF	–3.373 (–4.691)*	–27.933 (–4.583)*	1.571 (2.915)*	0.594 (1.117)	0.692 (0.168)	0.692 (0.461)	–0.451 (–0.615)	–0.451 (–0.175)	–13.923 (–2.787)*	–11.989 (–3.236)*	1.300 (0.156)	1.300 (0.721)
LEC	–1.599 (–0.734)	1.151 (1.891)***	–0.784 (–1.054)	–0.822 (–1.094)	–0.914 (306)	–0.586 (–0.655)	–24.498 (–3.141)*	–51.845 (–2.971)*	1.263 (0.202)	–1.934 (–2.405)**	–1.559 (–0.087)	–1.550 (–0.461)
LDC	1.174 (1.421)	–2.488 (–3.288)*	–0.511 (–1.304)	1.531 (3.329)*	–0.161 (–0.077)	–0.328 (–0.525)	–47.216 (3.325)*	–19.378 (–2.898)*	–0.678 (–0.254)	3.983 (4.960)*	0.566 (0.080)	0.566 (0.435)
LRE	0.519 (0.478)	–0.425 (–0.755)	–0.925 (–2.981)*	0.040 (0.148)	–19.576 (–2.384)**	0.381 (2.305)**	2.650 (3.453)	2.158 (2.882)*	–0.686 (–0.480)	–3.398 (–3.209)*	–1.935 (–0.237)	–5.449 (–1.142)

Table 10 Individual country analysis of fuel trade and disaggregated energy (continued)

Variable	*Benin*		*Côte d'Ivoire*		*Ghana*		*Nigeria*		*Senegal*		*Togo*	
	Exports	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*
					Long-run							
Constant	0.519 (0.011)	0.519 (0.030)	–0.462 (–0.068)	–0.784 (–0.145)	–5.776 (–0.033)	–0.542 (–0.046)	25.607 (1.008)	25.607 (0.826)	150.750 (2.346)**	–0.686 (–0.051)	1.085 (0.007)	–4.598 (–0.101)
R-Square	0.5687	0.805	0.892	0.691	0.425	0.233	0.857	0.867	0.454	0.759	0.491	0.790
Bound Test (K)[a]	4.423 (5)	2.614 (5)	3.702 (5)	2.765 (5)	3.377 (5)	4.731 (5)	2.454 (5)	5.417 (5)	11.973 (5)	2.706 (5)	3.262 (5)	3.305 (5)
LM Test	1.428	2.626***	3.454**	1.797	2.266	2.657***	0.079	1.029	1.622	0.894	0.793	2.261
ARCH	14.939*	0.651	0.188	1.108	1.098	4.284	0.238	0.786	1.337	0.580	2.693	0.072
Jaque Bera	1.314	1.159	0.249	7.988	12.470*	24.060*	0.723	2.717	31.893*	0.479	0.239	0.319
RR Test	4.061***	32.326*	0.837	0.003	4.888**	0.228	1.719	0.082	34.713*	0.390	1.133	0.008

Source: Estimated regression model using ARDL Co-integration techniques.

Notes: *,**,*** represent 1%, 5% and 10% significant levels respectively and figure in parenthesis refers to the t-statistic value. RR Test = Ramsey Reset Test.

[a]The critical Value Bound at 1% = (3.41 – 4.68); 5% = (2.62 – 3.79) and 10% = (2.26 – 3.35) for lower and upper bound.

3.3.3 Trade in manufactures and disaggregate energy consumption

Short-run and long-run results of the impact of fossil fuel and electricity use on trade in manufactures are presented in Table 11. ARDL-bounds test results for the export models reveal that F statistics is higher than the upper bound critical value at 1% for Benin, Nigeria and Senegal, suggesting that null hypothesis of no co-integration is rejected, and long-run co-integration relationship is found among the variables. However, for Côte d'Ivoire, Ghana and Togo, the F-statistics fall within the lower and upper bounds at 10% implying inconclusive decision. Diagnostics tests employed support the correctness of the models estimated. *In the short-run*, significant effect of fossil fuel use on manufactured export is observed for Benin, Senegal and Togo such that 1.0% rise in fossil fuel consumption lead to a greater positive response in Benin than the negative response in other countries. The effect of electricity consumption is significant negative in only Benin and Senegal where elasticity is –1.73 and –4.76 respectively. West African countries are fringe players in the world market for manufactures, thus, increased production with either electricity or fossil fuel does not guarantee rising export of these products from these economies. The impact of foreign income on export of manufactures vary from significant positive in Benin and Côte d'Ivoire to significant negative in Senegal and negligible effect in Ghana, Nigeria and Togo. Similarly, the results show significant positive effect of domestic credit on manufactured export of Benin and Côte d'Ivoire but significant negative effect on the export of Nigeria. The negative effect may reflect the underdeveloped and inefficient financial system in most of West African countries including Nigeria, and the crowding out effect of foreign investment (in most heavy manufacturing activities) on domestic investment. Moreover, real exchange rate has significant (negative) effect in all the countries except Côte d'Ivoire and Togo where insignificant effect is found, reflecting the less competitive nature of manufactured exports in these economies. The error correction terms also reflect the speed of adjustment that range from about 22% in Togo to 85% in Benin.

In the long-run, the effects of fossil fuel and electricity consumption are significant (negative) in only Benin and Senegal, with very high responsiveness of manufactured export to the consumption of these energy types. These negative and insignificant effects may be linked with inefficiency in the energy utilisation and non-competitiveness of manufactured products (originating from these economies) in the world market. Similar to short-run estimates, foreign income has significant positive effect on export of manufactures in Benin and Côte d'Ivoire, but significant negative effect in Senegal. Also, significant effect of domestic credit is observed for the case of Benin (positive), Côte d'Ivoire (positive), Nigeria (negative) and Senegal (positive) ,while the effect of real exchange rate is significant (negative) in only Benin. Thus, improvement in access to domestic credit may promote manufactured export in some West African countries (especially Benin, Côte d'Ivoire and Senegal), while real exchange rate may hurt such export.

In terms of import of manufactures, diagnostic tests establish the specification of the models as appropriate. Also, ARDL-bounds test the F statistics is higher than the upper bound critical value at 10% suggesting that null hypothesis of no co-integration is rejected for Ghana and Nigeria and long-run co-integration relationship is confirmed among the variables. However, for Benin, Côte d'Ivoire, Senegal and Togo, the F-statistics, which fall within the lower and upper bounds at 10%, suggests inconclusive decision. The, *short-run* results reveal significant positive impact of fossil fuel

consumption on import of manufactures in Benin and Togo and significant negative effect in Senegal. However, significant (negative) effect of electricity consumption on manufactured import is discovered in only Benin and Senegal. Further, results disclose significant positive effect of domestic income on manufactured import in all selected countries, except Senegal where negative impact is found. In all the selected countries, the responsiveness of manufactured import is elastic, as income growth raises demand for foreign manufactured products. Moreover, while domestic credit shows significant (negative) effect on manufactures import of only Benin and Senegal, the effect of real exchange rate is negative and significant in almost all the countries except Senegal (positive) and Ghana (insignificant). This reflects the inefficiency of financial sector in financing import of manufactured goods, and the adverse effect of depreciating real exchange rate on import of the West African countries. The coefficients of the error correction terms are similar to those obtained for other sectors.

Long-run results show that both fossil fuel and electricity consumption have significant negative effect on manufacturing import of Senegal while consumption of these energy types have significant positive effect in Benin and Côte d'Ivoire respectively, reinforcing the earlier findings that the use of these energy types produce different effects on manufacturing import in these economies. Increased use of the energy variety to boost production implies reduction in imports. However, import of some manufactured goods such as plants and machineries may necessitate high energy use. Moreover, significant elastic response of manufactures import to a percentage increase in domestic income is found for almost all the countries, although this impact is negative in Senegal and insignificant in Togo. Domestic credit has significant (negative) effect on manufacturing import only in Côte d'Ivoire where 1.0% increase in domestic credit contributed about 0.75% reduction in manufactures import. However, manufactures import response to real exchange rate is significant negative in Côte d'Ivoire and Togo but significant positive in Senegal.

3.3.4 Trade in services and disaggregate energy consumption

Revealed in Table 12 are the effects of fossil fuel and electricity consumption on services export of the selected West African countries. The results show that, in the *short-run,* foreign income (both in the current and previous periods) has a significant positive impact on services export of only Benin and Togo. However, it has a significant negative impact on services export of Senegal and insignificant effect in Ghana and Nigeria. These results suggest that, an increase in foreign income raises services export of Benin and Togo and reduces that of Senegal. Also, the impact of fossil fuel on service export is negative and significant in only Senegal Benin and Togo, while it generated insignificant effect in the remaining countries. A significant positive impact of electricity consumption on services exports is noticed in only Benin, while a significant negative impact is shown in only Senegal, and insignificant impact in the remaining countries. Similarly, domestic credit has a significant positive impact on service export of Benin while a significant negative impact is indicated in Senegal and insignificant impact in the remaining countries. Moreover, a significant negative impact of real exchange rate on services exports is revealed in only Benin and Senegal. The error correction terms which show the speed of adjustment are similar to those discussed earlier.

Table 11 Individual country analysis of trade in manufactures and disaggregated energy

Variable	*Benin*		*Côte d'Ivoire*		*Ghana*		*Nigeria*		*Senegal*		*Togo*	
	Exports	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*
						Short-run						
D(LY)		22.202 (20.663) *		1.343 (2.743)*		1.204 (2.492)**		1.879 (5.497)*		–3.104 (–5.681)*		1.209 (2.232)**
D(LFY)	22.202 (4.283)*		1.343 (3.113)*		1.204 (0.309)		1.879 (0.463)		–3.104 (–4.217)*		1.209 (1.367)	
D(LFF)	21.999 (105.342)*	9.389 (95.992) *	0.406 (1.400)	0.406 (1.798)	0.274 (0.361)	0.274 (0.821)	0.407 (0.793)	0.407 (1.042)	–2.468 (–5.536)*	–2.468 (–7.728)*	–0.956 (–2.825)*	0.285 (1.868)***
D(LFF(-1))							0.525 (0.747)	0.525 (1.380)				
D(LEC)	–1.729 (–3.554)*	–22.00* (–109.30)*	–0.562 (–1.192)	1.046 (3.536))	–0.130 (–0.325)	–0.232 (–1.045)	0.056 (0.060)	0.056 (0.215)	–4.758 (–8.465)*	–4.758 (–36.874)*	–0.201 (–0.361)	–0.138 (–0.610)
D(LEC(-1))	2.114 (4.587)*	–0.978 (–5.156)					0.218 (0.226)					
D(LEC(–2))	1.358 (2.797)*											
D(LDC)	4.214 (15.576)*	–2.114 (–18.297)*	1.047 (4.106)*	0.027 (0.081)	0.151 (0.443)	0.151 (1.132)	–11.375 (–18.273)*	0.256 (1.694)	1.647 (3.957)	–1.165 (–11.346)*	–0.138 (0.568)	0.201 (1.159)
D(LDC(-1))							8.414 (15.858)*					0.238 (1.375)

Table 11 Individual country analysis of trade in manufactures and disaggregated energy (continued)

Variable	*Benin*		*Côte d'Ivoire*		*Ghana*		*Nigeria*		*Senegal*		*Togo*	
	Exports	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*
						Short-run						
D(LRE)	–3.217 (–7.865)*	–1.358 (–6.189)*	0.027 (0.143)	–0.424 (–2.24)**	–0.215*** (–1.99)	–0.215 (–1.309)	–0.989 (–2.203)**	–11.375 (–93.332)*	–1.639 (–11.291)*	1.647 (14.346)*	0.201 (0.447)	–0.42 (–1.96)***
D(LRE(-1))	–0.441 (0.309)	3.217 (14.829)*		0.424 (2.498)**		0.019 (0.149)	–1.021 (–2.293)**			1.639* (14.811)		0.424 (2.273)**
ECM	–0.849 (–6.011)*	–0.849 (–4.863)*	–0.683 (–5.011)*	–0.684 (–4.520)*	–0.397** (–2.510)	–0.397 (–2.54)**	–0.474 (–3.187)	–0.473 (–4.37)*	–0.60 (–4.046)*	–0.603 (–4.837)*	–0.22 (–2.02)***	–0.22 (–1.70)***
						Long-run						
LY		26.135 (4.376)*		1.964 (3.180)*		3.036 (2.605)**		3.972 (6.948)*		–5.15 (–3.148)*		1.153 (0.588)
LFY	37.188 (7.819)*		1.964 (2.605)**		3.036 (0.312)		3.972 (0.432)		–5.15 (–3.237)*		5.517 (1.398)	
LFF	–25.897 (–6.235)*	11.053 (4.998)*	0.594 (1.428)	–0.228 (–0.531)	0.106 (0.046)	0.692 (0.931)	–1.483 (–0.795)	–1.483 (–1.929)	–4.12 (–3.215)*	–4.09 (–3.661)*	–3.063 (–1.165)	0.382 (0.535)
LEC	–4.972 (–4.14)*	–26.782 (–4.862)	–0.822 (–1.428)	1.531 (4.478)*	–0.328 (–0.329)	–0.914 (–1.478)	0.198 (0.092)	0.117 (0.212)	–9.828 (–3.383) *	–7.894 (–4.904)*	–0.918 (–0.364)	–0.631 (–0.553)
LDC	4.961 (7.379)*	–2.488 (–4.090)	1.531 (3.057)*	–0.747 (–2.322)**	0.381 (0.464)	0.381 (0.977)	–69.164 (–3.137)*	0.080 (0.277)	3.983 (3.310)*	–1.934 (–3.883)	–0.631 (–0.547)	0.566 (1.230)
LRE	–2.748 (–3.985)*	–0.425 (–2.258)	0.040 (0.143)	–1.860 (–5.210)*	–0.542 (–1.681)	–0.461 (–2.648)	0.561 (1.675)	–51.384 (–4.379)	–2.720 (–3.856)	1.263 (3.390)*	1.653 (1.046)	–5.81 (–1.78)***

Table 11 Individual country analysis of trade in manufactures and disaggregated energy (continued)

Variable	*Benin*		*Côte d'Ivoire*		*Ghana*		*Nigeria*		*Senegal*		*Togo*	
	Exports	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*
Long-run												
Constant	0.519 (0.02)	0.519 (0.071)	–0.784 (0.896)	–0.620 (–0.133)	0.131 (0.001)	–0.050 (–0.006)	25.607 (0.406)	–17.780 (–4.633)	–0.678 (–0.085)	–0.678 (–0.140)	–1.087 (–0.039)	–1.935 (–0.121)
R-Square	0.839	0.757	0.565	0.938	0.870	0.881	0.899	0.944	0.659	0.904	0.848	
Bound Test (K)[a]	4.170 (5)**	2.959 (5)	3.268 (5)	2.411 (5)	2.439 (5)	4.903 (5)*	6.650 (5)*	3.710 (5)***	6.043 (5)*	2.169 (5)	2.509 (5)	2.923 (5)
LM Test	1.428	2.626***	3.454**	1.797	2.266	2.657***	0.079	1.029	1.622	0.894	0.793	2.261
ARCH	14.939*	0.651	0.188	1.108	1.098	4.284	0.238	0.786	1.337	0.580	2.693	0.072
Jaque Bera	1.314	1.159	0.249	7.988	12.470*	24.060*	0.723	2.717	31.893*	0.479	0.239	0.319
RR Test	4.061***	32.326*	0.837	0.003	4.888**	0.228	1.719	0.082	34.713*	0.390	1.133	0.008

Source: Estimated regression model using ARDL Co-integration techniques.

Note: [a]The critical Value Bound at 1% = (3.41 – 4.68); 5% = (2.62 – 3.79) and 10% = (2.26 – 3.35) for lower and upper bound.

*,**,*** represent 1%, 5% and 10% significant levels respectively and figure in parenthesis refers to the t-statistic value; Test = Ramsey Reset Test.

Long-run effect of fossil fuel consumption on services export is significant in Benin (negative) and Senegal (positive) where the consumption of this energy yields elastic response of service export. The effect of electricity consumption on service export is significant (negative) in Benin, Ghana and Senegal where elasticity is –2.94, –0.91 and –2.72 respectively. Similar to the results obtained for manufacturing export, consumption of these energy types appears to produce adverse effect on export of services originating from some of the selected West African countries. Foreign income exerted significant positive (and elastic) effect on service export of Benin and Togo, and significant negative (and elastic) influence in Senegal. In addition, domestic credit is found to have significant positive (negative) effect on service export of Benin (Senegal) with elasticity of 4.96 (–2.05), while real exchange rate has significant negative effect on export of Benin, Nigeria and Senegal.

The results in respect of the relationship between services import and disaggregated energy are also presented in Table 12. *In the short-run*, the results show a significant positive impact of domestic income on services import of Benin, Ghana, Nigeria, Senegal and Togo, while it has insignificant effect in the remaining country. Moreover, the results reveal a significant positive impact of fossil fuel on services import of Benin, Ghana and Togo, and a significant negative impact in Senegal, but insignificant effect in Nigeria. Electricity consumption generates a significant negative impact on service import of Benin, and a significant positive impact in Senegal, while it produces insignificant in the remaining countries. In the same vein, Benin and Senegal are the only countries with a significant impact of domestic credit on services import. However, while it has negative effect in Benin, it produces positive impact in Senegal, and insignificant effect in the remaining countries. Furthermore, the impact of real exchange rate on services imports is negative and significant in Ghana, Senegal and Togo but positive and significant in Benin .and insignificant impact in Nigeria.

In the long-run, fossil fuel consumption has significant negative impact on service import of only Benin, while electricity consumption exerts significant negative effect on service import of Benin and Nigeria. These results reflect that energy consumption is a major driver of import of service in some of the countries been analysed. There is significant positive influence of domestic income on service import of Benin and Ghana, while it produces significant negative impact in the case of Senegal (with elastic response of service import in all cases). Also, significant negative impact of domestic credit on service import is found in Benin, as 1.0% increase in domestic credit is associated with 1.60% decline in this import. However, real exchange rate has significant negative effect on service import of Togo, but significant positive effect in Benin and Senegal.

Table 12 Individual country analysis of trade in service and disaggregated energy

Variable	Benin		Ghana		Nigeria		Senegal		Togo	
	Exports	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*
					Short-run					
D(LY)		22.202 (32.01)*		1.204 (2.750)*		1.879 (3.859)*		–3.104 (–5.97)*		1.209 (2.55)**
D(LY(-1))		22.00 (23.305)*								
D(LY(-2))		1.729 (2.311)**								
D(LFY)	22.203 (11.964)*		1.204 (0.727)		1.879 (0.971)		–3.104 (–3.04)*		1.209 (2.825)*	
D(LFY(-1))							4.758 (5.337)*			
D(LFF)	–22.00 (–200.95)*	0.977 (20.279)*	0.274 (1.115)	0.274 (1.758)***	0.407 (0.567)	0.407 (1.349)	–1.17 (–4.289)*	–2.468 (–6.96)*	–0.957 (–7.39)*	0.285 (2.394)**
D(LFF(-1))					0.525 (0.747)		–0.75 (–2.728)*	1.165 (3.506)		0.138 (1.384)
D(LEC)	0.978 (5.485)*	–2.114 (–20.999)*	–0.233 (–1.249)	–0.130 (–1.127)	0.056 (0.155)	–0.583 (–1.642)	–1.639 (–7.42)*	1.647 (13.994)*	0.285 (1.091)	0.201 (1.031)
D(LEC(-1))	1.358 (8.172)*			0.215 (1.97)***						

Table 12 Individual country analysis of trade in service and disaggregated energy (continued)

Variable	*Benin*		*Ghana*		*Nigeria*		*Senegal*		*Togo*	
	Exports	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*
Short-run										
D(LDC)	4.2142 (58.133)*	–1.358 (–21.532)*	0.151 (0.796)	0.052 (0.749)	0.256 (1.292)	0.056 (0.382)	–0.408 (–2.254)**	0.753 (3.464)*	–0.138 (–0.733)	0.161 (1.125)
D(LDC(-1))			–0.052 (–0.281)				0.414 (2.887)*	0.408 (2.332)**		
D(LRE)	–3.217 (–22.418)*	4.214 (32.009)*	–0.019 (–0.397)	–0.019 (–1.960)***	–0.218 (–1.019)	0.256 (1.507)	–0.41 (–5.314)*	–0.41 (–3.296)*	0.201 (1.031)	–0.424 (–2.25)**
D(LRE(-1))		–0.44 (–2.739)**								
D(LRE(-2))		–0.441 (–3.806)*								
ECM	–0.849 (–5.847)*	–0.849 (–5.905)*	–0.397 (–2.890)*	–0.397 (–2.633)**	–0.47 (–4.139)*	–0.473 (–3.494)*	–0.60 (–5.037)*	–0.60 (–4.167)*	–0.219 (–1.561)	–0.219 (–1.457)
Long-run										
LY		9.256 (4.928)*		3.036 (4.503)*		3.972 (6.503)		–5.15 (–3.014)*		1.154 (0.742)
LFY	37.188 (6.074)*		3.036 (0.856)		3.972 (0.847)		–17.14 (–5.29)*		5.52 (1.73)***	
LFF	–27.933 (–5.859)*	1.151 (6.404)*	0.692 (1.166)	0.106 (0.217)	–1.483 (–1.374)	0.859 (1.213)	2.049 (3.590)*	–13.92 (–4.356)	–4.363 (–1.465)	–0.249 (–0.365)
LEC	–2.936 (–5.191)*	–2.488 (–5.457)*	–0.91 (–1.75)***	–0.489 (–1.493)	0.118 (0.156)	–2.34 (–2.797)***	–2.72 (–3.718)*	2.733 (3.874)	0.382 (0.221)	0.918 (0.788)

Table 12 Individual country analysis of trade in service and disaggregated energy (continued)

Variable	*Benin*		*Ghana*		*Nigeria*		*Senegal*		*Togo*	
	Exports	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*	*Exports*	*Imports*
					Long-run					
LDC	4.961 (5.827)*	–1.599 (–5.042)*	–0.029 (–0.077)	0.131 (0.676)	0.541 (1.335)	0.118 (0.398)	–2.05 (–4.208)*	–2.147 (–3.191)	–0.631 (–0.522)	–0.351 (–0.472)
LRE	–3.267 (–6.103)*	2.212 (5.068)*	–0.050 (–0.439)	–0.050 (–3.523)	–24.50 (–4.08)*	0.080 (1.476)	–0.686 (–5.39)*	150.06 (4.157)*	1.653 (1.216)	–0.85 (–0.419)***
Constant	0.519 (0.063)	0.519 (0.127)	–19.657 (–0.583)	–19.657 (–6.454)	–27.347 (–0.77)	–24.037 (–5.082)	–0.686 (–0.182)	0.254 (0.061)	–1.087 (–0.089)	–1.936 (–0.175)
R-Square	0.618	0.835	0.951	0.963	0.842	0.930	0.942	0.935	0.845	0.928
Bound Test (K)	8.351 (5)*	4.973 (5)*	4.303 (5)**	4.039 (5)**	2.612 (5)	2.383 (5)	3.478 (5)***	5.599 (5)	2.753 (5)	2.353 (5)
LM Test	0.025 (0.876)	1.802 (0.190)	0.331 (0.569)	0.029 (0.865)	0.177 (0.676)	0.411 (0.526)	0.712 (0.406)	1.235 (0.275)	0.170 (0.683)	0.016 (0.899)
ARCH	0.143 (0.707)	0.857 (0.360)	27.605 (0.000)*	0.216 (0.645)	0.761 (0.388)	4.470 (0.041)	1.633 (0.209)	2.652 (0.111)	0.465 (0.499)	1.283 (0.264)
JaqueBera	5.185 (0.075)***	1.648 (0.439)	9.369 (0.009)*	0.407 (0.816)	1.581 (0.454)	0.929 (0.628)	1.279 (0.528)	1.963 (0.375)	1.123 (0.570)	1.468 (0.480)
RR Test	1.164 (0.289)	0.110 (0.742)	0.034 (0.855)	2.632 (0.115)	14.408 (0.001)*	0.349 (0.559)	0.262 (0.612)	1.103 (0.302)	0.023 (0.881)	2.000 (0.168)

Source: Estimated regression model using ARDL Co-integration techniques.

Notes: *,**,*** represent 1%, 5% and 10% significant levels respectively and figure in parenthesis refers to the t-statistic value; Test = Ramsey Reset Test.

4 Summary, conclusion and policy lessons

This paper examined the impact of energy (fossil fuel and electricity) consumption on sectoral trade in selected West African countries over 1971 to 2015. It employed the both the panel data analysis and modified auto-regressive distributed lag (ARDL) approach to estimate trade-energy link models derived from the standard trade theories.

Panel data analysis indicates that the effect of fossil fuel consumption on agricultural, manufactured and services exports is negative, while that of fuel export is positive. However, electricity has positive effect on the exports of three sectors, while its impact on fuel export is insignificant. Further, fossil fuel generates negative impact on manufactured and services imports, but positive and insignificant effect on agricultural and fuel exports respectively. The effect of electricity on sectoral imports is positive except for agricultural products where it is insignificant.

Results of the country level analysis reveal that *in the short-run*, the impact of fossil fuel consumption on agricultural export is negative and significant in Benin, Côte d'Ivoire and Senegal, but insignificant in the remaining three countries. Also, the impact of electricity consumption on agricultural export is negative and significant in Benin but positive and significant in Côte d'Ivoire and Senegal. Further, the results indicate a significant positive impact of fossil fuel on agricultural import of only Benin; and significant negative effect in only Senegal, while insignificant influence is revealed in the remaining countries. In addition, a significant negative impact of electricity consumption on agricultural import is shown in only Benin and Senegal, while the effect is insignificant in the remaining countries. *In the long-run*, the results show a significant negative impact of fossil fuel on agricultural export of Benin, Côte d'Ivoire and Senegal, while indicating insignificant effect in the remaining countries. However, electricity consumption does not have significant impact on agricultural exports in all the countries except Benin where the impact is negative. For the impact of fossil fuel on agricultural import, the results also reveal a significant positive impact in only Benin, but a significant negative impact in only Senegal. Electricity consumption shows insignificant impact on agricultural import of four out of the six countries except Benin and Senegal where it reduces agricultural import and raises it respectively.

In the short-run, significant effect of fossil fuel use on manufactured export is observed for Benin, Senegal and Togo such that 1.0% rise in fossil fuel consumption lead to a greater positive response in Benin than the negative response in other countries. The effect of electricity consumption is significant negative in only Benin and Senegal. Results further reveal significant positive impact of fossil fuel consumption on import of manufactures in Benin and Togo and significant negative effect in Senegal. However, significant (negative) effect of electricity consumption on manufactured import is discovered in only Benin and Senegal. *The long-run* effects of fossil fuel and electricity consumption on manufactured export are significant (negative) in only Benin and Senegal. In addition, results show that both fossil fuel and electricity consumption have significant negative effect on manufacturing import of Senegal, while consumption of these energy types have significant positive effect in Benin and Côte d'Ivoire respectively.

The results show that, in the *short-run*, the impact of fossil fuel on service export is negative and significant in only Senegal Benin and Togo, while it generated insignificant effect in the remaining countries. A significant positive impact of electricity consumption on services exports is noticed in only Benin, while a significant negative impact is shown

in only Senegal, and insignificant impact in the remaining countries. Also, the results show a significant positive impact of fossil fuel on services import of Benin, Ghana and Togo, and a significant negative impact in Senegal, but insignificant effect in Nigeria. Electricity consumption generates a significant negative impact on service import of Benin, and a significant positive impact in Senegal, while it produces insignificant in the remaining countries. *Long-run* effect of fossil fuel consumption on services export is significant in Benin (negative) and Senegal (positive). Also, the effect of electricity consumption on service export is significant (negative) in Benin, Ghana and Senegal. Moreover, fossil fuel consumption has significant negative impact on service import of only Benin, while electricity consumption exerts significant negative effect on service import of Benin and Nigeria.

Short-run impact of fossil fuel consumption on fuel export is significant (positive) only in the case of Côte d'Ivoire, while the impact of electricity consumption is negligible in all the countries. Further, while fossil fuel and electricity consumption exert significant impact on fuel import of Benin and Senegal, the influence of electricity on the import is positive in only Benin. In the *long-run*, the impact of fossil fuel consumption on fuel export is significant and positive in only Côte d'Ivoire, but significant negative in Benin and Senegal. Also, electricity consumption has significant (negative) influence on fuel export in only Nigeria. Results also reveal that the effect of fossil fuel use on fuel import is significant (negative) in only Benin and Senegal, while electricity consumption exert significant impact on fuel import of Benin (positive), Nigeria (negative) and Senegal (negative).

It should be noted that, trade and other macroeconomics policies that promote sectoral exports would be at variance with energy conservation policy in countries where increased energy consumption promotes export, Further, low marginal energy efficiency (MEE) in the production of secroral exports could be addressed via appropriate pricing of energy products to ensure optimal input mix in the production activities of producers and by encouraging the use of low cost energy alternatives.. Large scale efficient public provision of energy infrastructure is imperative in these countries so as to minimise the costs of critical energy such as electricity and fossil fuel. High energy and infrastructure costs in West African countries (due to inefficient public sector supply and the high cost of alternative private provision) make their export non-competitive in the international markets. Moreover, the cost implications must be such that both residential and commercial end-users are not overly impacted adversely. In countries where there is a trade-off between energy use and sectoral import, liberal import policy that promotes that import should form part of energy conservation policy that could be applied. This could also mean that there is possibility for substitution between energy and imported inputs. However, where complementarity exists between energy use and sectoral import liberal import policy will hinder the effectiveness of energy conservation policy. Thus, energy conservation could be achieved via either the introduction of import tariffs on commodities or promotion of increased production of domestic import substitutes through provision of incentives to produces so as to lessen import and promote energy saving. It should also be noted that this analysis has implications for environmental pollution in the countries. Thus, if energy is a critical export production inputs, then environmental pollution could escalate except for a shift to the use of cleaner energy and the accompanying technologies.

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Notes

1 Diversification in this study is conceived as the shift from production of primary products to manufactured goods.

2 The choice of these panel unit root test are due to their favouring of unbalance panel data.

3 Côte d'Ivoire Service exports and imports models were not analysed due to data constraints.

4 WAMZ represents West African Monetary Zone; WAEMU means West African Economic and Monetary Union; and ECOWAS means Economic Community of West African States.