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Renewable Energy, Trade Performance and the Conditional Role of Finance and Institutional Capacity of sub-Sahara African Countries[1]

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Renewable Energy, Trade Performance and the Conditional Role of Finance and Institutional Capacity of sub-Sahara African Countries

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Abstract

The paper investigates the dynamic relationship between renewable energy usage and trade performance in sub-Saharan Africa (SSA), while considering the conditioning role of corruption control, regulatory quality, and the private sector access to finance. Focusing on 42 SSA countries for the period 2004-2016, and engaging the System generalized method of moments (GMM) technique for its estimation, this study found a negative relationship between renewable energy usage and the indicators of trade performance. However, with corruption control, improved regulatory framework, and better finance for the private sector, there are potentials for a positive net impact of renewable energy usage on manufacturing export. For renewable energy and total trade nexus, we find that improved regulatory framework and better finance for the private sector are important conditioning structures. These findings are significant because they highlight the different important structures of SSA countries that improve the effect of renewable energy use on trade outcomes. For instance, the consideration of the financial, institutional and regulatory frameworks in SSA countries in conditioning the renewable energy-trade nexus stipulates a clear policy pathway for countries in this region as the debate for transition to the use of renewable energy progresses.

Keywords: Environment; Green growth; Trade performance; Pollution; Renewable energy; sub-Saharan Africa

JEL Codes: C5; F1; Q4; Q5

1. Introduction

The realization that current production and consumption patterns that are not environmentally friendly – in terms of pollution - coupled with high economic dependencies of developing countries onprimary export, which increases environmental risks, has further reinforced the increasingattention on the importance of transitioning to renewableenergy usage for development (Njoh *et al*, 2019; Rezaee, Yousefi and Hayati, 2019). Such development is expected to result ineconomic progress and environmental sustainability, which is consistent with Amavilah *et al.* (2017)'s argument for inclusiveness and sustainability in the growth trajectory of African countries.

A number of countries, including those in sub-Saharan Africa (SSA), havemade some commitment through the signing of international agreements (e.g. Paris Climate Agreement) to lower carbon emission levels and adopt efficient production processes that minimize environmental risks. However, this has been difficult to implement, and progress towards the implementation of such agreements has remained sluggish due togrowing economic prosperity of SSA is connected with primary products extraction, which increases environmental pollution and other forms of emission (Akinyemi *et al*, 2017; Asongu, le Roux and Biekpe, 2017; Njoh *et al*, 2019; Obeng-Darko, 2019). Therefore, managingthis trade-off between environmental sustainability and economic progress has remained a challenge in SSA.

This paper contributes to this policy discussion by adopting a unique approach that rely on the data from the World Bank World Development Indicators, and other sources to estimate the direct relationship between renewable energy usage and two trade outcomes (total trade and manufacturing export) of SSA countries. The data also allows for theexploration of the conditioning effect of institutional structure (control of corruption), regulatory quality, and private sector access to finance on the nexus. As such, the analysis of this paper advances the proposition that althoughthe transition to renewable energy use may be costly on SSA's trade outcomes, such costscanbe significantly reduced with the improvement of these structures.

This inquiry is important for the following reasons. First, the relationship between renewable energy usage and trade performance is not completely documented in current literature, especially for SSA countries. This paper, thus, fills this scholarly gap. Second, in terms of policy importance of the findings in this paper, thenumerousbenefits from renewable energy usage (especially in relation to reduced carbon emission and environmental sustainability) isan opportunity to understandthose structures that matter in the SSA context in reducing the cost of transitioningto such sustainable energy sources. As it is well known, the usage of renewable energy and achieving competitiveness in industrial production and trade may be difficult in the SSA region consideringthe capital and technological demand,which are lacking in this region (Gui-Diby and Renard, 2015; Obeng-Darko, 2019). Further, regulatory qualityis another important matterto be considered in the transition to renewable energy usefor trade outcomes (United Nations Environment Programme-UNEP, 2013).These issues are considered in this study with empirical justifications for new generation policies on how to promote renewable energy usage for economic outcomes in the SSA region.

Third, there are numerous economic, social and environmental benefits in pursuingrenewable energy usage. They include job creation, reduced poverty and inequality, more sustainable use of natural resources, increased productivity, improved energy security, reduced greenhouse gas emission, improved competitiveness and trade balances, enhanced environmental quality, better health outcomes, amongst others (Organization for Economic Cooperation and Development-OECD, 2012; Osabuohien, Efobi and Gitau, 2015). However, not much is known about the benefit (or not) of renewable energy consumption on trade outcomes of SSA countries, and how such benefits can be achieved.

Thefocus of this study on trade outcomes in the SSA region is motivated based on the fact that the economies of SSA countries are diverse and shaped by internationaltrade relations. However, primary commodities mainly characterize the trade baskets of these countries, and sustainable energy consumption could further improve the export capacities of these countriesthrough industrial development and the expansion of the manufacturing capacity(International Energy Agency - IEA, 2017). There is the need for effective policies and institutional framework that could enhance the benefits from renewable energy consumption in the SSA countriesin achieving better productivity growth and trade flows. Therefore, adopting strategies that support renewable energy usage can have implications for competitiveness, especially for the SSA region that have hitherto relied on the export of primary and unrefined product. Thus, there is theneed for policy options that ensures that there is a *win-win* situation whereby those associated costs of renewable energy consumption is significantly minimized, and benefits from its consumption are leveraged upon.

The key findings from the analysisin this paperinclude, that:theuse of renewable energy has a consistent negative association with both total trade and manufacturing export, while improvement incorruption control, which is a measure of institutional quality, could eliminate the negative association seen for renewable energy and trade outcomes. The finding also establishes that there is a consistent complementary effect for regulatory quality and finance as regards the relationship betweenrenewable energy use and trade outcomes. These results are consistent when subjected to different robustness checks. Theassumed channels through which these impacts are seen include theproduction expansion that stems from a more reliable and sustainable energy source, which is seen when institutions, regulatory quality, and finance are improved in the sub-Sahara African region.

The findings of this paper extends the broad literature that has considered the relationship between renewable energy and economic outcomes, including Bulut and Muratoglu (2018), Kecek, Mikulic, and Lovrincevic (2019), Rath, Akram, Bal, and Mahalik (2019). However, the study of Aissa, Jebli, and Youssef (2014) is the closest to this paper, and the authors conclude that a significant evidence exist between renewable energy and trade in impacting output in Africa. However, this paper differs by focusing on how SSA countries can effectively adopt renewable energy source to achieve improved trade outcomes. The emphasis on the conditional effect ofinstitutional framework, regulatory quality, and financial structure on renewable energy-trade nexus further offers new insight into understanding the important structural transformation that are required in SSA countries, which has not been discussed in previous studies.

The rest of the paper is outlined as follows: the next section discusses the review of related literature, while the research method, the data, the model specification, and the estimation techniques are discussed in the third section. The empirical results are presented in the fourth section. The discussion and conclusion is in the fifth section.

2. Review of Related Literature

Studies that have considered the relationship between renewable energy and economic outcomes include Bulut and Muratoglu (2018), whoemployed co-integration and causality approaches to understand the relationship betweenrenewable energy consumption and economic growth in Turkey. The author found no causality between both variables.The contrary was found in Kecek, Mikulic, and Lovrincevic (2019) on the deployment of renewable energy plants and the economic effect for Croatia. The authors conclude that fostering renewable energy will potentially have more intensive effects on the national economy, but also call for better structural improvement to realize such potential. Adewuyi and Adeniyi (2015) in a different study that focus on West Africa engaged the vector error correction models to study how energy consumption affects trade outcome for six countries, and they found a heterogeneous effect across countries. For instance, while no significant relationship was seen for Benin, Cote d'Ivoire, and Togo, the opposite was seen for Ghana, Nigeria, and Senegal. Yet, Rath, Akram, Bal, and Mahalik (2019) evaluated a cross-country data in relation to renewable energy and total factor productivity growth, and concluded that indeed, renewable energy consumption boosts the total factor productivity of countries.

From the studies reviewed, it is not clear how developing countries in SSAcould maximize the economic benefit of renewable energy consumption through setting up important institutional, regulatory, and financial structures to support its adoption. This present study is focused on these three important structures as they have been resounded in the policy ecosystem as important issues to be considered in defining the pathway for renewable energy usage in the African region (African Development Bank, 2017a).

There are arguments in the literature to support the importance of the implementation of these structures to support renewable energy usage on trade.First, financing renewable energy is expensive and there is a huge financial resource gap in the SSA region to support its usage. Studies have suggested the implementation of the public-private partnership and investment to fill this resource gap (Salm, Hille, and Wustenhagen, 2016; Broughel and Hampl, 2018; Herrmann *et al*, 2018; Broughel, 2019). Other studies suggest that the capital market and the improvement of other financial development indicators are important factors that explain the extent to which renewable energy can be efficiently utilized for economic outcomes (Ji and Zhang, 2019). The argument being that,for instance, as more finance is made available to the private sector, investment in innovation and specific energy-generating technology will increase (see Mazzucato and Semieniuk, 2018) and likewise the productivity of firms will rise (see Rath, Akram, Bal, and Mahalik, 2019).

Second, the issue of the regulatory environment for the efficiency of renewable energy usage is also emphasized in some other studies (e.g. Obeng-Darko, 2019). The author highlights that the prospect for the efficiency of renewable energy usage in Ghana is slim because ofa poor legal and regulatory framework, which makes investors to lose confidence in economic participation. Such a conclusion was echoed in Ahmadov and Borg (2019) who highlighted that the quality of the regulatory process could largely determine the effectiveness of renewable energy usage. Other studies that support similar conclusion include Herrmann *et al* (2018) for Malawi, Bradshaw and Jannuzzi (2019) for Brazil, Washburn and Pablo-Romero (2019) for Latin American countries, and Rezaee, Yousefi, and Hayati (2019) for Iran.

Third, corruption (a reflection of a weak institutional framework) is another issue that is considered in the literature. These studies highlight that corruption increases the cost of renewable energy adoption through informal payments to self-interest public officers and other illicit fiscal charges (Njoh *et al*, 2019), which hurts economic engagement. Apart from economic cost, corruption can stall well-designed renewable energy policies, resulting in an adverse impact on economic outcome of countries (Gennaioli and Tavoni, 2016). The overall implication of such adverse effect includes slow economic growth and less productivity, which logically hurts trade outcome (Lambsdorff, 2003; OECD, 2014).

This current paper harnesses these arguments in the literature and complements studies which focus on the economic outcomes of renewable energy consumption and those mechanisms that can complement its efficient usage, especially in the SSA region (see earlier discussed studies, including Bulut and Muratoglu, 2018). This issue is also policy relevant as the institutional framework, regulatory quality, and financial structure are a resounding policy trio for renewable energy consumption in the SSA context. Yet, not much is known about how they affect renewable energy consumption-trade outcome nexus.

3 Data and Methodology

3.1 Variables and Data

The explained variable is the trade outcome in SSA countries, which is measured as total trade (*tot_trade*), and manufacturing export (*man_export*). The data for these variables are from the World Bank World Development Indicators (WDI). The inclusion of different dimensions of trade for theanalysisin this paper is motivated by the need to understand how renewable energy usageaffects different trade outcomes of the economies of SSA countries. More so, the use of different dimensions of trade allows for more policy implications from this study. Specifically, *tot_trade* measures the total export and import of goods and services in comparison to the total Gross Domestic Products (GDP) of the respective countries, while *man_export* measures the export from commodities like chemicals, basic manufactures, machinery and transport equipment, and other miscellaneous manufactured goods (excluding non-ferrous metals).The focus on the manufacturing export, as an additional measure of trade, is motivated by the recent policy drive in the region to improve Africa's manufacturing outcome for global competitiveness (African Development Bank, 2017b).

The main explanatory variable of this study comes from the World Bank World Development Indicatorsdatabase on renewable energy consumption as a percentage of total final energy consumption (*Renew*). This was the most appropriate proxy for renewable energy usage for which sufficient data is available for the sampledcountries. This data is defined as the percentage of energy whose natural sources are not depleted such as wind or solar, to total energy consumption in the respective countries. This variable was later interacted with the institutional, regulatory, and finance structure of SSA countriesto achievethe objectives of the paper. These structures are identified as corruption control (for institutions), regulatory quality, and access to finance.

Corruption control (*corruption*), which identifies both petty and grand forms of corruption, as well as those from the state by elites and private interests, is measured as a score from ‘0’ (weak) to ‘5’ (strong). Similarly, the regulatory quality (*reg_quality*), which reflects the government’s ability to formulate and implement sound policies and regulations that permit and promote private sector development, is also measured as ‘0’ (weak) to ‘5’ (strong). These two measures were obtained from the World Governance Indicators, and their original values range from ‘-2.5’ (weak) to ‘2.5’ (strong), which werelater rescaled by adding ‘2.5’ to each country’s score.

Access to finance (*bus_environ*), measures the extent to which the country has a favorable environment for industrial growth and private sector developmentthrough private sector access to finance - i.e. domestic credit from formal financial institutions to the private sector as a percentage of GDP. This variable was obtained from the World Bank’s WorldDevelopment indicators. Other important country characteristics, which potentially affect trade outcomes, were controlled for. They include, first, the countries’ human capital development (*Hum_cap*), which is expected to enhancelabor productivity and boost firm competitiveness (Zahonogo, 2016). This variable is measured using the tertiary school enrollment, and preferred to the primary and secondary school enrolment because it best captures higher level of human capital development for industrial development, and it is a more complete data compared to the other measures. Second, following Osabuohien *et al* (2019),some traditional trade theory variables that reflect a country’s supply side capacity to international trade, such as proxies for average productivity of labor supply (GDP per capita –*GDP_Pcap*), investment capital for each economy (i.e. gross fixed capital formation as a percentage of GDP – *GFCF*), and the Hirschman index of diversification as computed from United Nations Conference on Trade and Development data (*H_index*) and which is important to portray the benefit of economic diversification, were included as covariates. Finally, the real effective exchange rate, taken from the World Bank WDI, was included because it is animportant measure of trade price.

The data for this study is an extensive panel for 42 African countries over the sample period 2004–2016.The list of countries that were included in the sample, the mean value of renewable energy usage in comparison to total energy consumption, and the indicators of trade (total and manufacturing) are presented in Table A1 in the Appendix. The countries that were selected in the sample and the study period are based on data availability for the key variables. More so, this period is the most recent and available evidence to answer the research questions.

The summary statistics for each variable are in Table A2 in the Appendix, while the correlation matrix to test the bivariate relationships and the possibility of multicollinearity are presented in Table A3 in the Appendix. A quick overview of the expected relationship between the indicators of trade and renewable energy, without interacting with the indicators of the economic, institutional, and regulatory structures, is presented in Figure 1. As expected, it is evident from the Figure 1 that there is a negative bivariate relationship between the indicators of trade and the transition to renewable energy use in the SSA region. However, the extent to which this negative relationship can be cushioned out with the improvement of these structures in the SSA region is the focus of the econometric analysis in the subsequent section.

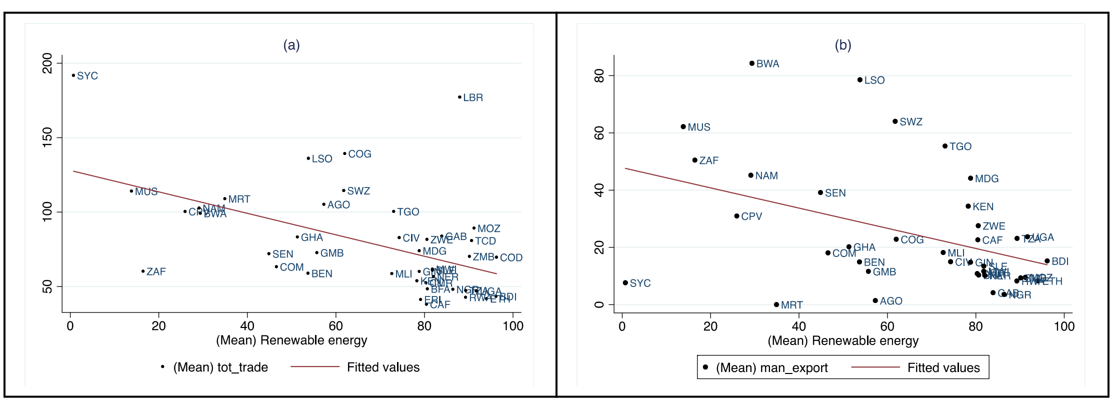

Figure 1: Bivariate Relationship – Trade and Renewable Energy Use in SSA (2004-2016)
Source: Authors' Computation from World Bank WDI (2018)

3.2 Estimation Technique

The empirical strategy aims at estimating the effect of renewable energyusageon trade performance, while considering the conditional effect of institutions, regulatory framework and access to financestructures in the selected SSA countries. The motive being tounderstand whether the negative effect proceeding from renewable energyusageon trade (as seen from Figure 1) can be reduced by the presence of these structures to promote the notion of 'two-steps-at-a-time' policy[2] option for enhancing the competitiveness of SSA export performance in the drive for a more sustainable energy policy.

The empirical strategy is underpinned by the studiesthat have shown statistically significant relationships between institutions, finance, the regulatory environment and renewable energy usage in countries (Gboney, 2008; Stern, 2015; Gennaioli and Tavoni, 2016; Mazzucato and Semieniuk, 2018; Sekrafi and Sghaier, 2018). These studies highlight that the extent to which countries engage in concrete project to promote renewable energy usage and the development of firm capacity to adopt such energy alternative will depend on the extent to which these structures are in existence. Implying that policies that consider renewable energy usage and economic outcomes will require a robust evaluation of how these three structures matter. The empirical regression model in equation (1) therefore represents this relationship of interest as:

$$Y_{i,t}^{*} = \beta + \emptyset RR_{i,t} + \delta S_{i,t}^{*} + \theta RR_{i,t} \times S_{i,t}^{*} + \varphi X_{i,t} + +\sigma\gamma_i + \lambda\tau_t + \varepsilon_{i,t} \quad , \qquad (1)$$

Where the explained variable 'Y^{*}' is the indicator for trade performance, 'RR' denote the indicator for renewable energy usage, whilethe indicators of the different structures of interest are denoted as *'S^{*}'*, while *'X'*is the set of control variables. The interaction term to test the conditioning effect is based on the multiplicative term between the indicators of the different structures of interest and renewable energy usage '$RR_{i,t} \times S_{i,t}^{*}$'. The identifiers $\phi, \delta, \theta, and\ \varphi$ are the coefficients to be estimated. The usual error term is represented in the model as $'\varepsilon'$.

[2] Such policy will promote the consumption of renewable energy along side any of these structures of interest.

The methodology assumes there is potential endogeneity concern in the econometric model as presented in equation (1). Some of the endogeneity concerns relate to simultaneity or reverse causality, the unobserved heterogeneity, and even the choice of the explanatory variables. For instance, the transition to the usage ofrenewable energy can be influenced by other factors that are identified in the error term, such as the level of funding from developed nations to transit from brown to green energy. In addition, there could be reverse causality running from trade to renewable energy usage, such that trade barriers that come from standards and regulations in developed countries influence the extent to which SSA countries adopt the usage of renewable energy for their production processes. More so, trading is a form of income-generating channel for countries to build their capital capacity for transition to other energy alternatives. To address the endogeneity concerns, the System Generalized Method of Moments (SGMM) estimator, as proposed by Blundell and Bond (1998), is applied in this paper. The SGMM estimator uses levels of the endogenous variables to the system as instruments and uses the first differences lag as additional instruments, making this technique appropriate in reducing biases and providing better precision in its estimates. More so, this technique is robust to heteroscedasticity and distributional assumptions, and implicitly incorporates fixed effects (Rajan and Subramanian, 2008), making it preferred to other estimation techniques when dealing with panel data estimation as it is in this study.

The additional tests to check the efficiency of the SGMM estimations are the autocorrelation '*AR (1)'* and '*AR (2)*' test and the *Hansen* test for instrument over-identification. These checks are important to evaluate the absence of autocorrelation in the residuals and the validity of the instruments (Tchamyou and Asongu, 2017; Tchamyou, Erreygers and Cassimon, 2019). The probability value of the *AR (1)*, *AR (2)* and *Hansen* tests are expected to be ≤ 0.05, ≥ 0.05, and ≥ 0.05, respectively.

What follows is the specification of the formal SGMM model for the effect of renewable energy usage on trade outcomes, and the conditioning effect on finance, institutions, and regulatory quality. This model is an expansion of equation (1) to include the lagged dependent variable, the country and time fixed effect following a standard SGMM model. Hence,

$$Y^*_{i,t} = \beta + \alpha Y_{i,t-1} + \emptyset RR_{i,t} + \delta S^*_{i,t} + \theta RR_{i,t} \times S^*_{i,t} + \varphi X_{i,t} + \sigma\gamma_i + \lambda\tau_t + \varepsilon_{i,t} \quad (II)$$

The variables are as earlier discussed inequation *(I)*, '$Y_{i,t-1}$' is the lag of the explained variable, 'γ_i' is the country fixed effect, and $'\tau_t'$ is the time-specific effect. The coefficients of interest for this study are $'\emptyset'$and $'\theta'$, such that the estimation of the overall effect of renewable energy usage is given by $\frac{\delta Y_{i,t}}{\delta R_{i,t}} = \emptyset + \theta S^*_{i,t}$, based on whether $\emptyset > or < 0, and\ \theta > or < 0,$ and the magnitude of B, $\frac{\delta Y_{i,t}}{\delta R_{i,t}}$ will be $>, or < 0$.

4 Main Empirical Results

4.1 Main Results

The results begin by presenting the bivariate correlations between the variables (see Table A3 in the appendix). As a result of the high correlation between institutional structure, regulatory quality, and access to finance, the regression results in Table 1 are estimated in a step-wise form. The main findings from theeconometric analysis in Table 1 are for the estimation model with total trade as a percentage of GDP - *tot_trade*, and for manufacturing export as a percentage of total merchandise export – *man_export*. There are four main issues from the estimations: they include the effect of renewable energy on trade (i.e. total trade and manufacturing export), the effect of institutional structures on the relationship between renewable energy variable and trade, the effect of regulatory framework, and the effect of finance – in terms of private sector access to credit. Two criteria validate the hypothesis of this study: a positive and a negative interaction term, depending on the direction of the estimated relationship. The interaction variable shows how the underlining structures affect the anticipated negative relationship between the use of renewable energy and trade outcomes. If negative, it implies that the interaction impact is a substitution effect, implying that the particular structure being discussed cannot improve the expected negative impact of renewable energy on trade in SSA countries. On the other hand, a positive interactive term suggests the opposite.

The diagnostic tests are first examined from Table 1 before discussing the main results. The *AR(2),Sargan*, and *Hansen* tests broadly validate the models in terms of the absence of autocorrelation in the residuals and the efficiency of the instruments that were applied in the SGMM estimations. Therefore, the following findings were seen from Table 1. First, as expected, the result suggests that renewable energy as a percentage of total energy consumption consistently has a negative effect on trade as a percentage of GDP in SSA countries. For instance, Columns 2a and 2b, and Columns 3a and 3b show that a percentage increase in the percentage of renewable energy to total final energy consumption will result in a significant decrease in the percentage of total trade to GDP of a magnitude that range from 0.595 to 2.541 percent depending on whether the control variables were included or not.This negative effect can be traced to the type ofexport that SSA countries engage in, which are mostly non-agricultural primary export, and the main players in the sector that generate these exports are engaged in polluting activities (Standing, 2007; International Labor Organisation, 2015; Loewenson, Hinricher, and Papamichail, 2016; Carvalho, 2017), which makes the transition to renewable energy sort of a paradox and unfavorable in SSA.

Similarly, a more consistent negative relationship is seen between measures of renewable energy and manufacturing export to total merchandise export in this region (see Columns 4a and b to 6a and b). This relationship ranges from 0.114 to 1.530 percentage decrease in manufacturing export, for a percentage increase in the use of renewable energy.As it is well known, renewable energy is expensive and capital-intensive, which makes it less incentivizing for its usage in both the primary and manufacturing sector of most SSA countries, which consist of mostly small scale enterprises and large multinationals in the extractive sector. These firms mostly dictate oligopolistic market conditions and are engaged in brown energy usage for most of their production (ILO, 2015). Hence, it is logical to expect that the trade outcomes in this region will be affected adversely if these countries are to transit to using renewable energy consumption.

Second, the institutional structure in SSA countries, in terms of corruption control, was found to have a negative conditioning effect on the nexus between renewable energy and trade as a percentage of GDP (see Columns 1a and b). However, when considering the marginal effect of such interaction, it is evident from Column 1b that a sample country with a corruption control level around the average value for the sampled countries (1.941) will see a 1.434 percent increase in the value of trade to GDP (percent). When excluding the control variables, the marginal effect becomes a negative 0.379 percent decrease in trade to GDP. This pattern is similar to the effect seen for the volume of manufacturing export as a percentage of total merchandise export, which was 0.611 percent increase for a sample country with a corruption control level that is around the average value for the entire sample (see Column 4b).

These results support the argument that improving corruption-control positively influence the relationship between renewable energy and trade to GDP percent, and manufacturing export to total merchandise export outcome.Some assumed channels through which corruption-control enhances the relationship between renewable energy and trade outcomes have been identified in the literature to include reduction in the cost of doing business and enhanced innovative input in the business processes, which enhance firms' economic capacity to transit to using renewable energy for their business operations (Shleifer and Vishny, 1993; Ehrlich and Lui, 1999; La Porta *et al*, 1999; Treisman, 2000; Glaeser and Saks, 2006; and Dutta and Sobel, 2016). Hence, as corruption-control is improved, those private andsocial deadweight losses that stem from public sector corruption are eliminated and firms can have more economic resources to transit to renewable energy.

Third, despite the fact that a regulatory framework in SSA countries has a negative impact on total trade outcome (-76.101 percent and -71.353 percent in Columns 2a and 2b of Table 1), and an unclear relationship with manufacturing export (see Columns 5a and 5b of Table 1), they have potentials for improving the relationship between renewable energy usage, total trade outcome and manufacturing export. For instance, the statistical significance of the interaction terms in Columns 2b (for trade as a percentage of GDP) and Columns 5b (for manufacturing export as a percentage of trade) are not within acceptable thresholds of 1 or 5 percent. This is despite the positive value of the coefficient. Thus, implying that an improved regulatory framework is potentially important in enhancing the outcome of renewable energy usage in SSA countries. More so,total trade and manufacturing export, for instance, are outcomes of an efficient industrial production system, in which, energy input is a significant overhead cost borne by firms, andan improved regulatory framework creates an efficient market system for alternative energy supply. This is such that firms' can be more competitive from renewable energy usage, and productivity will therefore rise. UNEP (2013) also highlights the potential of regulatory frameworks for opening-up the energy supply market, for infrastructure developers, investors and financiers, to engage in the supply side of such energy alternatives at an appropriate and efficient scale.

Fourth, access to finance, which was measuredusing private sector access to credit from formal financial institutions, was found to have a positive effect on trade outcomes in most of the estimations. With a unit improvement in access to finance, the effect on trade as a percentage of GDP ranges from 1.007 to 1.468 percent (see Columns 3a and 3b). For manufacturing export, a positive effect is seen in Columns 6a (0.185 percent), although when controlling for other covariates, the coefficient in Columns 6b turned negative. The consistent positive effect that is seen in most of the estimations is expected considering the overwhelming literature on how finance affects trade outcomes of countries (Osabuohien *et al*, 2017; 2019).

In relation to the interaction term of this variable (access to finance) with renewable energy, the results from Table 1 suggest that an increase in the credit available to the private sector will improve the relationship between themeasure of renewable energy usage and total trade to GDP by a magnitude of 0.030 percent, and 0.013 percent for manufacturing export as a percentage of total merchandise export in the sampled SSA countries. In terms of the net effect, improvement in the renewable energy usage will result in a 0.070 percent increase in trade performance for a country around the average value of credit available to the private sector (see Column 3b), and 0.139 percent decrease in manufacturing export to total merchandise export – which is better than the direct effect of -0.436 (see Column 6b).It is imperative to note that the magnitude of the coefficients for the interaction term between access to finance and renewable energy usage are not economically significant considering that they are less than a percentage impact on trade and manufacturing export in the sampled countries.

4.2 **Robustness Checks**

The results from the estimations (when controlling for other covariates) show that improving the institutional structure, the regulatory framework, and access to finance have a positive net impact on trade as a percentage of GDP and manufacturing export as a percentage of total merchandise export. However, the consistency of these results in Table 1 is subjected to a battery of checks. First, the sample is reduced to exclude those sampled countries prone to be outliers such as Congo Republic, Cape Verde, Lesotho, Liberia, Mauritania, Mauritius, Namibia, Seychelles, Swaziland, and Togo. These countries have trade to GDP percentage value that is higher than 100, which may influence the regression estimates.

Second, the regression estimation is re-parameterize by including some other control variables to reduce the likely incidence of omitted variable bias. The additional control variables include: (a) total labor force in the respective countries, which is an important variable for trade considering that trade in this region islabor intensive; and (b) innovation, which is measured as the total number of scientific and technical journal articles published by scientist in the respective SSA countries. The inclusion of innovation is motivated by the fact that it improves the productive capacities of the sampled countries (Oluwatobi *et al*, 2015; Tchamyou, 2017).

Third, a different regression specification was performed using the fixed effect regression technique, which relaxes some of the assumptions in the SGMM estimates and controls for important factors such as geographic, strategic, or other time-invariant features that affect the relationship of interest.

Considering the first check, where countries with trade values that can potentially be an outlier were excluded from the sample and the relationships of interest were re-estimated and presented in Table 2, the results show that while corruption control could not reduce the adverse effect of renewable energy usage on total trade (-0.638 percent), it could improve the relationship between the consumption of renewable energy and manufacturing export (0.529 percent). This result is consistent with the outlook in Table 1. Similar to the results that were presented in Table 1, better access to finance increases the extent to which renewable energy benefits both total trade and manufacturing export with values of about 0.030 percent and 0.013 percent, respectively. There is still no significant relationship in the extent to which the improvement in regulatory framework affects the renewable energy and trade outcome nexus, especially when controlling for other country-specific covariates as displayed in Tables 1 and 2.

For the second and third checks, where additional control variables (labor force and measure of innovation) were included, similar signs of the coefficients of the interaction variables as in Table 1 are seen. Although the significant values vary as expected in some of the estimations in Table 2 (such as *Renew×bus_environ* in check 2 and *Renew×reg_quality* in checks 2 and 3), a significant number of the estimations had similar significant effects as displayed in Table 1 and their signs were largely consistent. Likewise, the final check, where the regression model was estimated using the fixed effect regression, the results found were not significantly different from the earlier outlook in Table 1. Most of the signs were largely consistent and the significant values did not vary as much. These results broadly show that the association between renewable energy usage and trade outcomes can be enhanced by considering the improvement of the institutional, regulatory, and financial sector structuresof SSA countries, especially for manufacturing export.

	Trade as a Percentage of GDP						Manufacturing Export as Percentage of Total Merchandise Export					
	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b
	0.265***	0.321**	0.340***	-0.308	0.483***	0.114	-0.453***	-0.369***	-0.258***	3.267	-0.426***	0.033
Initial(Lag)	(0.000)	(0.044)	(0.000)	(0.315)	(0.000)	(0.261)	(0.000)	(0.000)	(0.000)	(0.274)	(0.000)	(0.475)
	0.858*	2.672***	-2.541***	-1.799*	-1.483***	-0.595**	-1.530***	-0.415	-1.312**	-1.707	-0.114***	-0.436***
Renew	(0.056)	(0.001)	(0.000)	(0.073)	(0.000)	(0.010)	(0.000)	(0.158)	(0.048)	(0.631)	(0.000)	(0.001)
	40.534***	70.394***	----	----	----	----	27.981***	-16.294**	----	----	----	----
corruption	(0.001)	(0.000)	----	----	----	----	(0.000)	(0.025)	----	----	----	----
	----	----	-76.101***	-71.353***	----	----	----	----	-32.771	40.165*	----	----
reg_quality	----	----	(0.000)	(0.008)	----	----	----	----	(0.166)	(0.098)	----	----
	----	----	----	----	1.007***	1.468***	----	----	----	----	0.185***	-1.141***
bus_environ	----	----	----	----	(0.000)	(0.001)	----	----	----	----	(0.000)	(0.000)
	-0.637***	-0.638**	----	----	----	----	0.650***	0.529***	----	----	----	----
Renew× *corruption*	(0.001)	(0.016)					(0.000)	(0.000)				
	----	----	0.585**	1.008*	----	----	----	----	0.512*	0.877	----	----
Renew× *reg_quality*			(0.012)	(0.073)					(0.080)	(0.522)		
	----	----	----	----	0.017***	0.030***	----	----	----	----	0.004***	0.013***
Renew× *bus_environ*					(0.000)	(0.010)					(0.000)	(0.000)
Controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
ME @ mean of structures	-0.379	1.435	-1.450	0.081	-1.107	0.070	-0.268	0.611	-0.358	-0.073	-0.017	-0.139
ME @ 90^{th} of structures	-0.952	0.862	-1.032	0.802	-0.826	0.565	0.316	1.086	0.009	0.555	0.056	0.082
AR2	0.317	0.140	0.308	0.080	0.322	0.172	0.610	0.629	0.047	0.360	0.583	0.775
Sargan	0.220	0.640	0.217	0.845	0.328	0.743	0.228	0.480	0.276	0.170	0.333	0.720
Hansen	0.994	0.862	0.999	0.519	0.957	0.842	0.999	0.790	0.960	0.990	0.985	0.924
Instruments	28	17	28	17	25	31	25	14	39	14	24	33

Notes: The two-step estimation for the system-GMM regressions was used. The two-step procedure is asymptotically efficient and robust to all kinds of heteroskedasticity. Probability values for the estimates are given in parentheses. The autocorrelation tests, Sargan, and Hansen tests are also the probability values. The significance values are such that ***0.01, **0.05, and *0.10.

Table 1: SGMM Estimations for Trade Outcomes, Renewable Energy Usage, and Interaction Terms

Interaction Term	Trade to GDP	Manufacturing export	Checks	Covariates	Estimation
			Check 1		
Renew× *corruption*	-0.638** (0.041)	0.529*** (0.000)	Drop countries that have trade to GDP percentage values that are potential outliers.	Covariates as reported in Table 1 were included.	SGMM was estimated. The Sargan, Hansen, AR2 test were efficient. The instrument ratio was consistent.
Renew× *reg_quality*	1.008* (0.073)	0.877 (0.522)			
Renew× *bus_environ*	0.030*** (0.010)	0.013*** (0.001)			
			Check 2		
Renew× *corruption*	-0.601** (0.011)	0.252*** (0.000)	Include additional covariate –Labor Force – since it is an important component of trade.	Labor force was included with the covariates that were reported in Table 1	SGMM was estimated. The Sargan, Hansen, AR2 test were efficient. The instrument ratio was consistent
Renew× *reg_quality*	3.279*** (0.006)	0.200** (0.013)			
Renew× *bus_environ*	0.022 (0.165)	0.042* (0.068)			
			Check 3		
Renew× *corruption*	-0.603** (0.021)	0.269*** (0.000)	Include measures of innovation - the total scientific and technical journal articles published.	This additional variable was included with the covariates reported in Table 1.	GMM was estimated. The Sargan, Hansen, AR2 test were efficient. The instrument ratio was consistent
Renew× *reg_quality*	18.582* (0.071)	0.207** (0.028)			
Renew× *bus_environ*	0.044*** (0.000)	0.011*** (0.000)			
			Check 4		
Renew× *corruption*	-0.234** (0.037)	-0.255*** (0.001)	Conduct a fixed effect regression to check whether the kind of estimation technique applied matters.	Covariates as reported in Table 1 were included.	The Fixed effect regression.
Renew× *reg_quality*	0.040** (0.013)	0.431*** (0.000)			
Renew× *bus_environ*	0.003*** (0.007)	0.008** (0.017)			

Table 2: Further Regression onTrade Outcomes, Renewable Energy Usage, and Interaction Terms
Note: The significance values are such that ***0.01, **0.05, and *0.10.

5. Discussion and Conclusion

This paper assessed the relationship between renewable energy usage and trade performance for countries in sub-Sahara Africa. It examined how three conditioning variables (indicators of institutional structure, regulatory framework and finance) can mitigate the hypothetical costof renewable energy on trade performance in SSA countries. Despite the 'cost' of renewable energy, this study highlights its potential economic, social and environmental benefits such as enhancement of the productive capacity of economic agents in the region for trade outcomes. Overall, the results suggest that there are potentials for a positive net impact on manufacturing export with the usage of renewable energy and the improvements in the institutional structure (i.e.

strengthening corruption control), regulatory framework, and finance for the private sector. In contrast, the net impact on total trade as a second measure of trade performance is only positive for regulatory framework and finance for private sector.These results are consistent with some other empirical studies like Boluk (2013) and Raza, Shahbaz and Nguyen (2015).

A number of reasons aregiven to explain these results. First, the cost of doing business increases from informal payments and other unlawful fiscal payments to import, register, and approve technologiesin countries where there ispoor control of corruption. Such cost declines theproductivity and competitiveness of firms with the adoption of renewable energy. Further, otherpublic-private initiatives and fundingto help the private sector ameliorate the huge financial burden in adopting renewable technology will be inefficiently directed and utilized in countries with poor corruption-control. More so, it is a notable experience that some initiatives to boost technology growth in African countries are met with public administration bottlenecks, which are most times tied to corrupt public officers seeking for private benefit from such initiatives. The underlining fact is that with corruption-control, the cost of adopting renewable energy will be reduced, and firm accessibility to government programmes and other efforts to boost energy usage can be more efficient for better productivity and competitiveness in this region, which will have a positive impact on trade outcomes.

Secondly, when government policies and regulations are in favor of firms adopting renewable energy, this can reverse the negative relationship earlier observed between renewable energy usage and trade outcomes. This could be in terms of availability of subsidies and research and development support, thus enhancing the overall productivity of firms that participate in the export market. More so, regulatory quality can also affect the prices of renewable energy, by allowing for a freer renewable energy market for consumers, and other fiscal and pricing incentives to encourage renewable energy usage (Obeng-Darko, 2019). These efforts will enhance the productivity of firms and their export competitiveness.

Finally, in terms of access to credit, firms' performance will improve with the usageof renewable energy when they have sufficient financial support to adopt such technology. Even though the availability of cost effective and potentially efficient renewable energy technologies is a necessary condition for growth (Kalirajan and Lin, 2016), these technologies are still relatively expensive for many small and medium scale enterprises in this region (Efobi *et al*, 2019). Implying that in cases where there are better access to finance for the private sector, the potential for a positive outcome from the adoption of renewable energy is higher, which fits the result seen from the earlier estimations.

The main policy implication of the results from this paper is that renewable energy usage is expensive on trade – including manufacturing export, in the SSA region. However, with the improvement of vital structural factors such as enhanced access to finance, regulatory quality, corruption-control, the costs associated with the negative impact can be minimized and even eradicated in the long term.

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APPENDIX

S/N	Country	*tot_trade*	*man_export*	*Renew*	S/N	Country	*tot_trade*	*man_export*	*Renew*
1	Angola	99.790	1.433	54.444	22	Liberia	177.274	0.000	87.952
2	Benin	58.024	15.004	53.674	23	Madagascar	74.511	45.317	78.804
3	Botswana	99.398	83.528	29.349	24	Malawi	60.369	11.660	81.783
4	Burkina Faso	49.544	10.216	80.280	25	Mali	57.678	17.769	76.267
5	Burundi	43.889	15.032	96.144	26	Mauritania	110.898	0.009	34.754
6	Cabo Verde	100.493	34.168	25.685	27	Mauritius	115.448	62.203	13.816
7	Cameroon	53.423	10.698	80.315	28	Mozambique	87.406	8.464	91.185
8	Central Afr. Rep.	37.723	19.822	80.439	29	Namibia	102.328	45.604	29.094
9	Chad	80.903	0.000	90.632	30	Niger	57.406	10.303	82.024
10	Comoros	62.140	18.101	46.665	31	Nigeria	50.845	3.841	86.907
11	Congo Dem Rep	69.724	0.000	96.258	32	Rwanda	42.373	7.962	89.270
12	Congo Rep	136.214	22.850	60.622	33	Senegal	72.015	39.398	44.852
13	Cote d'Ivoire	85.421	15.001	74.286	34	Seychelles	188.559	7.853	0.674
14	Eritrea	41.336	0.000	79.117	35	Sierra Leone	74.733	9.986	75.357
15	Ethiopia	43.099	8.370	92.999	36	South Africa	60.300	50.445	16.439
16	Gabon	85.333	4.183	86.663	37	Swaziland	132.641	64.047	56.376
17	Gambia	73.201	10.635	56.063	38	Tanzania	47.832	22.990	89.323
18	Ghana	78.561	20.818	51.844	39	Togo	100.613	55.786	72.433
19	Guinea	60.169	14.690	82.375	40	Uganda	47.061	23.621	91.681
20	Kenya	56.111	34.400	79.445	41	Zambia	69.996	9.373	90.142
21	Lesotho	143.708	75.387	53.593	42	Zimbabwe	83.248	28.769	80.543

Table A1: Means of Sample Countries for New Business Entries, and Indicators of Mobile Technology

Variable	Obs.	Mean	Std. Dev.	Min	Max
tot_trade	514	80.035	37.945	21.124	311.355
man_export	418	24.621	22.203	0.000	94.461
Renew	504	67.296	25.152	0.354	97.882
Hum_cap	320	7.900	6.977	0.469	40.044
GDP_Pcap	546	2009.311	2587.275	188.143	13276.030
GFCF	504	22.326	8.827	2.000	60.018
H_index	546	0.771	0.077	0.454	0.935
corruption	546	1.941	0.610	0.970	3.660
reg_quality	546	1.865	0.598	0.260	3.630
bus_environ	514	22.407	25.438	1.095	160.125

Table A2: Summary Statistics of Main Variables

	tot_trade	*man_export*	*Renew*	*Hum_cap*	*GDP_Pcap*	*GFCF*	*H_index*	*Corruption*	*reg_quality*	*p.sect_fin*
tot_trade	1.000	----	----	----	----	----	----	----	----	----
man_export	0.286	1.000	----	----	----	----	----	----	----	----
Renew	-0.439	-0.414	1.000	----	----	----	----	----	----	----
Hum_cap	0.334	0.479	-0.630	1.000	----	----	----	----	----	----
GDP_Pcap	0.421	0.323	-0.702	0.648	1.000	----	----	----	----	----
GFCF	0.226	0.032	-0.272	0.126	0.190	1.000	----	----	----	----
H_index	0.054	-0.086	0.251	-0.196	-0.131	0.195	1.000	----	----	----
corruption	0.215	0.428	-0.662	0.494	0.504	0.349	0.002	1.000	----	----
reg_quality	0.025	0.425	-0.517	0.552	0.471	0.350	-0.092	0.719	1.000	----
bus_environ	0.069	0.400	-0.622	0.732	0.537	0.087	-0.491	0.487	0.580	1.000

Table A3: Pairwise Correlation Analysis