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Woody Biomass Energy Consumption and Economic Growth in Sub-Saharan Africa

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Abstract

In this study, determinants of the relation between woody biomass energy consumption and economic growth were discussed. The relationship was examined by Autoregressive-Distributed Lag (ARDL) model for selected Sub-Saharan African countries such as Angola, Benin, Guinea-Bissau, Mauritania, Niger, Nigeria, Seychelles and South Africa for the period of 1980-2013. According to empirical results, there is unidirectional causality from woody biomass energy consumption to economic growth for Angola, Guinea-Bissau and Niger; from economic growth to woody biomass energy consumption for Seychelles. The bidirectional relationship is supported for Benin, Mauritania, Nigeria and South Africa. The results of this paper demonstrate that structural changes should be implemented in renewable energy policies of the selected countries.

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Keywords: Woody Biomass Energy Consumption, ARDL, Economic Growth, African Countries

1. Introduction

Energy dependence of the world mainly rests on fossil fuels, coal, petroleum, crude oil and natural gas as sources of thermal energy; gaseous, liquid and solid fuels and chemicals whose reserves are finite so in the danger of depletion. While fossil fuels as non-renewable energy sources, generated from died organisms, biomass energy is made of living organism so it can be recycled. The only nature-friendly and renewable energy resource known that can be originated from various sources and used as a substitute for fossil fuel is biomass which can be made of all water- and land-based organisms, vegetation and trees, virgin biomass and all dead and waste biomass such as municipal solid waste, bio solids (sewage), animal wastes (manures) and residues, forestry and agricultural residues and other types of industrial wastes (Klass, 2004).

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Biomass is briefly described as organic matter renewable over time, which can be used as a renewable energy resource, either directly by combustion to produce heat or indirectly, after conversion into various forms of semi-processed bio-fuels (such as wood pellets or ethanol). Wood is still one of the most important types of the biomass which defines 87% of the total biomass energy, either harvested used as fuel or derived from wood products. It is primarily consisted of carbohydrates and lignin produced by photosynthetic process and it can be directly used in modern energy applications such as producing electricity, liquid fuels and making bio-chemicals (Foster et.al. 2007; Wicke, et.al. 2011; Petrie, 2014). Woody biomass potential is generally abound in stumps, tree branches, residuals of sawmills and sawdust, lops.

Benefiting from forests for bio-energy has gained popularity in the second half of the twentieth century because of the major issues such as high incidence of deforestation, high costs of fuel, scarcity in energy supply, dependence on foreign energy sources, global climate change and air pollution. Biomass is a most popular form of bio-energy, contributes to poverty reduction in developing countries, a notable tool in decreasing environmental degradation, meets the energy demand in all forms that people need, leads to developing agricultural productivity especially in rural lands and increased energy security and independence from imports. The better using of forest energy sources such as residues, wastes, balancing supply and demand across the various types of the forest and other wood-based biomass resources is necessary to meet energy demand of future. That deforestation highly relies on agro-industrial production. The primary wood-based uses of forest resources are used in household, businesses and industrial processing by utilizing wood and wood-based products (FAO, 2010; Eleri and Eleri, 2009).

Woody biomass is expected as the one of the main domestic energy sources by satisfying Africa’s growing energy demand. Almost half of the world’s population and nearly 81% of Sub-Saharan Africa (SSA) depend on woody biomass energy especially for cooking, household and economic activities. This rate is far beyond than other regions. For instance, even if usage of woody biomass rises in China, India and much of the developing countries, they cannot reach Sub-Saharan African’s consumption because it is anticipated to grow over the next few decades. On the other side, woody biomass energy sector employs a remarkable workforce fetching for thousands of people (AFREA, 2011).

Accessing to energy, especially for renewable energy is so crucial for Africa which is in the tendency to sustained economic growth and has positive trends in human development indicators. Thus, bio-energy has a strategic role in the country’s development. Bio-energy is currently the primary energy source for almost 2.7 billion people worldwide (Wicke, et.al. 2011; Stecker et.al. 2013), playing a traditional role in Africa by composing nearly 90% of total energy supply especially in Sub-Saharan Africa. Although the International Energy Agency (IEA) expects to decrease in total energy rate of biomass and wastes by 2035, it is predicted that biomass energy will still have substantial effect on the country’s energy consumption (IEA, 2010; Stecker et.al. 2013). As well as the total primary energy demand, biomass and wastes have major share of total energy consumption of Africa. According to IEA’s estimations, biomass and wastes will have share between 51% and 57% in Africa’s total energy consumption by 2035. However, dependence on biomass energy varies across regions of Africa. For instance, African countries suffered from poverty have high biomass ratios in total energy, especially for woody biomass. In some countries such as Burundi, Rwanda and the Central African Republic, biomass energy utilization is 90% or greater (Dasappa, 2011; Stecker et.al. 2013). In Sub-Saharan Africa (SSA), people heavily rely on “traditional biomass energy” especially for cooking, lighting and heating considered other regions (Eleri and Eleri, 2009; Stecker et.al. 2013). In Africa, almost 80% of the population utilized from traditional biomass energy particularly for cooking. Therefore, renewable energy sources, especially woody biomass resources, have vital role in Africa so they should be used effectively (Stecker et.al. 2013).

South Africa has the highest woody biomass energy consumption in Africa. The producing of woody biomass energy provides wide opportunities for South Africa such as reducing in the amount of solid wastes, achieving climate conditions, creating employment occasions, improving life opportunities, chance for development. Historically, South Africa post-apartheid economy mainly hinge on mining operations which necessitates energy-intensive activity (Haw and Hagues, 2007; Etambakonga, 2013). Thus, the country’s economy heavily bases on woody biomass energy because South Africa has turned traditional biomass into modern biomass by demographic trend for people mitigate from rural areas to urban. However, woody biomass energy is still not grown enough because South Africa has woody biomass potential estimated at more than 1000 times higher than its current status while 75% of Africans have no chance to access to electricity Even though the increasing costs of fossil fuels, greenhouse gas emissions, woody biomass' benefits to economy and environment, it is not well imposed on across the country especially because of limited water. Sub-Saharan Africa largely covered by arid land (Etambakonga, 2013), and annual rate of deforestation is numbered as 0.7%. Only 11.3% of the land of the terrain is nationally guarded. Thus, woody biomass energy producing conditions are in inadequate generally (Eleri and Eleri, 2009).

As contribution of the paper, the causal relationship between economic growth and woody biomass energy consumption was analyzed for selected Sub-Saharan African countries. In this study, a long-run and a causal relationship between economic growth, woody biomass consumption was applied by two stages. Firstly, it was used ARDL approach developed by Pesaran et.al. (2001). Secondly, traditional Granger causality procedure was practiced.

Literature review is given in the second section. Economic background of woody biomass energy consumption in Sub-Saharan Africa is expressed in third section. Econometric theory and methodology are identified in the fourth section. The fifth section consists of the empirical results while the last section includes conclusions and policy implications.

2. Literature Review

Recently, the relationship between economic growth and biomass energy consumption was studied by many researchers (See Payne (2011), Bildirici (2012, 2013), Bildirici and Ozaksoy (2013, 2014a, 2014b), Bildirici (2014), Bildirici and Ersin (2014), Öztürk and Bilgili (2015), Bilgili and Öztürk (2015)) and the relationship between price of biofuels and agricultural commodities.

Payne (2011) examined the causal relationships between biomass energy consumption and real GDP for USA, by using the Toda–Yamamoto causality test for the period of 1949–2007. Bildirici (2012 and 2013) examined short and long-run causality analysis between biomass energy consumption and real GDP by ARDL method from 1980 to 2009.

According to the study by Bildirici and Ozaksoy (2013), the causality process between biomass energy consumption and real GDP was investigated by applying ARDL method and VEC approach to the annual data of ten countries for the period between 1960 and 2010. For all countries, bidirectional causality was determined according to the strong and long-run causality between biomass energy consumption and real GDP.

Bildirici (2014) investigated the co-integration and causality relationship between the biomass energy consumption and economic growth in the transition countries by the Panel Auto Regressive Distributed Lag (ARDL) method and Pedroni co-integration analysis for the period of 1990–2011. The analysed countries are gathered under two groups. For Groups 1 and 2, Pedroni panel co-integration test and ARDL bound test results show that biomass energy consumption and economic growth are co-integrated. Fully modified ordinary least squares results suggested that biomass energy consumption has positive effect on the economic growth.

Bildirici and Ozaksoy (2014a) analyzed the relationship between biomass energy consumption and economic growth by ARDL and Panel Cointegration method for some transition countries from 1980 to 2011. According to the results, causality relationship is explained by conversation hypothesis for Croatia, Hungary, Slovenia and Slovakia and by growth hypothesis for Bulgaria and Romania.

Bildirici and Ersin (2014) discussed the relationship among biomass energy consumption, oil prices, and economic growth. This paper focused on the relationship because it was accepted that the biomass energy consumption is affected by economic growth and the oil price.

Bildirici and Ozaksoy (2014b) evaluated the relationship between oil prices and biomass energy consumption was analysed by BDS test, non-linear ARDL approach and two non-linear Granger cointegration methods for the period of 1973-2012 in the USA. Augmented non-linear Granger causality test developed by this paper determined there is a uni-directional Granger causality relationship between oil price and biomass energy consumption in the asymmetric case for positive and negative crude oil price changes in short-run and strong causality forms.

Öztürk and Bilgili (2015) investigated the long-run dynamics of economic growth and biomass consumption nexus by applying dynamic panel analyses for 51 Sub-Sahara African countries for 1980–2009 period. The results indicate biomass consumption, openness and population have an impose on economic growth in African countries.

Bilgili and Öztürk (2015) explained long-run dynamics of biomass energy consumption and GDP growth through homogeneous and heterogeneous variance structure for G7 countries. The estimates confirm the growth hypothesis which identifies positive effects of biomass energy consumption on economic growth in G7 countries and biomass energy consumption enhances the economic growth.

3. Data and Econometric Methodology

3.1. Data

The woody biomass data used in this study was collected from "material flows" for Angola, Benin, Guinea-Bissau, Mauritania, Niger, Nigeria, Seychelles, South Africa and per capita GDP was derived from "World Bank Development Indicator" for 1980-2013 periods.

3.2. Methodology

3.2.1. ARDL approach

In ARDL-UECM method the standard log-linear functional specification for the wbc variable is presented as:

$$\Delta wbc = \alpha + \sum_{i=1}^{m} \beta \Delta wbc_{t-i} + \sum_{j=0}^{n} \varphi \Delta py_{t-j} + \phi wbc_{t-1} + \varphi py_{t-1} + \varepsilon_{1t} \quad (1)$$

where Δ *and* ε_{1t} are the first difference operator and the white noise term.

The null hypothesis of no cointegration among the variables in Eq. (1) are $H_0: \phi=\varphi=0$ against the alternative hypothesis $H_1: \phi\neq\varphi\neq 0$. If the calculated F-statistics are below the upper CV, we cannot reject the null hypothesis of no cointegration. One set of critical values assumes that all variables in the ARDL model are I(0), while the other is calculated on the assumption that the variables are I(1). Thus, rather than using standard critical F statistic values, the upper (for I(1)) and lower (for I(0)) bounds of the F statistics presented by Peseran et al. (1997) are used.

3.2.2. Granger Causality

Following, error-correction based on the Granger causality model is used. The advantage of using an error correction term is to test causality which allows testing for short-run causality through the lagged difference explanatory variables and for long-run causality through the lagged ECMt-1 term.

The Vector Error Correction model was used to analyze relationships between the variables which was constructed as follows:

$$\Delta py = \alpha_0 + \sum_{i=1}^{m} \beta_i \Delta py_{t-i} + \sum_{j=1}^{n} \phi_i \Delta wbc_{t-j} + \varsigma_1 ECM_{t-1} + e_{1t} \quad (2)$$

$$\Delta wbc = \alpha_0 + \sum_{i=1}^{p} \vartheta_i \Delta py_{t-i} + \sum_{j=1}^{q} \theta_i \Delta wbc_{t-j} + \varsigma_2 ECM_{t-1} + e_{2t} \quad (3)$$

where residuals e_t are independently and normally distributed with zero mean and constant variance and ECM_{t-1} is the error correction term resulting from the long-run equilibrium relationship.

The Vector Error Correction model should be a starting point for the causality analysis.

4. Econometric Results

4.1. ARDL Test and Long-Run, Short-Run Elasticity Results

According to F statistics, we have enough evidence to reject the null hypothesis of no cointegration at a 5 percent significance level for the relationship between wood biomass energy consumption and real per capita GDP for Angola, Benin, Guinea-Bissau, Mauritania, Niger, Nigeria, Seychelles and South Africa.

According to long-run and short-run elasticities, the ARDL cointegration analysis assumes the existence of a unique long-run relationship between variables. One should ascertain the existence of an unique cointegration vector before using the ARDL technique.

The Table reveals the arguments for valid long-run relationships among the variables. It is possible to predict the long-run elasticities by using ARDL approach which was presented in the Table.

Table 1: ARDL Test Results (Selected Sub-Saharan Countries)

Countries	F-statistics		Long-run		Short-run		ECM
	WBC	Y	WBC	Y	WBC	Y	
Angola	6.309*	2.716		0.1886 (-0.424)		0.03742 (2.07216)	-0.1645 (-1.898)
Benin	0.773	5.831*	0.9012 (5.9059)		0.3579 (3.2857)		-0.3971 (-3.0255)
Guinea-Bissau	0.276	5.350*	2.2629 (8.1301)		3.1617 (2.2993)		-0.4657 (-3.2680)
Mauritania	7.174*	1.390		-2.4947 (-0.4633)		-0.1641 (-2.1667)	0.0317 (0.5688)
Niger	1.197	4.279*	1.9343 (1.6613)		0.7281 (2.3405)		-0.1296 (-1.5518)
Nigeria	2.155	5.096*	8.8434 (1.7958)		1.0793 (3.9063)		-0.1220 (0.1322)
Seychelles	8.330*	1. 166		0.4733 (13.9951)		-0.04342 (-0.3116)	-0.5653 (-4.0815)
South Africa	10.606*	0.552		0.03742 (2.07216)		0.03300 (1.8575)	-0.8820 (-4.6183)

The elasticities are interpreted as usual, for instance, a 1 percent increase in per capita income, when other things equal, leads to 0.4733 and 0.03742 percent increase in wood biomass energy consumption for Seychelles and South Africa. Thus, wood biomass energy consumption can be interpreted as “normal good” for these countries. However, a 1 percent increase in per capita income, when other things equal, leads to 2.2947 and 0.1886 percent decrease in Angola and Mauritania. Thus, wood energy consumption can be interpreted as “inferior good” for these countries. ECM coefficient with its negative sign is statistically significant and expounds how quickly variables converge to equilibrium.

The ECMs in Table 3 indicate that there is a mechanism to correct the disequilibrium between real GDP and wood energy consumption. The error correction terms are negatively and statistically significant, showing a low speed of adjustment of any disequilibrium towards a long-run equilibrium state.

4.2. The Result for Granger Causality Test

The ARDL methods indicate whether there is a relationship between wood biomass energy consumption and economic growth but it does not determine the causality relationship. If ARDL model determines the causality relationship must exist in at least one direction. The Table summarizes the Granger causality relationship between woody biomass energy consumption and economic growth. The short-run and long-run causality results determine that there is one-way causality from woody biomass energy consumption to economic growth for Angola, Guinea-Bissau and Niger; from economic growth to woody biomass energy consumption for Seychelles. For Benin, Mauritania, Nigeria, South Africa, there is the evidence of bidirectional causality.

Table 2: Granger Causality Test Results (Selected Sub-Saharan Countries)

Countries	$\Delta y \rightarrow \Delta wbc$ $\Delta wbc \rightarrow \Delta y$		$\Delta y \rightarrow \Delta wbc$ $\Delta wbc \rightarrow \Delta y$		$\Delta y \rightarrow \Delta wbc$ $\Delta wbc \rightarrow \Delta y$		$\Delta y \rightarrow \Delta wbc$ $\Delta wbc \rightarrow \Delta y$
	WBC	Y	WBC	Y	WBC	Y	
Angola	6.309*	3.716		0.1886 (-0.424)		0.03742 (2.07216)	0.1645 (1.4984)
Benin	0.773	5.831*	0.9012 (5.9059)		0.3579 (3.2857)		-0.3971 (-3.0255)
Guinea-Bissau	0.276	5.350*	2.2629 (8.1301)		3.1617 (2.2993)		-0.4657 (-3.2680)
Mauritania	7.174*	1.390		-2.4947 (-0.4633)		-0.1641 (-2.1667)	0.0317 (0.5688)

5. Conclusion and economic policy implications

In this paper ARDL method is used to examine the relationship between woody biomass energy consumption and per capita real GDP for selected Sub-Saharan African countries. Accordingly, woody biomass energy has directly impact on the countries’ economic growth because Sub-Saharan African countries have energy-intensive economies; energy has a vital role in their socio-economical development by improving life standard of living. Woody biomass is exploited as a predominant renewable energy source all over the area.

According to our test result, the short-run and long-run causality results show that there is unidirectional causality from woody biomass energy consumption to economic growth for Angola, Guinea-Bissau and Niger which supports the growth hypothesis; from economic growth to woody biomass energy consumption for Seychelles which indicates to the conservation hypothesis. For Benin, Mauritania, Nigeria, South Africa, there is the evidence of bidirectional causality which promotes the feedback hypothesis. ARDL test results support the opinion that woody biomass energy consumption can be accepted as “normal good” for Seychelles and South Africa. However for Angola and Mauritania, woody biomass energy consumption is regarded as “inferior good”.

Woody biomass is commonly approved as a prevailing energy source not only in Africa but also for other forest landed territories. Woody biomass energy consumption enhances economic growth and development of countries, creates new employment opportunities, improves air quality, reduces oil dependency, poverty and greenhouse gas emission. Thus, governments should stand up against unconsciously utilizing of woody biomass energy sources and regulate energy policies.

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