Energy Efficiency in West Africa Economies: Implication for Sustainable Energy use

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Short Abstract

In recent years, energy efficiency figures prominently in energy policies of African countries. This study analyzes the total-factor energy efficiency in West Africa economies over the period 1990-2013 using DEA model. The empirical analysis is carried out in two steps. In the first step, energy efficiency scores are calculated. In the second step, excesses in energy and CO_2 and shortfall in GDP are determined. Average energy efficiency scores over the study period showed that the five most energy-efficient countries are Senegal, Niger, Benin, Burkina Faso, and Ghana, whereas the five least energy-efficient countries are Guinea, Nigeria, Togo, Mali and Liberia. Energy efficiency scores with and without undesirable output are identical for Ghana, showing that she seem to be the best in sustainable energy utilization. Based on DEA scenarios, we found that, all the countries generate excesses in energy use causing shortfall in GDP. The DEA model highlights that if countries reduced excesses in energy use and CO_2 as well as used efficiently capital and labor, they would have increased the GDP. A decrease of energy consumption from traditional biomass and a better exploitation of renewable energy from biomass will adjust energy consumption and improve energy efficiency and environmental quality.

Keywords: Energy efficiency, Data Envelopment Analysis, Slack Based Model, West Africa

1. Introduction

In recent years, energy efficiency figures prominently in energy policies of African countries. Energy is a key factor in their economic and social development and the causal effects between energy and growth have been well demonstrated (Esso and Keho, 2016; Esso, 2010; Ouedraogo, 2010). Faced with a growing population and increase in economic activities, countries must provide sufficient energy to increase economic output while preserving the environment. A growing volume of research has focused on energy efficiency measurement in the macro-level by comparing the performance trends of countries in terms of energy utilization in the economy. As in any economy, energy is consumed in transportation, industry, commercial activities, utilities, agriculture and households. From primary sources (biomass, petroleum, natural gas, hydroelectricity, etc.), it is transformed into final energy at the stage of use (electricity, fuel, etc.). Available in various forms, the promotion of policy for an efficient and sustainable management of energy use is necessary. The concept of energy efficiency is defined under different ways. According to the International Energy Agency (IEA), energy efficiency is the way to manage and restrict economic growth in energy consumption. This definition corresponds to the indicator of energy intensity that is energy consumption divided by the economic output (Gross Domestic Product). Economists have proposed another indicator of energy efficiency that combine energy consumption, capital and labor to produce an economic output and is well known under the concept "total-factor energy efficiency" (Hu and Wang, 2006; Zhou and Ang, 2008; Honma and Hu, 2009). With regards to these indicators, an economy is energy-efficient if the country shows a low level of energy intensity or has a total-factor energy efficiency score close to one. In other words, energy consumption is efficient if it offers more services for the same amount of energy, or the same service for less energy.

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In West Africa, primary energy consumption is mainly dominated by traditional use of biomass. The ECOWAS White Paper on access to energy services indicated that biomass represents 80% of domestic energy consumption in the region. The share of biomass among ECOWAS states vary from 22% in Cape Verde to 94% in Liberia. Other countries with figures in excess of the regional average are Burkina Faso (91%), Nigeria (83%) and Sierra Leone (81%) (Adenikinju, 2008). The World Energy Outlook 2014 also indicated that in West Africa, 80% of the population was relied on traditional use of biomass for cooking in 2012. These share also vary from 31% in Cape Verde to 98% in Liberia. The high access to energy in traditional form can be a threat to the health of populations, degradation and pollution of the environment. Moreover, energy intensity in West Africa is one of the highest in the world and was estimated to 0.56 ktoe / million$, while it is 0.46 ktoe / million$ in China, 0.16 ktoe / million$ in United Nations, 0.13 ktoe / million$ in Latin American, 0.11 ktoe / million$ in European Union and 0.09 ktoe / million$ in Japan (ECREEE, 2014). The high energy intensity indicates an inefficient use of energy. This means that, the countries use more energy per unit Gross Domestic Product. In the region, countries differs in terms of economic development, investment capacity and labor force. In addition, they differ in energy supply. Some are net energy exporters, others are largely importers. In pursuit of sustainable growth, countries needed to combine energy, capital and labor in the production process in the best way that is friendly to the environment protection. Indeed, while Africa countries are smaller CO_2 emission, energy consumption is correlated to the quantity of CO_2 generated. According to the objectives of ECOWAS Renewable Energy Policy, countries should improve energy security and energy sustainability as well as reduce the negative environmental externalities of the current energy system.

This study aims to analyze energy efficiency in West Africa countries using a standard DEA and Slacked Based DEA models over the period 1990-2013. In the literature, energy intensity and total-factor energy efficiency are commonly used in macro-level policy analysis. Energy intensity, known as partial-energy efficiency is defined as energy consumption divided by the Gross Domestic Output (GDP), while the total-factor energy efficiency through DEA models combines energy consumption with economic inputs (capital and labor) to produce the economic output (GDP). An increase number of researchers have demonstrated that the measurement of energy efficiency by partial-factor could result in a misleading of estimates (Hu and Wang, 2006; Zhou and Ang, 2008; Honma and Hu, 2009). Following these studies, we use total-factor energy efficiency to measure and compare energy efficiency level among West African countries. Indeed, countries in Africa are faced with low capital investment capacity, misallocation of capital and labor and limited access to clean energy. Analyzing energy efficiency taking into account these three factors is adequate to show how energy use can be improved regarding a good economic performance. This study uses labor, capital and total primary energy consumption as input variables, Gross Domestic Product (GDP) as the only desirable output and the CO_2 emission from energy consumption as the undesirable output.

The contributions of this present study are three-fold. Firstly, the study shows an empirical evidence of the total-factor energy efficiency in the 15 Countries of West Africa. Indeeed, ECOWAS Centre on Renewable Energy and Energy Efficiency (ECREEE) drawn up a regional energy efficiency policy and actions to be adopted and implemented to improve energy efficiency and security. Such empirical study could help policy makers to formulate policies for the countries. Secondly, we compute energy efficiency scores in two ways. The first way does not consider undesirable output while the second take it into account. Energy consumption in all the countries are dominated by biomass source, however they are heterogeneous in CO_2 emission. A country can be the most efficient output and less efficient with undesirable output. The interest of this contribution is to show how energy efficiency scores are overestimated without taking into account CO_2 emission from energy consumption. Thirdly, the study does not limit energy efficiency analysis to efficiency scores. In addition to them, excesses in energy consumption, capital, labor and CO_2 emission and the shortfall in the economic output were calculated through three scenarios that an economy can set (*Scenario-1*: the economy wants to use less energy for a given GDP growth; *Scenario-2*: the economy wants to achieve a maximum of GDP growth for a given quantity of energy and *Scenario-3*: The economy considers a reduction in energy consumption and an increase in GDP simultaneously while reducing CO2 emissions). The purpose of this contribution consists of determining the GDP surplus that can be achieved if excess inputs (energy, capital and labor) and excesses in bad output (CO_2 emission) were reduced.

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2. Methods

We measure the energy efficiency using standard DEA developed by Charnes, Cooper and Rhodes (1978) and Slack Based DEA models developed by Tone (2001). DEA model is the mathematic program that combines outputs and inputs to calculate efficiency level of a production or consumption activity. The efficiency measurement began with the work of Farrell (1957) inspired by those of Koopmans (1951) and Debreu (1951). It is intimately related to the estimation of the production frontier based on distance function. Farrell (1957) distinguished between technical efficiency and allocative efficiency. The concept of technical efficiency refers to the ability to produce maximum output from a given set of inputs. The study considers five variables, namely three inputs (capital, labor and energy), one desirable output (Gross Domestic Product) and one undesirable output (CO2 emission). In the first approach, energy efficiency is analyzed without undesirable output while the second take into account of undesirable output. The second approach takes into account the environmental impact (CO2 emissions) that represents an undesirable product from energy consumption. The study employs the data of fifteen (15) West Africa countries to empirically estimate the total factor energy efficiency over the period 1990-2013. The fifteen countries include Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo. Data are collected for each country on the same period. Data on total primary energy consumption (in millions of tons equivalent oil) and CO2 emission (million Metric tons) are collected from the International Energy Agency (IEA). Labor force (in millions of people) is defined as the economically active population ages 15 and older

3. Results and discussion

We found that shows for all the countries energy efficiency changed over time. Countries are fully energetically efficient with a score equal to 1 for a small number of years and are inefficient for the other years. No one of the countries showed a constant trend of full energy efficiency over the period of the study (fig 1). The results indicate that in average on the period of the study, Benin, Guinea and Senegal, Burkina Faso and Gambia have the highest efficiency score in absence of consideration of CO_2 emission, while Sierra Leone, Togo, Nigeria, Mali and Liberia are the less energetically efficient. The highest average energy efficiency score over the study period is 0.98 (for Benin, Guinea and Senegal). Mali and Liberia present the lowest average energy efficiency scores with respectively 0.78 and 0.69. In the second case, when taking account of the CO_2 emission, we found that the five first countries with a high level of energy efficiency score are Senegal, Niger, Benin, Burkina Faso, and Ghana. Nigeria, Togo, Mali and Liberia remained the less efficient in energy use. Senegal presents the highest average energy efficiency score over the study period with a value of 0.92, while Mali and Liberia still present the lowest average energy efficiency score with a value of 0.68 and 0.65, respectively.

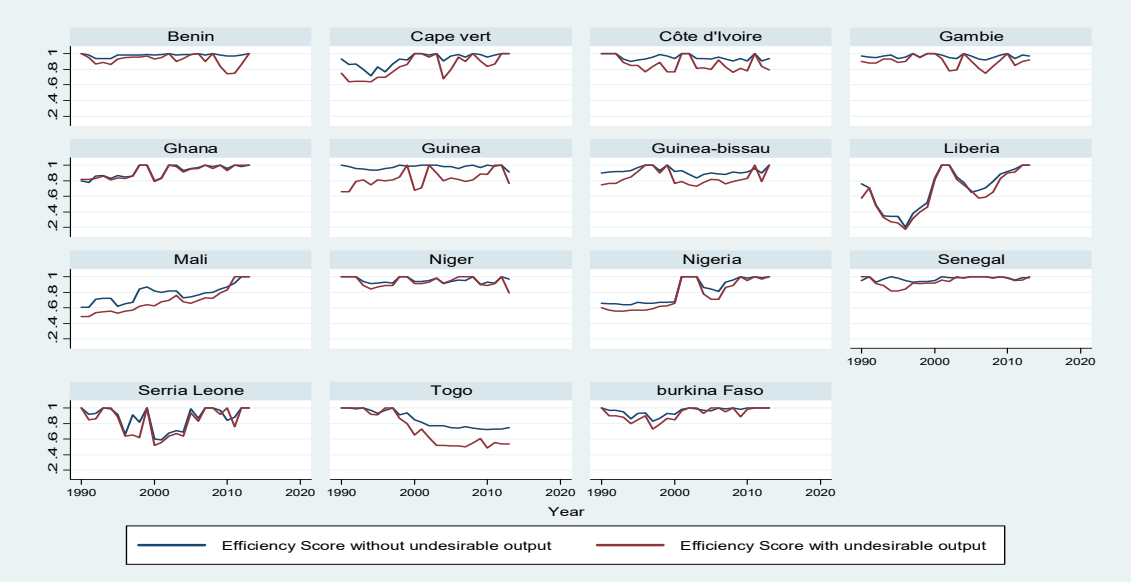

Figure 1: Trend of energy efficiency with and without CO_2 emission in ECOWAS Countries, 1990-2013

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Through the Slacked Based DEA model, we determined the the proportion of waste generated in resources utilization and the economic performance that could be achieved if the resources were used efficiently. We found that excesses in energy use are higher in Togo (39.9%), Guinea (22.4%), Benin (15.4%), Mali (14.9%) and Cape Verde (13.7%). The countries with lower excesses in energy use are Burkina Faso (5.6%), Côte d'Ivoire (5.6%), Senegal (6.6%) and Ghana (6.9%). The countries with higher excesses in energy use are those with higher excesses in CO_2 emission: Togo (58.1%), Guinea (24.9%), Mali (22.2%), Cape Verde (21.8%) and Benin (17.5%). Ghana, Côte d'Ivoire, Burkina Faso and Niger and Senegal showed low excesses in CO_2 emission with 2.8%, 5.2%, 7.4%, 7.5% and 7.6%, respectively. The countries showing higher shortfall in GDP are: Liberia (25.6%), followed by Mali (20.8%), Nigeria (8.9%), Sierra Leone (8.7%), Guinea (8.7%) and Togo (8.6%). Benin, Senegal, Gambia, Ghana and Côte d'Ivoire are low proportion in terms of GDP shortfall with, 0.04%, 0.06%, 0.17%, 0.40% and 0.92%, respectively.

4. Conclusions

In this study, we investigated total-factor energy efficiency in the fifteen West Africa economies over the period 1990-2013. We employed standard DEA and Slack Based DEA model to estimate energy efficiency scores with undesirable output (CO_2 emission) and without undesirable output, respectively. We consider capital, labor and primary energy consumption as inputs, CO_2 emission as undesirable output and Gross Domestic Product as desirable output. Energy efficiency was examined in two steps. In the first step, efficiency scores were estimated and in the second step we computed the slacks in inputs and outputs regarding the target that an economy can set about energy use. Benin, Guinea and Senegal, Burkina Faso and Gambia were the most efficient when CO_2 emissions are not taken into account in the DEA model. Sierra Leone, Togo, Nigeria, Mali and Liberia are the less energetically efficient. However, country rankings changed when CO_2 emissions are included in the Slack Based DEA model. Senegal, Niger, Benin, Burkina Faso, and Ghana became the most efficient whereas Nigeria, Togo, Mali and Liberia remained the less efficient. For all the countries energy efficiency changed over time. No one of the countries show a constant trend of full energy efficiency over the period of the study. Energy inefficiency and inconstant trend are explained by some factors such as: Fuel and oil supply problems, dysfunction and obsolescence of energy equipment and infrastructure, capacity constraints in neighboring energy exporting countries, political crises and civil wars. All these factors limited the continued availability of energy needed to support economic activities. Based on DEA scenarios, we found that, all the countries generate excesses in energy use causing shortfall in Gross Domestic Product. The slack based DEA model highlights that if countries reduced excesses in energy use and CO2 as well as used efficiently capital and labor, they would have increased the Gross Domestic Product. Policy lessons that could be drawn from this study is that countries should decrease energy consumption from biomass and fuel fossil and better develop renewable energy in order to improve energy efficiency. Countries have potential in biomass energy that can be used to produce renewable energy. Energy policies that encourage the production of secondary energy from biomass can increase the availably of clean energy and support a sustainable growth.

5. References

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