Energy consumption, inter-fuel substitution and economic growth in Nigeria

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ABSTRACT

Nigeria’s energy mix has been dominated by petroleum with a year on year increase due to huge petroleum subsidy by the government. This study adopts the translog production function to investigate the potential for inter-factor and inter-fuel substitution between capital, labor, petroleum and electricity. Ridge regression has been adopted to estimate the model’s parameters due to evidence of multicollinearity in the data. The results show that all input pairs are substitutes; and as such, adopting competitive pricing policies and removal of petroleum subsidies and price ceilings would redirect industries towards an increased use of electricity and increase capital and labor intensiveness. In addition, the study shows that a 5% and 10% increase of investment in petroleum reduction technologies for the period 2010, 2011 and 2012 would reduce CO2 emissions by 1.13518, 1.8554, 1.2722 and 2.27119, 2.37109, 2.49444 million metric tons respectively. Furthermore, the study points to evidence for convergence in relative technical progress among the various input pairs with electricity registering the fastest rate. These imply that petroleum would gradually lose its dominance in Nigerian energy mix. © 2016 Elsevier Ltd. All rights reserved.

1. Introduction

The energy sector has become the bedrock of every economy and it is the major propeller of all socio-economic activities including: education, agricultural, fisheries, production, health, food security, employment, regional and sub-regional development. Nigeria being the most populous country in Africa has embarked on intensive developmental agenda coupled with the influx of investments from emerging and developed economies to cash on the advantage of unlimited CO2 emission by protocol to establish high emission industries due to low capital formation faced by the Nigerian economy. Even though there has been immense benefits from these foreign investments, its energy sector has become the most challenging sector with regards to solving environmental problems associated with energy use, providing energy for all citizens at affordable prices and the challenge to develop an alternate cleaner energy source to substitute the already dominated fossil fuel. Notwithstanding the dominance of petroleum products in the Nigerian energy mix, currently driven by availability of large petroleum deposit in the region and huge petroleum subsidy by the government, possess serious environmental concerns. Nigeria’s fuel subsidy cost 8billion usd in 2011 accounting for 30% of government’s expenditure and 118% of the capital expenditure (source: US Energy Information Agency. EIA) [1].

Nigeria has the second largest amount of proven crude oil reserve in Africa and the 10th in the world. This has led to the heavy reliance on petroleum as its main energy source. Petroleum has been predominantly used in the industrial sector, transportation and electricity generation with 79% of electricity generated from oil while 21% from hydro. Nigeria has not done much in the development of renewable energy with only 5% which is made up of 1% hydro and 4% natural gas accounting for its total energy mix. CO2 emission increased from 58.7558 million metric tons in 1984 to 105.99749 million metric tons in 2005 (see Fig. 1). This is as a result of high percentage of about 58% of industrial petroleum use in its energy mix. Electricity development in Nigeria has been very poor due to high distribution lost from illegal connections and frequent damage to electricity installations through violence from aggrieved factions among the local people. According EIA [1], electricity...
production in Nigeria has always fallen short of demand with only 41% having access to electricity with long hours of blackouts and load shedding among communities for electricity use. The contribution of Nigeria's CO2 emissions from energy use to its environmental pollution and global warming cannot be ignored with various stake holders calling for various policies to embark on the use of cleaner energy sources to control the environmental problems albeit not implemented (see Table 1). Though Nigeria's CO2 emission and the environmental problem association with its energy use has become a major national and international concern, very little has been done in this area in terms of research on energy substitution for a cleaner energy source. Even though Adeyomo et al. [2] attempted to analyze the energy substitution possibilities in Nigeria, his focus was mainly on the inter-fuel substitution possibilities in the industrial sector with the explanation that it is the largest contributor to the Nigerian economy however focusing on the country-specific will take care of all energy consuming sectors with policy formulation cutting across all sectors.

The main objective of this paper is first to attempt investigating the possibilities of inter-factor and inter-fuel substitution in the Nigerian energy economy. This factor and energy substitution will to some extent analyze how the use of energy and non-energy inputs can be substituted for policy recommendation to achieve environmental sustenance, vis-a-vis economic growth and energy security. Second, this study will help in the generation of future forecast that will match the demand and supply of energy and factor inputs that is base not only on total energy consumption but substitutability among energy inputs and that of factor inputs over time for a reliable result since the demand model will take into account the elasticities of substitution of both energy and factor inputs. Third, with the knowledge of which energy and factor inputs are close substitutes and the estimation of their technical progress over time, will provide clear energy policy as to which energy source or factor inputs should Nigeria commit resources into for the development of cleaner energy and to be sure of the success of any energy reform policy geared towards the promotion of cleaner energy source and controlling CO2 emissions. Fourth, the construction of energy oriented computable general equilibrium (CGE) for Nigeria could be based on the estimate from this paper since this varies from the normal CGE model where the former takes into account different energy and factor input forms to come out with a reliable CES which can be used to assess the impact of other energy-related policies (e.g. taxes and subsidies, price hikes and price regulations) on the economy. In support of the use of elasticity of substitution of energy and factor inputs in the estimations, Hupmann D. and Egging R [3] affirm to this method that it will provide room for embedding the energy sector in the broader economy thereby allowing for well-founded welfare analysis specifically including the interdependence between economic activities and energy prices. It is also affirmed by Xie C. and Hawkes A. D [4] that energy substitution brings optimization of developmental policies in the various sectors of the economy. While the use of energy substitution brings valuable insights, it is without drawbacks compared to other methods which includes; dynamic multi-fuel market equilibrium model used by Hupmann and Agging [3] and the differential fuel allocation method used by Suh [5]. In the first place, Hupmann and Agging pointed to the fact that, due to the large aggregation of energy substitution approach, many vital details become absent and also if a particular fuel is not used at all in the base year, the model becomes un-adjustable to accommodate for large future penetration of fuel rates even if the economic conditions calls for that. Second, Suh pointed out that, energy substitution lacks the ability to reflect the firm's optimum maximization conditions of cost inputs and the provision of direct elasticity of input demand with respect to Divisia volume index and input prices unlike the use of differential fuel allocation method. Third, Nastasi B. and Lo Basso G. [6] also argue that, the integration of other renewable energy sources into the grid becomes difficult since this may negatively affect electric cables due to stress owing to change in time responds, and terms of energy mix composition due to market shocks provided by the feed-in-tariff incentive schemes and due to different renewable energy priority of dispatch mainly driven by national policies rather than their conversion efficiency. Finally, to the best of the authors' knowledge, the only country-specific studies on inter-factor and inter-fuel elasticities of substitution for Africa is P.K Wesseh Jr. et al. [7] on Liberia and Lin et al. [8] on Ghana. Therefore, the current study will add to the literature by considering other African countries. Despite the importance and opportunities of inter-factor and inter-fuel substitution as documented in the present study, the empirical literature has paid no attention to Nigeria even though Nigeria has been one of the highest CO2 emitters in Africa coupled with its high petroleum use. This study will therefore fill the literature vacuum on this topic and provide a basis for developing more effective energy policy. In addition, the study provides insights on the potential for CO2 emissions reduction given the existence of inter-fuel substitution possibilities.

The remaining of the paper is structured as follows: section two introduces a brief literature review, Section three describes the dataset and how it was processed, section four describes the model framework and the estimation procedures, section five presents the empirical results and discussion and section six presents the
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