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Delving into Liberia's energy economy: Technical change, inter-factor and inter-fuel substitution

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ABSTRACT

The industrial energy mix of Liberia is dominated by petroleum products. This has generated serious environmental problems, contributing immensely to CO_2 emissions and other pollutants in the country. This study has attempted to investigate the potential for inter-factor and inter-fuel substitution between capital, labor, petroleum and electricity in Liberia by employing a translog production and cost function approach. Ridge regression procedure has been adopted to estimate the parameters of the function due to multicollinearity in the data. Estimation results show that all inputs are substitutes. These suggest that price-based policies, coupled with capital subsidy programs can be adopted to redirect technology use towards cleaner energy sources like electricity; hence, retaining the ability to fuel the economy, while also mitigating greenhouse gas (GHG) emissions. Substitution between energy and labor and energy and capital implies that removal of price ceilings on energy in Liberia would tend to reduce energy use and increase capital and labor intensiveness. Notwithstanding, the study seems to show no evidence of convergence in relative technological progress of the four inputs implying that petroleum will continue to play a dominant role in the energy consumption mix of Liberian industry while labor investment will continue to outweigh capital inputs. Finally, the findings of this study provide general insights and underscore the importance of policies that focus on installed capacity of renewable electricity, energy intensity targets as well as merger of enterprises.

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1. Introduction

The energy sector is a driving force for nearly all socio-economic activities of Liberia as it propels industrial and commercial activities and enhances the delivery of basic social services. In fact, some of the key services that are inherently linked to the energy sector

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include transportation, electricity, communications, agriculture and fishery, health, education, and tourism. Besides its share to the overall gross domestic product (GDP) of Liberia as a sector, energy also contributes to employment, trade, fiscal revenues, food security, and regional and sub-regional development. The current energy economy of Liberia is dominated by petroleum products that are imported in refined forms, and woody traditional biomass consumed primarily for cooking and heating as in nearly all of Sub-Sahara African countries (see Wesseh and Zoumara [1])[1]. The patterns of energy use in Liberia, i.e. petroleum and electricity have been steadily increasing since the year 1991. As the economy grows, coupled with the recent discovery of oil, the use of these inputs is also expected to increase.[2] Petroleum is the most important fuel used in economic production. According to a UNDP 2010 study, the energy consumption mix of industry in 2008 was approximately 90% petroleum and 10% electricity. The dominance of petroleum in the energy mix has generated serious environmental problems, contributing immensely to CO_2 emissions and other pollutants in Liberia. As can be seen from Fig. 1, the amount of CO_2 emissions from the consumption of petroleum increased from 0.34 million metric tons in 1991 to 0.74 million metric tons in 2010 representing a total increase of 117.6%. Since 1991, emissions from the consumption of petroleum grew at an annual rate of 4.2%, making the control of CO_2 emissions of great urgency. Even though one may argue that Liberia's contribution to global warming is negligible on a global scale, chances are if climate change continues, the country is likely to be disproportionately affected by its impacts considering indicators experienced in the country.

Various interest groups have clamored for the use of cleaner and greener fuels and renewable energy sources. In Liberia, a broad range of policies have been introduced (albeit not fully implemented) to address some of these issues as well as to reduce the country's dependence on imported fossil fuels (see Table 1). Notwithstanding, the success of these initiatives will to a large extent depend on the degree of substitutability happening between different factors of production and fuel types. Indeed, the effects of output growth and changing fuel prices on the demand for energy depend on inter-fuel substitution and the substitutability of energy and other factors of production. These issues have attracted a great deal of attention in a large number of energy demand studies, with the majority of these studies focusing mainly on developed economies. Undertaking such a study for Liberia is necessary for several reasons. First, with increasing demand for classical factor and energy inputs as the economy grows and expands, forecasts need to be done so as to match this demand with the necessary supply. These forecasts should be based not only on the trend of total energy input consumption, but also on the degree of inter-fuel and inter-factor substitution happening across time. In other words, forecasts on future energy demand using demand models can be more reliable if the elasticities of substitution are taken into account. Second, the urgency to control CO_2 emissions in Liberia seems to suggest a need for the use of cleaner fuels. In fact, part of the objectives of Liberian public policies is to see that greenhouse gas emissions is reduced by 10% by the energy sector and to improve energy efficiency by 20% by 2015 (Wesseh and Zoumara [1]). This is a clear manifestation that if policy makers know which energy sources are highly substitutable, the information can be used to assess whether the promotion of the use of relatively cleaner energy sources as opposed to petroleum for instance would be

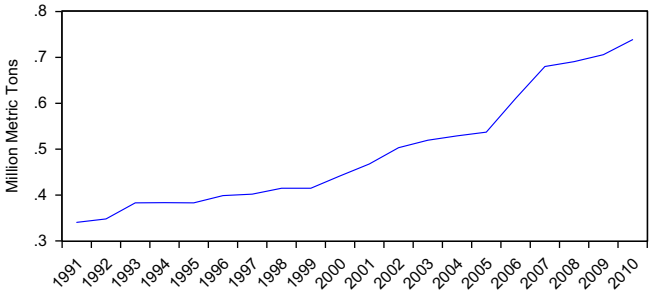

Fig. 1. CO_2 emissions from the consumption of petroleum (million metric tons). . *Source*: US EIA database [2]

successful. Third, the estimates could be used to construct energy-oriented computable general equilibrium (CGE) models for Liberia. The difference between normal CGE models and energy-oriented CGE models is that the latter introduces production functions through constant elasticity of substitution (CES) forms, where output is a CES combination of energy and non-energy inputs such that different energy forms may be substituted with one another. With energy and factor substitutions taken into account, the modeler can study the impacts of certain energy-related phenomena and policies (e.g. price hikes, price regulation, taxes and subsidies) on the economy. Finally and perhaps most importantly, inter-factor and inter-fuel elasticities of substitution have never been computed for Liberia. Hence, this study is expected to contribute in filling the literature gap for Liberia by estimating inter-factor and inter-fuel substitution elasticities through the use of a new and appropriate dataset and rigorous econometric methods. The rest of the paper proceeds as follows: Section 2 presents a brief review of existing studies. Section 3 gives a description of the dataset used in the study. Section 4 describes the model framework and estimation procedure. Section 5 presents the empirical results and discussion. Section 6 draws the conclusion and provides relevant policy suggestions.

2. A brief literature overview of existing studies

A considerable number of studies have employed various empirical methods to extract the elasticity of substitution among different inputs from data collected by researchers. Notwithstanding, the most popular method of estimating these elasticities in the field of energy economics studies has been the use of transcendental logarithmic (translog) cost functions due to flexibility of the specification, satisfaction of desired properties of production and cost functions, a tractable methodology, and the model itself being easy to understand. One of the first of these studies was conducted by Pindyck [4] on the estimation of inter-actor substitution elasticities across 10 developed countries. Pindyck's estimates show a positive elasticity of substitution between capital and energy; hence, these two inputs may be considered substitutes, a contradiction to what has been found in earlier studies (e.g. Halvorsen [5]). Also, labor and energy inputs were found to be substitutes in the study. Shankar and Pacauri [6] went further by analyzing not just inter-factor substitution, but also inter-fuel substitution possibilities in the context of India's industrial energy demand patterns. In general, the estimates of these parameters among different fuels were found to be low thus implying weak substitution or complementary possibilities among fuels, with oil and coal showing the highest degree of potential substitutability in several industries, particularly in the iron and steel industry. Electricity and coal were also found to be substitutable but to a lesser extent. Another significant result was derived from the estimates of the elasticity of substitution

[1] In Liberia, the market for woody biomass is informal. For this reason as well as the unavailability of data, this study does not consider traditional biomass energy.

[2] Wesseh and Zoumara [1] have shown that economic growth in Liberia depends on the level of energy consumption.