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Energy savings in Nigeria. Is there a way of escape from energy inefficiency?

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ABSTRACT

This study estimates the transition probabilities for different energy-use states in Nigeria, using the Markov Switching Regression technique. According to the results, both energy-efficient and energy-inefficient states are less persistent, but comparatively, the energy-inefficient state is more persistent. Thus, in Nigeria, it is much difficult to escape from the energy-inefficient state than the energy-efficient state. Several reasons may explain this phenomenon, and they include: inefficient regulatory system; poor institutional structure; high corruption; proliferation of second-hand goods; undeveloped markets; high incidence of poverty, and inefficient pricing in the energy sector. Pricing policies should be combined with institutional improvement and infrastructural development if Nigeria wants to achieve a sustainable energy-efficient state, in the long-term.

1. Introduction

Energy consumption and greenhouse gas emissions are two interrelated concepts [1–5]. Abadie et al. [6] find that energy, both consumption and transformation, account for a greater part of anthropogenic greenhouse gas (GHG) emissions. Energy efficiency policies are thus an integral aspect of smart environmental policies targeted at reducing energy related emissions and the depletion of limited natural resources [6,7]. In terms of cost effectiveness, energy efficiency provides the best cost-effective way of combating the adverse effects of climate change [8]. For instance, Trianni et al. [9] assert that, promoting industry energy efficiency provides the best tool (in terms of cost-effectiveness) to reduce energy related greenhouse gas emissions. According to a report by the International Energy Agency [IEA], energy efficiency policies could reduce carbon dioxide emissions by about 10–15%. Where there are infrastructural deficits and poor institutions, the benefits of energy efficiency achieved via effective pricing and related growth policies are more likely to be short-lived Thus, the political structure, regulatory framework, and the nature of markets of economies have important implications for the sustainability of energy efficiency benefits [10]. Though important, the issue of what drives a sustainable energy-efficient state is scarcely investigated in the literature. Motivated by this, the current study investigates the different energy-use states in Nigeria and the likely country-specific conditions that might help sustain the most energy-efficient state.

The study models Nigeria as a two-state-energy-use economy, using the two-state Markov-Switching dynamic regression (MSDR) technique. Thus, at any point in time, Nigeria is either classified as using energy efficiently or inefficiently. This study adopts Adom's [10] definition of energy-efficient state. According to Adom [10], *in intertemporal sense, energy-efficient state is a period with a negative growth rate in energy intensity, and vice versa*. The time-scale definition of efficiency by Adom [10] measures performances over time, which is in contrast to the frontier-based definition of efficiency that measures performances based on the best practices. Based on the time-scale definition of efficiency, "a country does not have to be on the frontier to be considered efficient or away from the frontier to be considered inefficient [10, pp 252]". Next, in the two-state energy-use model, the effects of behavioral, technical, and structural changes are controlled for. Specifically, the price of crude oil and real income per capita are included to capture behavioral changes, and trade openness and industry value – added are added to capture technical effects and structural shifts respectively. In this regard, the empirical specification of the present study is more robust to the omitted bias problem than the model estimated by Adom [10] for Cameroon, which did not control for shifts in economic structure. With regard to the conventional studies on the drivers of energy intensity [11–31], the present study makes the following contributions. First, for studies that adopt linear models [16–25], the present study estimates a non-linear model that allows the behavior of variables to change from one state to

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another state; this has the added advantage of testing for variable's asymmetric effects endogenously in the model. Second, unlike previous studies that adopt non-linear models [26–31] for similar analysis, the present study does not impose the assumption of one abrupt change. In this study, processes that changed in the past are allowed to change again; this makes it possible to estimate transition probabilities, which determines the persistence of different energy-use states in the economy. Consequently, estimation of the duration of the different energy-sue states and the 'helping drivers' of sustainable energy-efficient state are derived as by-products of the estimation.

Nigeria is an economic giant in Africa with huge dependence on the petroleum sector [29,32]. Unfortunately, the challenges in the country's energy sector, particularly the electricity sector, imposes serious constraints on the country's development process. Incidences of collapse of firms and loss of jobs induced by frequent power outages have been witnessed in the country [29,33,34]. The demand-supply gap in the energy sector [35–38] reiterates the need to promote energy efficiency in Nigeria. Though some structural changes, such as growth in foreign direct inflows [29], improved trade flows and relations, growth of the less energy-intensive sectors, promotion of energy efficiency programmes [33,37], and phasing out of government fuel subsidies, have taken place in the country, they have been inadequate to ensure that the economy achieves an absorbing energy-efficient state. This is underpinned by the fact that, there are still problems with the country's institutional structure, regulatory framework, and infrastructural development. This study provides a probabilistic inference on the likely persistence of the different energy-use states in Nigeria. Based on the estimated transition probabilities, the study explains the implications of the current institutional structure, regulatory framework, high corruption, energy pricing regime, and nature of markets for the different energy-use states in Nigeria.

Section 2 reviews the empirical literature. Section three explains the empirical model. Section 4 discusses the results, and Section 5 concludes with some policy deductions.

2. Review of empirical literature

Energy intensity changes mask technical, behavioral, and structural changes. Therefore, in modelling energy intensity changes, these effects have to be incorporated into the model. In the empirical literature, foreign direct inflows (FDIs) and trade openness have been used to capture the technical aspects of energy intensity changes. FDIs and trade openness promote energy efficiency by inducing technical efficiency and competition. However, the energy-saving effects of FDIs and trade openness remain inconclusive in the literature. In China, Blackman and Wu [39] find that, FDIs increase energy efficiency via competition and demonstration effects. Eskeland and Harrison [40] find that, FDIs improve energy efficiency in the manufacturing sector in Venezuela, Mexico, and Cote d′Ivoire. This is confirmed by Zheng et al. [41], Elliot et al. [42], Mielnik and Goldemberg [43], Ting et al. [44], Hubler [45], and Adom [28]. On the contrary, Antweiler et al. [46], Hubler and Keller [20], and Adom and Kwakwa [27] did not confirm the positive effect of FDIs on energy efficiency.

With respect to trade openness, Fisher-Vanden et al. [21] argue that the impact on energy intensity is ambiguous. According to Cole [47], the actual effect of trade openness on energy efficiency depends on whether or not the energy consumed by exports exceed the energy saved by imports. Adom and Amuakwa-Mensah [49], Shen [48], Hubler [45], and Fisher-Vanden et al. [21] find that, higher trade openness drive energy intensity downwards. This result is also confirmed by Adom and Kwakwa [27], Adom [28–30], and Adom [10]. However, Adom and Kwakwa [27], Adom [10], and Adom [28–30] reveal that there is a significant structural effect in the trade openness-energy intensity relationship.

In terms of the behavioral aspects of energy intensity, studies have explored the important roles of price of energy and income. While there seems to be unanimity in the results for price, the results seem inconclusive for income. Using data for 22 transition economies, Cornillie and Fankhanser [50] find that higher price reduces energy intensity. Fisher-Vanden et al. [21] find a similar result for China, in a study that employed panel regression. Their results have also been confirmed by Lin and Moubarak [51], Herrerais et al. [52], and Hang and Tu [26]. Filipovic et al. [53] used panel data for countries in the European Union and concluded that, price of energy negatively affect energy intensity in the European Union. Li and Lin [31] find evidence of an asymmetric price effect in China, while Adom [10,29,30] stressed that the energy price-energy intensity relationship is significantly driven by structural effects.

For income, some studies find that higher income decreases energy efficiency [54–57], while others report otherwise [40,103, and 24]. Adom [10], Sadorsky [24], Galli [58], and Filipovic et al. [53], on the other hand, show that the income-energy intensity relationship is an inverted U. Thus, there is a threshold of income that is required to drive consumers to be energy efficient. Adom [28] further stressed that, during recessions, energy efficiency deteriorates but improves once the economy enter into the boom phase of the business cycle.

The level of energy consumption in any economy is significantly driven by the structure of the economy. Where energy intensive activities dominate, energy consumption is expected to rise per unit of output produced. Industrialization has been found in the literature to drive energy intensity upwards. Inglesi-Lotz and Pouris [59] conclude that, the shift from energy intensive activities to less energy intensive activities contributed to the fall in energy intensity in South Africa. This result is also confirmed by Adom [30]. The author finds that the fall in energy intensity in South Africa is due to de-industrialization. Lin and Moubarak [51] show that, the fall in energy intensity in China is largely due to shift in economic structure. Hubler and Keller [20] and Poumanyvang and Kaneko [57] report that, the high energy-intensive sector drive energy intensity upwards. Li and Lin [31], however, find the effect of industrialization on energy intensity to be asymmetric. Also, Adom and Kwakwa [27] and Adom [29,30] claim significant structural effects in the industrialization-energy intensity relationship, while Adom and Amuakwa-Mensah [46] demonstrate the industrialization-energy intensity relationship to be conditioned on FDI and trade openness. The review of the literature shows technical, structural, and behavioral factors drive energy intensity and therefore these determinants are controlled for in the study's model, which is discussed next.

3. Model and data

3.1. Model

First, the growth rate in energy productivity for Nigeria from 1971 to 2012 is plotted (see Fig. 1). The pattern of the data changes drastically over time; this is a reflection of the different economic and political structures that characterized these periods. One difficulty about the visualization of Fig. 1 is that, it is not obvious what processes may have contributed to the outcome of each year's observation and at what probability. By fitting a linear model to this data, the researcher ignores these interesting aspects of the data, which could affect the results of the study.

The study assumes a two-process model (i.e. state 0 and 1) to capture the different dynamics of the data. Mathematically, Energy intensity, in a two-state process, can be modelled as Eqs. 1 and 2, where dlei is the growth rate in energy intensity, μ_0 and μ_1 denote state 0 and state 1, respectively, and ν_t is the white noise term.

$$dlei_t - \mu_0 = \theta(dlei_{t-1} - \mu_0) + \nu_t \quad (1)$$

$$dlei_t - \mu_1 = \theta(dlei_{t-1} - \mu_1) + \nu_t \quad (2)$$

Eqs. (1) and (2) assume that, there is one abrupt change. Thus,