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Does renewable energy concentration increase the variance/uncertainty in electricity prices in Africa?

Philip Kofi Adom*, Michael Insaidoo, Michael Kaku Minlah, Abdul-Mumuni Abdallah

Department of Banking and Finance, University of Professional Studies, Accra, Ghana

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ABSTRACT

Africa's population is growing at a faster pace, and the growth in megacities and rate of urbanization has been very rapid. Alongside, economic growth is expected to be very robust in the future. Altogether, these will pose serious challenges for the energy system in Africa; a condition that makes the development of renewables (RES) a necessity in the continent. Though the continent is well-endowed with RES, it is least developed and deployed, partly due to limited research and development in the sector. Particularly, the macroeconomic implications of RES have not been thoroughly studied in the continent, which leaves a big literature gap for the continent. This motivates the current study to investigate into the macroeconomic implications of RES using Ghana as the case study, a country that is well-endowed with RES and one of the few in the continent that has integrated RES into their overall energy policy. Specifically, in this study, we examined the implications of RES concentration on electricity price uncertainty. Further, we investigated the persistent profile effect of both system-wide and individual shocks on the equilibrium relations. Finally, we decomposed the variance in electricity price into permanent and transitory components and explained what drives these trends.

1. Introduction

Africa's population is growing at a faster pace, and the growth in megacities and rate of urbanization has also been very rapid. It is expected that by the year 2050, about 2.1 billion people will be added to the population in Africa (African Development Bank, [56]). Urbanization has also increased from the rate of 14% in 1950 to 40% in 2016, and this is expected to reach 50% by 2030 and level of at 56% by 2050 (African Development Bank, [56]). Also, economic growth is expected to be robust in the future. Altogether, these will pose serious future challenges to the energy system in the continent given the fact that the continent is already beset with serious energy supply constraints. To help secure the energy system in the continent and improve energy security, which is an important caveat to achieve the Sustainable Development Goals (SDGs), the development and deployment of renewable energies (RES) is very crucial. Though Africa is one of the continents in the world with huge RES potential, the technology is least developed and deployed. Creating the enabling environment for private sector participation and the political will to develop these technologies will prove crucial to future security of the energy system in the continent.

However, there are concerns that the intermittent nature of RES supply may increase the uncertainty in electricity pricing; possibly impede effective business and investment decisions, and even erode profits of companies. Obviously, this could be a potential risk source that may discourage governments to commit significant resources to developing the technology. So far, however, no consensus has been reached in the literature regarding this phenomenon, which makes further study in this area important. A study that analyses the macroeconomic implications of RES will certainly provide useful information to governments' decision on developing RES in the region. Unfortunately, such studies on Africa are missing in the literature. Given that the continent is one of the densely populated in the world, with high incidence of poverty, poor energy access and huge renewable energy resource potential, this represents a major gap in the renewable energy literature.

This study attempts to fill this gap in the literature by examining the macroeconomic implications of increasing the share of renewables in total generation mix on the variance in electricity prices using Ghana as the case study. Ghana is one of the countries in Africa with huge renewable energy potentials in hydro, wind,

* Corresponding author.
E-mail addresses: adomonline@yahoo.co.uk, Philip.adom@upsamail.edu.gh (P.K. Adom), Michael.insaidoo@upsamail.edu.gh (M. Insaidoo), Michael.minlah@upsamail.edu.gh (M.K. Minlah), abdul.mumuni@upsamail.edu.gh (A.-M. Abdallah).

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solar, biogas, and Photovoltaic. In West Africa, Ghana controls about 11.5% of the total renewable energy projects identified in the region [20]. The hydro capacity in the country is one of the biggest in the continent. Ghana has the highest concentrating solar power in West Africa and her wind power potential is the second in the region [31]. Ghana is also one of the few Africa countries that has integrated renewable energy into the overall energy system policy. Like other countries, in Africa, these technologies are least developed and deployed in the country. However, with the implementation of the Renewable Energy Law Act 832, which target 10% renewable energy share in total energy generation by 2020, the trend is likely to reverse in the future. Obviously, analysing the macroeconomic implications of renewable energy concentration on the price variance in the electricity sector in Ghana has both national and regional significance. Particularly, for Ghana, the consequential positive/negative effects of developing and deploying RES will spillover to Togo, Benin, and Burkina Faso that depends on Ghana's power sector.

The current study provides the first empirical attempt on the role of RES in electricity price uncertainty both at the national and continental level. Context wise, there have been earlier attempts to study the electricity sector in Ghana. Gyamfi et al. [14], Eshun and Amoako-Tuffour [20], and Asmah et al. [6] adopt a more descriptive approach to study Ghana's electricity sector. Eshun and Amoako-Tuffour [14] review the power sector in Ghana. Specifically, the energy imbalance in the power sector, impediments to solving this imbalance, and the major institutional and regulatory constraints are discussed in their study. More so, demand-side pricing and supply-side options, which includes renewables, were enumerated. Gyamfi et al. [20] rather focus their investigation on how renewable energy can help improve energy security in the electricity sector. Similarly, Asmah et al. [6] also investigate the role of renewable energy in Ghana's electricity sector. Both Gyamfi et al. [20] and Asmah et al. [6] come to the conclusion that there is huge renewable energy potential in the country but with serious bottlenecks. However, they agree that with the renewed government effort both in physical investment and regulatory frameworks, renewable energy sources are likely to contribute significantly to the security of the power sector in Ghana.

Other studies have rather adopted a more quantitative approach to studying the electricity sector in Ghana. Adom et al. [4] model aggregate domestic electricity demand quantitatively. Factors such as income, industry factors, and demographic changes were considered as important demand drivers in Ghana. Adom and Bekoe [2] go a step further to obtain long-term forecast of aggregate domestic electricity demand in Ghana based on the autoregressive distributed lag method and the partial adjustment method. Mensah et al. [34] also model demand for the different energy sectors, which included electrical energy. They also confirm the importance of income and demographic changes as demand drivers in Ghana. Adom and Bekoe [3] and Adom [5] address the issue of structural break and its implications for demand drivers in the electricity sector. Based on different techniques, both studies conclude that, there is a significant structural shift in the effects of demand drivers in Ghana's electricity sector. Abdul-Salam and Phimister [1] rather investigate the modelling of electricity planning in Ghana. Specifically, the study develops a model for electricity planning in which the appropriate distributional pattern of on grid and off grid electricity are evaluated considering both cost efficiency and the politico-economic dynamics. Lin et al. [30] investigate the issue of substitutability of factor inputs and fuel inputs among capital, labour, petroleum and electricity in Ghana with the aid of a translog production and cost functions. The present study differs from these context studies in a number of ways. First, we estimate a price model in which we investigate the effect of renewable energy concentration in the electricity sector on the uncertainty in electricity pricing. Obviously, the issue of price uncertainty is very important from the business and investment point of view. Since price outcomes are driven by both demand- and supply-side events, the current study presents an almost close to a complete analysis of the electricity sector in Ghana; something which previous studies are deficient in. Second, we examine the persistent profile effect of system-wide shocks and shocks in macroeconomic indices on the equilibrium price relations in the electricity sector. This has important implications for the free versus control market systems debate. Third, we employ the multivariate Beveridge-Nelson decomposition technique to examine the permanent and transitory components of electricity price uncertainty and what drives these trends.

We structure the remainder of the study as follows. Section 2 reviews the empirical literature. Section 3 discusses the energy situation in Ghana. Section 4 presents the method and data. Section 5 discusses the main findings of the study. Section 6 concludes the paper with policy recommendations.

2. Literature review

The debate on whether RES increase/decrease prices in the electricity sector is unending. Overall, the results are inconclusive even for same country-specific studies, which motivates further studies on the subject. While one section of the literature argues in favour of the potential of RES to reduce electricity prices (see Refs. [8,18,21,22,33,38,39,53,55] *inter alia*), the other side of the literature argue against the potential of RES to reduce electricity prices (see Refs. [7,16,37,50,52] *inter alia*).

Though the empirical literature on the potential impact of RES on the price level in the electricity sector continues to grow, the same cannot be said of whether RES reduce or increase the volatility in electricity prices. As popularly argued by many, the intermittent nature of renewable energy supply is likely to increase the uncertainty level in electricity prices. Similar to the studies on the RE-price level relations, the empirical results on the RE-price volatility relations remain inconclusive. Such studies have emerged as very important since they have important implications on business and investment decisions and profit margins of the industry.

Green and Vasilakos [19] examined the market behaviour with large amounts of intermittent generation in thirty regions in the Great Britain. Specifically, the effects of intermittent wind generation on hourly equilibrium price and output were examined. They concluded that the price volatility increases when they match the wind profile for each month to the actual hourly demand. Milstein and Tishler [36] used data from Israel to examine the impact of intermittently renewable energy on generation capacity mix and market prices. They also concluded that the introduction of Photovoltaics (PV) increase the price volatility in the electricity sector. Ketterer [27] used the GARCH method to assess the effects of wind and solar power capacity on electricity prices in Germany. The results showed that, higher wind power generation reduce the price level but increases the daily price volatility in the electricity sector. However, the author did acknowledge that this has reduced after the regime change in 2010, but the volatility-increasing effect of wind power still remains.

On the contrary, studies such as J'onsson et al. [23], Tveten et al. [51], and Woo et al. [54] have concluded otherwise while Rintamaki et al. [48] provide a mixed position for a comparative study of Denmark and Germany. J'onsson et al. [23] used a non-parametric method to study the influence of wind power on the variance in electricity price in Germany. The results showed that an increase in wind power generation reduces both the level and volatility of