International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2015, 5(3), 754-758.

Empirical Analysis of Renewable Energy Demand in Ghana with Autometrics

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ABSTRACT

Increased investment in renewable energy (RE) has been identified as a potential solution to the intermittent power supply in Ghana. Recently, a RE Act has been passed which has a target of 10% of RE component in Ghana's energy mix by 2020. Whilst effort is been made to enhance supply through feed in tariffs, education and tax reduction on RE related equipment, there is the need to understand the drivers of RE demand. Due to dearth of studies on RE demand in Ghana, this study seeks to fill both policy and research gap on renewable demand trend in Ghana. In this study, the general unrestricted model through autometrics is used to estimate the determinants of RE demand in Ghana. The results indicate that both economic factors and non-economic affect the demand for RE. In addition, the underlying energy demand trend exhibits energy using behaviour. The study recommends that economic factors such as consumer subsidies should be considered when promoting RE demand.

Keywords: Renewable Energy, Energy Consumption, Autometrics, Ghana
JEL Classifications: Q41, Q42, Q43

1. INTRODUCTION

Ghana's involvement and development of renewable energy (RE) sources began in the mid-1960s through the construction of a hydroelectric dam. Prior to that period, the main source of power generation and supply was carried out by some few isolated diesel generators across the country alongside detached electricity supply systems. More than four decades later, the hydro power potential dominated as it gained recognition and acceptance to be the main source of energy supply contributing substantially to the energy mix of the country. In 1961, the Volta River Authority was commissioned to officially generate electricity in Ghana. As the threat of energy supply insecurity tripled due to obsolete thermal plants, poor rainfall pattern and population increase, the country could no longer rely on hydropower for energy generation (Ackah et al., 2014). Hence, the need to diversify resources into alternatives that had less prospect for depletion.

In 1998, import duty and value added tax on solar and wind systems and their components were reduced. In 1999, the RE Service Project (RESPRO), which was a 3 years project which was funded by the United Nations Development Project (UNDP) to create a non-profit trust to manage and extend solar to needy communities. RESPRO designed, installed and provided instructions to users, and supervised the installations of 2000 solar panels that were distributed to schools and households.

Pedroni (1999; 2004) heterogeneous panel integration test show a long-run equilibrium relationship between real gross domestic product (GDP), RE consumption, non-RE consumption, real gross fixed capital formation, and the labour force with the respective coefficient estimates positive and statistically significant. There is little difference in the elasticity estimates with respect to renewable and non-RE consumption. The results from the panel error correction model reveal bidirectional causality between renewable and non-RE consumption and economic growth in both the short- and long-run. Also, there is bidirectional short-run causality between renewable and non-RE consumption indicative of substitutability between the two energy sources.

Sardorsky, 2009 also presents and estimates two empirical models of RE consumption and income for a panel of emerging economies.

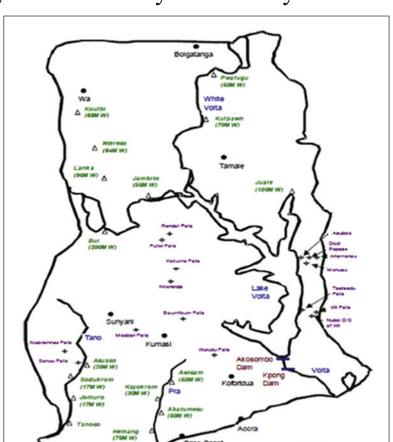
Panel cointegration estimates show that increases in real per capita income have a positive and statistically significant impact on per capita RE consumption. In the long-term, a 1% increase in real income per capita increases the consumption of RE per capita in emerging economies by approximately 3.5%. Long-term RE per capita consumption price elasticity estimates are approximately equal to −0.70. Wolde-Rufael (2005) investigates the long-run relationship between energy use per capita and per capita real GDP for 19 African countries for the period 1971-2001 using a newly developed cointegration test proposed by Pesaran et al. (2001). Sari and Soyatas (2004) found that different energy consumption items have different effects on real output and energy consumption appears to be almost as important as employment with respect to economic development in Turkey, where lignite, waste, oil and hydraulic power compromise the top four among all alternatives sources of energy. Yildirim et al. (2012) found the unidirectional causality from biomass energy consumption and real output. Using a multivariate panel error correction model within a framework of production model.

In Ghana, though attention has been given to electricity (Ackah et al., 2014; Adom et al., 2012; Kwakwa, 2012), natural gas (Mensah, 2014; Ackah, 2014) and gasoline demand (Ackah and Adu, 2014), little has been studied on the demand for RE. The little that has been down focused on RE policies (Gyamfi et al., 2015; Iddrisu and Bhattacharya, 2015). This study therefore attempts to provide demand elasticities that can shape RE policy in Ghana.

The contribution of this paper is two-fold. First, the comprehensive determinants of RE in Ghana is studied. Second, for the first time, autometrics, which is capable of capturing the underlying energy demand trend (UEDT) is applied to RE study in Ghana.

2. RESOURCES IN GHANA

This chapter explains the energy process and the three RE sources that the study is based upon. It also gives a brief background, current situation and future plans of the various RE sources. RE in Ghana is extracted from the ambient environment and over the years has evolved around three main sources namely; biomass, hydropower and biogas. Currently alternative sources of RE such as solar and wind energy are being developed to help alleviate the current energy crisis faced by the country.



Source: KITE/UNDP, 1999

2.1. Biomass

Biomass is the most common form of RE widely used in the third world countries, (World Bank, 2001). Biomass is Ghana's main energy resource in terms of endowment and consumption (IEA, 2014). Biomass resources cover about 20.8 million hectares of the 23.8 million ha land mass of Ghana, and is the source of supply of about 60% of the total energy used in the country (Ghana Energy Commission, 2004).

Biomass is ideally produced in rural areas and provides a sustainable alternative to grid electricity. This is because the resource is readily available in the rural areas of Ghana. In most rural Ghanaian homes, large quantities of biomass in the form of firewood and charcoal are used for domestic activities such as lighting, heating and cooking. In the urban centres however, the type of biomass required is mostly determined by the energy conversion process and the form in which the energy is required, for instance, charcoal is used as a viable substitute to replace liquid petroleum gas for cooking, which in nut shell provides high-energy outputs, to replace conventional fossil fuel energy sources (Karekezi et al., 2003). In 2008, Ghana's biomass energy consumption was 11.7 million tonnes; and this was as a result of the fact that the economy depends heavily on climate sensitive sectors such as agriculture, forestry and hydropower. While petroleum products and electricity consumption were 2.01 million tonnes and 8059 GWh, respectively. In terms of total energy equivalents, biomass (fuel wood and charcoal) constituted 65.6%, with petroleum products and electricity accounting for 26.0% and 8.4%, respectively.

The development and use of RE and waste-to-energy resources have the potential to ensure Ghana's energy security and mitigate the negative climate change impacts.

Even though biomass provides sustainable and substantial amount of energy, in the long-run it results in deforestation and damage the ecosystem. It is in this regard that, the Ghana biomass group and biomass UK Limited carried a comprehensive study in 2009 to identify other means of the generating biomass without necessarily cutting down trees.

2.2. Hydropower

This section further looks at the generation of energy from hydro. Basically, a majority of the hydroelectric power and energy comes from dammed water which is derived from running water, turbine and generator. Electricity generated from hydropower depends on the availability of water supply. The energy generated from the water is then transformed into electricity through hydraulic turbine of the hydroelectric power plant, which is often held at a dam (Sorensen, 2002). The hydropower that is generated from the dam is used to generate electricity to supply high peak demand and in the event of low electricity demand, the water is released back inside the lower reservoir for storage. Hydropower promises enormous contribution to boosting the energy base of the country. This stems from the fact that the country has an abundance of hydro resources. Ghana has a hydropower potential of 2000 MW, of which 1200 MW corresponds to large hydropower projects, and the rest in the form of small hydro power projects.

Ghana relies heavily on hydropower for electricity, accounting for 85% of electricity generation. The sector has evolved around three major phases namely; prior to Akosombo, The hydro years which comprised of the Kpong and Akosombo hydroelectric projects and the thermal complementation. Poor rainfall in past years however limited the capacity of Ghana's large hydro generation units leading to blackouts (IEA, 2013). This resulted in the need for the development of a thermal plant to reliably complement the Akosombo and Kpong power plants.

The first power plant was a combined cycle power plant with an installed capacity of 330 MW combined by two 110 MW GE Frame 9E combustion gas turbines, and one 110 MW steam turbine generator became operational in 1997. Additional plant with installed capacity of 220 MW, with a future expansion of up to 330 MW was developed to ease the load on the hydro systems which would reduce the vulnerability in the power system of Ghana (Aryeetey, 2005). The Bui hydroelectric project which was envisaged in 1925 to be a major hydro power source was also constructed in 2009 and started generating power for the grid in 2013, thereby increasing the installed electricity generation capacity in Ghana by 22%.

The development of mini-hydro is however expected to grow as additional 21 mini hydro sites have already been identified to expand the power generation sector in the country. The generating capacity of these sites is expected to range between 4 kW and 325 kW.

2.3. Biogas

Biofuels (biogas, biodiesel, and bioethanol) play a major role in the energy mix of Ghana. Biogas is generated from by-products of anaerobic fermentation of organic waste such as cow dung, poultry droppings, pig manure, kitchen waste, grass faecal matter and algae (Ministry of Energy & Petroleum, 2010). Biogas technology is noted for improving sanitation, generating clean energy, and producing rich organic fertilizer (Ghana Energy Commission, 2009). Apart from improving sanitation, biogas plants are also known for generating energy and organic fertilizer. Unlike biomass, it has proven to be a practicable and promising technology as it provides a very reliable and clean source of energy when proper management programmes are followed.

Currently, Ghana's source of biofuel is generated from a vast arable and degraded land mass which has been used to cultivate crops and plants and thereafter converted into a wide range of solid and liquid biofuels. This technically has the potential to contribute about 278,000 biogas plants yearly but so far only a little over 100 biogas plants have been developed. The two primary biofuels consumed in Ghana are ethanol and biodiesel. Ethanol is mainly used in the transportation sector to fuel motor vehicles and also in the industrial sector as feedstock for chemicals.

Assimilation of past and current research report on biogas in Ghana suggest that cultivation of feed stocks and production of liquid biofuels for export is growing with biofuel projects gradually gaining grounds in the country (ISSER, 2010). The utilisation of biogas technology for cooking in residential households and small power generation has been successful as a draft bioenergy policy document is seeking to substitute national petroleum fuels consumption with biofuel by 10% by 2020 and 20% by 2030 (MLGRD, 2008).

There are currently a number of community-based, small-scale biofuel projects also underway in different parts of the country; a more detailed evaluation of agricultural bioenergy potential was carried out and the feedback obtained suggests that Ghana has a suitable potential of bioenergy resources and this holds considerable promise for future energy delivery in the country.

3. METHODOLOGY

The automatic variable selection (autometrics) works by first specifying a general model based on based on previous findings, geographic and demographic characteristics, technological and economic trends (Pellini, 2014). A misspecification test, lagged forms, significance levels and the desired information criterion is then set. This will allow valid inference from the specification (Hendry and Krolzig, 2005). This step is followed by the elimination of insignificant variables by a search tree algorithm.

Ibrahim and Hurst (1990) posit that due to lack of information, energy demand studies in developing countries often use only price and income as predictors. In this study, energy related carbon emissions (CO_2) energy resource depletion and labour are added as predictors.

$$R_t = F(Y_t, P_t, L_t, C_t, CO_{2t}, ED_t) \tag{1}$$

$t = 1,\ldots, T$ index time periods. Equation (1) relates RE demand (R), GDP (Y_t), energy depletion ($ED_{,t}$), energy-related carbon emissions (CO_{2t}) and energy price (P_t), L is population of those over 15 years. All data were sourced from the World Bank Development indicators. (Cleveland et al., 2000; Ayres et al., 2003) highlight the positive relations between energy consumption and GDP. In addition, the indirect relations between price and energy demand has receive considering attention in the literature (Gately and Huntington, 2002; Graham and Glaister, 2002; Wadud et al., 2011). Although RE is believe to replenish itself after successive units are drawn, it will be important to examine how energy resource depletion influence its consumption.

$$R_t = \beta_0 + \beta_{rt-1}R_t + \beta_y Y_t + \beta_p P_t + \beta_{ed} ED_t + \beta_{co_2} CO2_t + \beta_l L_t + \mu_t \tag{2}$$

Hendry and Krolzig (2005) suggest that model selection is a vital step in empirical research especially where a prior does not predefine a complete and correct generally accepted specification. Since different set of factors can potentially influence the demand for natural gas, it will be prudent to have an econometric that automatically select the significant factors based on some predefined criteria.

In order to examine the determinants of RE demand in Ghana a general unrestricted model GUM consisting of all predictors is specified. Autometrics then uses a tree-search to remove insignificant variables to select the final model (Pellini, 2014). We begin by specifying a GUM error correction model saturated with impulse indicator and step dummies.

$$\Delta R_t = \beta_0 + \beta_1 t + \Delta\beta_{R-1} R_{t-1} + \Delta\beta_y Y_t + \Delta\beta_{y-1} Y_{t-1} + \Delta\beta_p P_t + \Delta\beta_{p-1} P_{t-1} + \Delta\beta_{ed} ED_t + \Delta\beta_{ed-1} ED_{t-1} + \Delta\beta_{co_2} CO2_t + \Delta\beta_{co_2-1} CO2_{t-1} + \Delta\beta_l L_t + \Delta\beta_{l-1} L_{t-1} + \sum^{T} \delta_i I_t + \sum^{T} \delta S_t + \varepsilon_t \quad (3)$$

Where t is the linear trend, $I_{i,t}$ are impulse indicator dummy and $S_{i,t}$ are the step dummies. These tests include the AR test (Breusch and Godfrey, 1980) where the null hypothesis state no correlation in the residual. Again, the autoregressive conditional heteroskedasticity test (Engle, 1982) where the null states that is serial correlation is employed. Other vital tests include the normality test (Bera and Jarque, 1982) which test normality in the residual, the hetero test (Breusch and Pagan, 1979) which test for homoscedasticity in the residual and finally, reset test (Ramsey, 1974) which test for linearity in the functional form of the regression.

4. DISCUSSION AND ANALYSIS

Table 1 presents the findings of the study. All necessary diagnostic tests were conducted to obtain the preferred model. From the results, the various coefficients are very significant at 5%. In the case of labour, any 1% increase leads to a 0.96% increase in RE demand. This finding confirms the believe that population growth in an important indicator of energy consumption. In addition, since more than 60% of Ghana's energy demand is supplied by RE, increase in population automatically increase demand for renewables. Similar findings were recorded for the lag dependent variables. This implies that the demand of renewable for previous years after the present demand positively.

Increase in income has been found to be a major driver of energy demand (Hunt et al., 2003). This positive relationship between income and RE demand in Ghana can be attributed to two main reasons. First, due to unreliable power supply and prolonged power outages, many households have purchased solar panels as a substitute to grid power. Second, increase in income also increase electricity consumption, which is a by-product of renewable (hydro) in Ghana. To this end, any 1% increase in income leads to a 0.106% increase in RE consumption.

Table 1: Renewable 1973-2011

Predictors	Coefficient	Standard error
ghr_2	0.975874	0.1710
ghr_3	0.460484	0.2252
Ghl	0.961342	0.1655
ghl_3	−0.932033	0.1904
ghC_3	0.0199314	0.005125
ghy_2	0.106247	0.03098
ghy_3	0.111726	0.3058
Ghp	−0.0418962	0.005455
ghh_2	0.0309947	0.005603
Sigma	0.00242579	RSS
R^2	0.999492	F(8,27)
Adjusted R^2	0.999342	Log-likelihood
Number of observations	36	Number of parameters
Mean (ghr)	3.61458	Se(ghr)

Consistent with the findings of Adom and Bekoe (2013), energy prices had an indirect relationship with RE consumption. This implies that, as the price of energy goes up, RE demand declines. This provides a policy implication to provide well targeted RE price subsidies to encourage demand. This finding is in line with Ghana's attempt to establish a RE fund to support demand.

4.1. The UEDT

According to Hunt et al. (2003), UEDT maybe non-linear and reflect not only technical progress, which usually produces greater energy efficiency but other factors such as changes in consumer tastes and the economic structure that maybe working in the opposite direction. However, such trends are not directly seen, although they may exert a dominant influence on the properties of the relevant energy series.

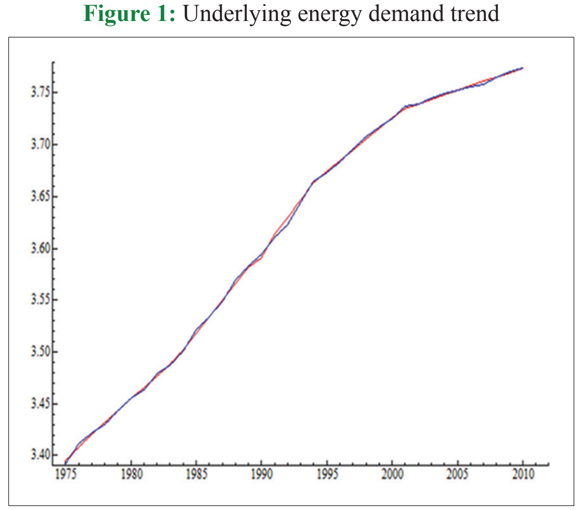
Majority of energy demand studies have recognized the import and trends in energy demand, focussing mainly on the contribution of technical progress.

The UEDT shows an upward trend which signifies "energy using behaviour" (Ackah et al., 2014). This means Ghana has not been efficient when it comes to RE consumption (Figure 1).

5. CONCLUSION

Due to unreliable power supply and the quest to reduce the impact of energy generation and consumption on the climate, RE is gradually becoming the fuel of choice of Ghana. These have led to the introduction of feed in tariffs, tax exemption on the importation of RE equipment and RE subsidy programme by the government of Ghana. In order to ascertain policy options that can be designed to enhance RE demand, this study attempts to examine the predictors of RE consumption in Ghana. The study employs automatic variable selection model. The findings indicate that both economic and non-economic factors affect RE demand. However, the results indicate an inefficiency trend in terms of RE

Figure 1: Underlying energy demand trend



consumption of the estimated period. We therefore recommend that Ghana Energy Commission should devise more effective public education mechanism to encourage energy efficiency behaviour especially in this time of power crises.

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