Modelling Renewable Energy Economy in Ghana with Autometrics

Ackah, Ishmael and Asomani, Mcomari

Africa Centre for Energy Policy, Accra, Ghana

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Ishmael Ackah
Africa Centre for Energy Policy, Accra
And Kwame Nkrumah University of Science and Technology
Kumasi, Ghana
Ackish85@yahoo.com

Mcomari Asomani
Research Assistant
mcomari.asomani@gmail.com

Abstract

Renewable energy consumption has been identified as a potential solution to the intermittent power supply in Ghana. Recently, a Renewable Energy Act has been passed which has a target of 10% of renewable energy 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 renewable energy related equipment, there is the need to understand the drivers of renewable energy demand. In this study, the general unrestricted model through *Autometrics* is used to estimate the determinants of renewable energy demand in Ghana. The results indicate that both economic factors and non-economic affect the demand for renewable energy. 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 renewable energy demand.

Key words: Renewable energy, energy consumption, Autometrics, Ghana

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 (VAT) on solar and wind systems and their components were reduced. In 1999, the Renewable Energy Service Project (RESPRO), which was a 3-year 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 2,000 solar panels that were distributed to schools and households.

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

Sardorsky, 2009 also presents and estimates two empirical models of renewable energy 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 renewable energy consumption. In the long term, a 1% increase in real income per capita increases the consumption of renewable energy per capita in emerging economies by approximately 3.5%. Long-term renewable energy 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 gross domestic product (GDP) for 19 African countries for the period 1971–2001 using a newly developed cointegration test proposed by Pesaran, M. H., Shin, Y, & Smith, R. (2001).

The contribution of this paper is twofold. First, the comprehensive determinants of renewable energy in Ghana is studied. Second, for the first time, autometrics, which is capable of capturing the underlying energy demand trend is applied to renewable energy study in Ghana.

2.0 Renewable energy sources in Ghana

This chapter explains the energy process and the three renewable energy sources that the study is based upon. It also gives a brief background, current situation and future plans of the various renewable energy sources. Renewable energy 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 renewable energy such as solar and wind energy are being developed to help alleviate the current energy crisis faced by the country.

Biomass

Biomass is the most common form of renewable energy widely used in the third world countries, (World Bank, 2001). Biomass is Ghana's main energy resource in terms of endowment and consumption (GBG, 2009). Biomass resources cover about 20.8 million hectares of the 23.8 million hectare land mass of Ghana, and is the source of supply of about 60% of the total energy used in the country (Ghana Energy Commission, 2002).

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 LPG for cooking, which in nut shell provides high-energy outputs, to replace conventional fossil fuel energy sources (See 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 8,059 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 renewable energy 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.
This was achieved through the process of establishing Pelletizers in the country to recycle cocoa pods, previously thrown away by farmers, into pellets using local labour (GBG, 2009).

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 (Sorenson, 2000). 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 2,000 MW, of which 1,200 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 percent 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 4kW and 325kW.

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, 2013). Biogas technology is noted for improving sanitation, generating clean energy, and producing rich organic fertilizer (GEC, 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. Biodiesel on the other hand is used primarily for heating and generating electricity (Arthur et al, 2011)

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.

Figure 1.0 renewable energy growth trend

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 (CO2) energy resource depletion and labour are added as predictors.

$$R_t = F(Y_t, \mathrm{P}_t, \mathrm{L}_t, \mathrm{C}_t, \mathrm{CO}_{2t}, \mathrm{ED}_t) \qquad (1)$$

$t = 1, \ldots, T$ index time periods. Equation (1) relates renewable energy demand (R), GDP (Y_t), energy depletion ($ED_{,t}$), energy-related carbon emissions ($CO2_t$) 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) 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 (Wadud et al. 2011). Although renewable energy is believe to replenish itself after successive units are drawn, it will be important to examine how energy resource depletion influence its consumption.

$$R_t = \beta_o + \beta_{Rt-1}R_t + \beta_y Y_t + \beta_p P_t + \beta_{Ed} ED_t + \beta_{co2} CO2_t + \beta_l L_t + \mu_t$$

(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 renewable energy 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.

$$\Delta R_t = \beta_o + \beta_i t + \Delta\beta_{R-1}R_{t-1} + \Delta\beta_y Y_t + \Delta\beta_{y-1}Y_{t-1} + \Delta\beta_p P_t + \Delta\beta_{p-1}P_{t-1} + \Delta\beta_{Ed}ED_t + \Delta\beta_{ed-1}ED_{t-1} + \Delta\beta_{co2}CO2_t + \Delta\beta_{co2-1}CO2_{t-1} + \Delta\beta_l L_t + \Delta\beta_{l-1}L_{t-1} + \sum^{T}\delta_i I_t + \sum^{T}\delta S_t + \varepsilon_t$$

(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, 1981) where the null hypothesis state no correlation in the residual. Again, the ARCH test (Engle, 1982) where the null states that is serial correlation is employed. .

4.0 Discussion and Analysis

This chapters discusses the results and provides an overview of the main findings.

Table 1

Renewable 1973-2011

	Coefficient	**Std 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)
Adj. R^2	0.999342	Log-likelihood

No. of Observations	36	No. of parameters
Mean(ghr)	3.61458	Se(ghr)

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 percent. In the case of labour, any 1% increase leads to a 0.96 percent increase in renewable energy 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 renewable energy, 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.

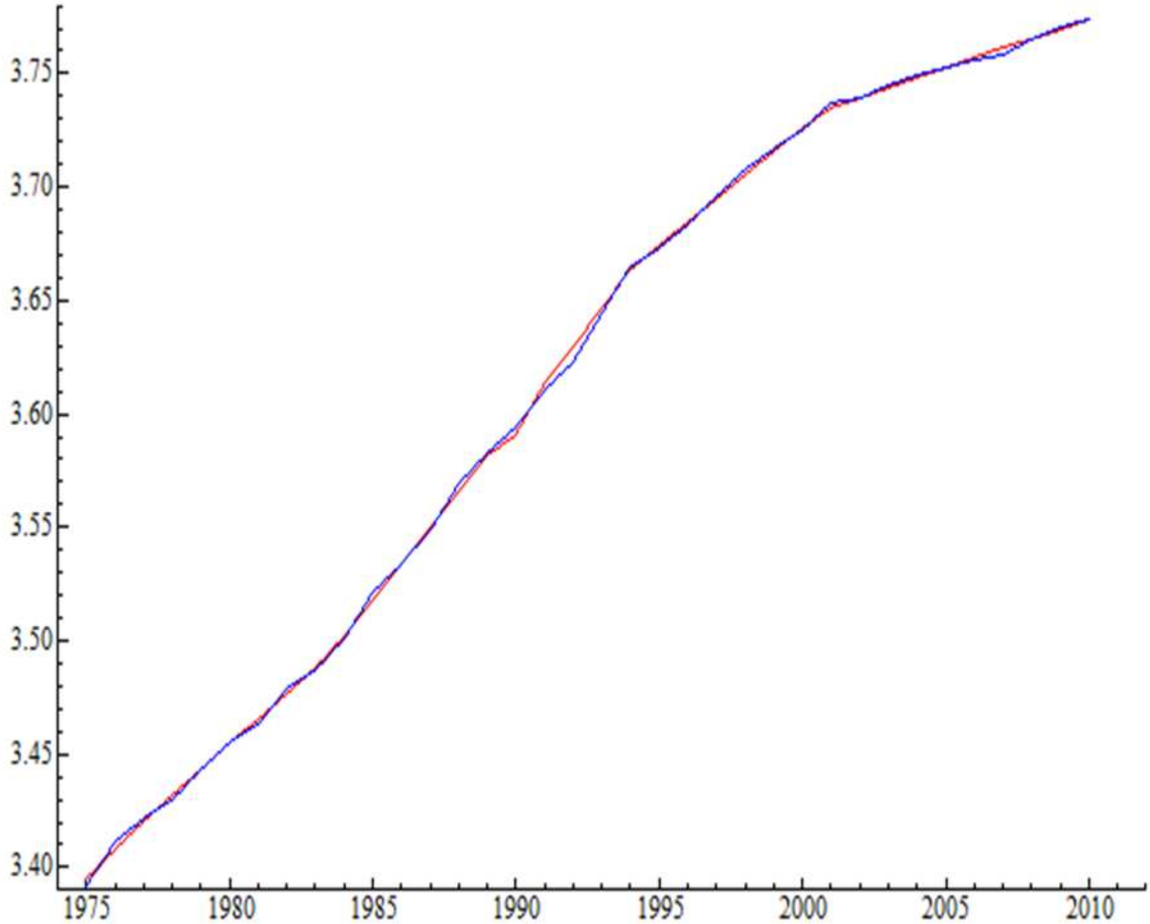
From the income point of view, any 1 % increase leads to 0.11 percent increase in renewable energy demand. The inference that can be made from this is that, when the income of people increases, they turn to have a higher purchasing power therefore their renewable energy consumption increases. On the other side of it, when people have higher incomes they are able to purchase a lot of electrical appliances hence the increase in the demand of renewable energy.

Moreover, in relation to price, any 1% increase leads to 0.04 percent decrease in renewable energy demand. On the flipside of income, as price increases people turn to spend less on renewable energy hence an inverse relationship is established.

For capital, any 1% increase leads to 0.02 percent increase in renewable energy demand. This means that government's policy on reducing taxes or better still giving tax rebates it will encourage renewable energy investment.

When it comes to Human Capital development, any 1% increase leads to 0.03 percent increase demand in renewable energy demand. It is believe that educated consumers are more enlightened and environmentally conscious. Therefore the higher the education, the more their consumption of renewables.

Figure 1. UEDT



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 renewable energy consumption. This trend is similar to the underlying demand trend of natural gas for Ghana in Ackah (2014).

5. Conclusion

Due to unreliable power supply and the quest to reduce the impact of energy generation and consumption on the climate, renewable energy 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 renewable energy equipment and renewable energy subsidy programme by the government of Ghana. In order to ascertain policy options that can be designed to enhance renewable energy demand, this study attempts to examine the predictors of renewable energy consumption in Ghana. The study employs automatic variable selection model. The findings indicate that both economic and non-economic factors affect renewable energy demand. However, the results indicate an inefficiency trend in terms of renewable energy 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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