An investigation into the determinants of hydropower generation in Ghana

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Abstract

The role of electricity to the growth and developmental process of an economy cannot be overemphasized. Therefore, it is the quest of authorities in every economy to meet the supply of electricity needs of the citizens and industries. Although both renewable and non renewable energy source are available for an economy to generate electricity from, the recent concern for cleaner environment has raised interest of many government, environmentalists and policy makers to generate electricity power from renewable source - that are noted for emitting low carbon emission - prominent among them is hydro source. Meanwhile, the electricity supply for the Ghanaian economy which for years was mainly from hydro source has witnessed a reduction in her hydropower generation in the midst of growing electricity consumption but limited supply pushing the country to resort to power sharing. The paper thus investigates into the drivers of the declining hydro power generation in Ghana using annual time series data for the period 1977-2011. Estimations from the Fully Modified Ordinary Least Squares, Dynamic Ordinary Least Squares and Canonical Cointegration Regression estimators revealed Ghana's hydropower generation is influenced by foreign direct investment, alternate source of energy, environmental degradation and trade openness.

Key words: renewable energy; electricity, hydropower, FMOLS, CCR, DOLS, Ghana

Introduction

Electricity as a source of energy has become an essential commodity for the development of an economy and it is well documented in the literature, particularly the positive relationship between economic growth and electricity usage. Thus the growth of an economy increases with electricity usage. Due to the fact that electricity is needed as a critical input for the productive sectors of the economy namely the manufacturing, financial, communication, transport, education, commercial, health, entertainment and construction, more electricity is consumed towards achieving the desired level of growth and development in an economy. However, an increase in electricity consumption and the high carbon source of electricity power generation particularly from fossil fuel source has threatening environmental consequences as it contributes to the emission of green house gases that lead to global warming and climate change. Consequently policy makers, governments and environmentalists among others have in recent times sought for ways of minimizing the emission effect of energy uses.

As a result of the interrelationship between electricity consumption and economic growth on one hand, and climate change and energy consumption on the other hand, there has been the quest for efficient usage of energy and the search for low-carbon emission electricity (energy) generation source. Given the above development, the world's attention to the usage of renewable energy as an alternative energy source has gained prominence in recent times. To guide policy making, studies have also been conducted to examine the determinants of renewable energy consumption or the causality between renewable energy and other macroeconomic variables (see Sadorsky 2009a; Salim and Rafiq 2012; Omri et al. 2015; Jebli et al. 2016; Mehrara et al 2015; Apergis et al. 2010; Farhani 2013) although they compare less in number to studies on non renewable energy. For instance earlier studies by Sadorsky (2009a) found that CO2 emissions and income significantly have a positive effect on renewable energy consumption in the long run while oil price has negative effect for G7 countries. Another study by Sadorsky (2009b) on emerging countries found income to positively increase renewable energy consumption. For a number of OECD countries Apergis and Payne (2010a) over the period 1985–2005 confirmed that renewable energy consumption and economic growth granger cause each other for both short- and long-run periods. Again it was established that long run relationship between real GDP, renewable energy consumption, real gross fixed capital formation, and the labor force exists. Another study by Apergis and Payne (2010b) on the causal relationship between renewable energy consumption and economic growth for 13 Eurasia countries using the 1992–2007 period, established a long run relationship between real GDP, renewable energy consumption, real gross fixed capital formation, and labor force. Also in both the short-run and long-run a bidirectional causality between renewable energy consumption and economic growth was realized. Using data for the period of 1984-2007, Apergis et al. (2010) also examined the causal relationship between CO_2 emissions, nuclear energy consumption, renewable energy consumption, and economic growth for a group of 19 developed and developing countries and established a positive relationship between emissions and renewable energy consumption. A later study by Apergis and Payne (2011) on six Central American countries over the period 1980–2006 obtained bidirectional causality between renewable energy consumption and economic growth in both the short- and long-run. Salim and Rafiq (2012) analyzed the determinants of renewable energy consumption of six major emerging economies, namely Brazil, Philippines, India, Indonesia, Turkey and China. They found that income and emission of pollutants contribute to renewable energy consumption.

Recently Rafiq et al (2014) compared the renewable energy adaption of China and India for the 1972 to 2011 period. In the short run the authors found causality from carbon emission to both renewable energy generation and output and from renewable energy granger to output. In the long run bidirectional causality was found among the variables. For the Chinese economy unidirectional causality was found from output to renewable energy and from carbon emission to renewable energy. In the long run they observed unidirectional causality from output to renewable energy generation and bidirectional causality between carbon emission and renewable energy generation. Mehrara et al. (2015) investigated into the driving forces of renewable energy consumption for Economic Cooperation Organization (ECO) countries, over the period 1992-2011 and found socio-economic environment, institutional environment proxies, urban population, and human capital as the explanatory variables of renewable energy consumption.

Also, Jebli and Youssef (2015a) using data for the period 1980–2009 established a short-run unidirectional causality running from trade, GDP, CO_2 emission and non-renewable energy to renewable energy for the Tunisian economy while Jebli and Youssef (2015b) for a sample of 69 countries noted a bidirectional causality between non-renewable energy and trade in the short run and long run for the period of 1980–2010. Ackah and Kizys (2015) examined the determinants of renewable energy demand in oil-producing African countries over the period of 1985 to 2010 . They established that real income per capita, energy resource depletion per capita, carbon emissions per capita and energy prices contribute significantly to the demand of renewable energy demand for these countries. Jebli et al. (2015) found import and export granger cause renewable energy consumption for sub Saharan African countries over the period of 1980-2010. In a much recent research, Jebli et al. (2016) examined the role of trade, renewable and non renewable energy towards environmental degradation for OECD countries over the period 1980–2010. The authors observed a bidirectional causality between renewable energy consumption and imports on one hand and renewable and non-renewable energy consumption on another hand. Again in the short run they found export and output granger cause renewable energy.

Works by Omoju (n.d), Carley, 2009; Johnstone et al., 2010; Marques and Fuinhas, 2012; Marques et al., 2010; Menz and Vachon 2006 have also looked at various factors that influence the generation of renewable energy. For insatnce Menz and Vachon (2005) established renewable portfolio standards and requiring electricity suppliers to provide green power options to customers positively increased wind power development. On the other hand they found wind power development is reduced by retail choice reduces that in several states of America. Aguirre & Ibikunle 2014 in their study obtained a positive effect for CO2 emissions, Kyoto protocol, biomass and solar potential on renewable energy development but a negative effect for participation of coal, oil, natural gas and nuclear power in electricity generation. Omoju (nd) also noted for the Chinese economy that income, trade openness, FDI increases renewable energy development while carbon emission and fossil use reduce.

Many economies particularly, the developed countries and developing Asian economies have intensified the development of their renewable energy for electricity generation. According to the International Finance Corporation 2015 report, globally the dominant renewable source of energy for electricity is hydro, contributing about 16 percent of electricity generated and this figure is expected to grow. The report continues to say that Asia has by far the largest hydropower technical potential, followed by Latin America and North America. China has the highest existing energy generation and uses 24 percent of its potential. As a renewable source, hydropower has the potential of contributing to sustainable development; it relies less on imported fuels with their associated risk of price volatility, supply uncertainty and foreign currency requirements; and it offers other pecuniary benefits such as storage for drinking and irrigation, drought-preparedness, flood control protection and aquaculture among others (International Finance Corporation 2015). With these potentials associated with hydropower, many countries from the developed countries and developing Asian economies have harnessed their hydropower resources opportunities.

However, many developing countries including Ghana blessed with numerous hydro sources have failed to generate the needed power to meet the growing energy demand of industries and households. Meanwhile, the role of electricity in Ghana's growth and development cannot be overemphasized and its demand has been increasing steadily. For instance from 2000 to 2009, there was a 1.4% annual growth in peak power demand of 1,258 MW to 1,423 MW respectively (PSEC and GRIDCo., 2010) which exceeds the generating capacity of electricity in the economy predominantly from hydro source and thermal plants. With the numerous water bodies in the country, Ghana has built three hydro plants on her river bodies. The Akosombo power dam built in

1966 on the Volta river is the first and largest hydro source of power. It has an installed capacity of 1020MW. The Kpong hydro power plants built in 1982 also on the Volta river has the capacity of 160 MW. The latest power plants is the Bui power plants whose capacity is 400MW of power is built on the Bui river. There are laid down plans to harness other opportunities from other water bodies in the country. Until then, to supplement the country's electricity generation, Ghana relies on thermal plants that together generates 790 MW).

However addressing the nation's problem of inadequate electricity supply, ensuring sustainable electricity supply for the future generation and climate change through carbon emission requires Ghana increases her reliance on renewable energy source for electricity generation. Notwithstanding this the development of renewable energy particularly hydro power has been sluggish as it took close to 20 years for the second project to be built and over another 30 years for the third project to be built. Furthermore, hydropower generation in the country comparatively has been reducing over the years. Data from the world development indicators reveal that between 1971 to 1991 the share of hydro power generation in the total electricity generated electricity grew at annual average rate of 6% but this has reduced to 2% from 1991 to 2011.

The above situation calls for recognizing the factors behind the falling trend of hydro share of electricity generation in the Ghana which will come in handy when studies have been conducted to reveal such factors. Identifying the driving force of the low hydro power generation will offer guidelines for policy makers. However, to the best of the author's knowledge, such a study does not exist for the country. It is against this background that the present study aims at examining the forces behind the falling hydro power generation in Ghana.

The present study contributes to the literature on renewable energy in a number of ways. Firstly previous studies on renewable energy mentioned earlier have focused on the determinants of the consumption side with little known about the generation side. But as the world's concern for climate change and energy has increased it is important to consider the supply or generation side of renewable energy. However, such studies are scarce. The only papers the author has come across to have dealt with the issue of generation renewable energy are Omoju (n.d), Kwakwa (2015), Carley, 2009; Johnstone et al., 2010; Marques and Fuinhas, 2012; Marques et al., 2010; Menz and Vachon 2006 but even they have little evidence on the development of hydropower generation. With such dearth of study on the drivers of renewable energy generation more studies are needed to offer inputs for policy making of which this papers does.

Secondly, the paper provides evidence from sub Saharan Africa (SAA) region where energy poverty is high despite the abundance of rich energy resources both renewable and non-renewable. Also as a region that is said to be negatively affected by climate change it is important that efforts are made to reduce emissions that contribute to climate change which includes generating power from the renewable energy resources especially water. However, countries in the sub region including Ghana have failed to fully develop and generate energy from the renewable resources. The results from the study thus throws light on the possible reasons for that.

Thirdly although this is not the only study on electricity (energy) in the Ghanaian context this paper is novel because previous studies on energy have placed emphasis on identifying the drivers of the various dimensions of energy consumption (Acka and Adu 2013; Mensah and Adu 2013; Ackah et al. 2014; Ackah and Adu 2014; Adom et al. 2012; Adom and Bekoe 2013; Adom 2013; Karimu

2013; Kwakwa et al. 2013; Manyo-Plange 2011; Kuunibe et al. 2013; Adom and Kwakwa 2014, Adom and Bekoe 2012; Kwakwa and Aboagye 2014), the energy-growth nexus (see Kwakwa 2014; Kwakwa 2012; Adom 2011; Dramani et al. 2012; Bildirici 2013; Wolde-Rufael 2006) and the effect of energy on carbon emission (Kwakwa et al 2014). However, none of these studies have dealt with the determining factors of the energy supply side of the economy as it is captured in this paper.

To this end, the paper modeled hydroelectricity generation as a function of foreign direct investment, alternate source of energy, environmental degradation, trade openness and financial development for the 1975-2011 period using annual time series data. The Fully Modified Ordinary Least Squares, Dynamic Ordinary Least Squares and Canonical Cointegration Regression estimators revealed Ghana's hydropower generation is influenced by foreign direct investment, fossil fuel usage, environmental degradation and trade openness. Thus both economic and environmental factors are very crucial and they should be incorporated in plans to generate more hydroelectricity.

The rest of the paper is organized as follows. Section 2 presents the methodological and data issues .Section 3 discusses the estimated results. Section 4 concludes the article and draws some policy implications.

2. Methodology

2.1 Economic motivation and model specification

In deciding on which variables to choose as explanatory variables of the hydroelectricity generation for Ghana the study draws inspiration from economic theory and empirical studies.
The theory of supply suggests that the supply of a good and service is determined primarily by the price of the good, cost of production and technology. This is expressed mathematically as

$$QS = a + \beta_i X \qquad 1$$

Where QS is the quantity supplied, a is a constant term, β_i is the coefficient of the explanatory variables X which in this case price of the good, cost of production and technology

From equation 1 the generation of hydropower (ES) can be expressed as

$$ES = a + \beta_i X \qquad 2$$

From empirical research, environmental degradation is included in the explanatory variables as it has been identified as a factor that increases desire of economies resort to renewable energy supply (Omuju n.d). On the other hand a deteriorated environment may limit the energy which can be generated from hydro energy (see Ubi et al. 2013). For instance bush fires and climate change affect the pattern of rainfall and subsequently the level of water which will negatively affect power generated from hydro. Another variable of interest is foreign direct investment. By increasing the resources available for production, increasing research and development and promoting investment activities an increased foreign direct investment (see Borensztein et al. 1998; Alfaro et al. 2004; Freckleton et al. 2012; Umoh et al. 2012; Sakyi et al. 2015) channeled towards the hydropower sector is expected to enhance generation of electricity.

The energy mix in the generation of electricity (Ubi et al. 2013, Omuju n.d) is also of interest here. Because the supply of hydro electricity is likely to receive competition from other source of energy regarding the allocation of scarce resources of an economy, the study examines the effect the alternative source of energy will have on hydro power generation. From the argument that trade liberalization leads to specialization, efficiency (Sakyi et al 2015) and increases stock of knowledge or transfer of ideas and technology (Asiedu 2013), trade openness can in this regard increase power generated from hydro source for an economy. Financial development can also enhance energy generation by making readily funds for investment.

Following from the above discussions an empirical model that is developed for this study takes the form:

$$ES = a + \beta_1 PR + \beta_2 PCO + \beta_3 TECH + \beta_4 END + \beta_5 FDI + \beta_6 FOS + \beta_7 TO + \beta_8 MS + \mu \quad 3$$

Where *ES* and *a* remain as explained earlier on, the betas stand for the coefficients of the explanatory variables. *PR* is the price of electricity, *PCO* is the cost of production, *TECH* is level of technology, *END* environmental degradation, *FDI* is the foreign direct investment, *FOS* is the alternate source of energy, *TO* represents trade openness and *MS* represents financial development. Owing to the difficulty involved in getting data on cost of production, price and technology the final estimation dropped these three variables. To interpret results as elasticities, the log form of all the variables used for the final estimation.

2.2 Data and econometric technique

The study aims at investigating the effect of foreign direct investment, trade openness, financial development, environmental degradation and alternative source of energy on the generation of hydroelectricity for Ghana. Time series data for period 1975-2011 accessed from WDI (2015) is used for the study. In this study the measure of hydroelectricity supply is electricity production from hydroelectric sources (% of total) and foreign direct investment is measured as foreign direct investment, net inflows (% of GDP). Trade openness is represented by the sum of import and export as a share of GDP; financial development is measured as money supply; and environmental degradation is measured is emission of carbon dioxide. Table 1 below gives a summary statistics of the variables.

Table 1: summary statistics of the variables

Statistics	FOS	FDI	TO	CO	MS	ES
Mean	23.28891	2.049809	55.84996	4655.504	22.61127	90.16432
Median	20.74249	1.186981	56.66912	4055.702	22.85738	98.88652
Maximum	40.79426	9.517043	116.0484	8929.145	34.10823	100.0000
Minimum	11.52890	-0.660372	6.320343	2079.189	11.30499	53.41072
Std. Dev.	6.906735	2.701024	30.89970	1989.023	6.589494	13.52787
Observations	37	37	37	37	37	37

With time series estimation, it is important to run unit root test of the series in order to know their stationarity situation. Identifying whether the variables are stationary or not is critical since non stationary variables could lead to spurious regression. In the literature *nonstationary* variable is of the nature of random walk:

$$X_t = X_{t-1} + \varepsilon_t \qquad 4$$

where ε is a stationary random disturbance term. The series has a constant forecast value, conditional on t, and the variance is increasing over time. The random walk is a difference stationary series since at the first difference of X it becomes stationary:

$$X_t - X_{t-1} = (1-L)\, X_t = \varepsilon_t \qquad 5$$

The number of times a series is differenced for it to become stationary or the number of unit roots contained in the series determines the order of integration. If it is differenced once like the one above then it is integrated of the order one, I(1). If at levels that is without taking the difference of the series it is stationary then it is integrated of the order zero I(0).

In this regard all the variables to be used in estimating equation (2) are subjected to the unit root test using the Augmented Dickey Fuller (ADF) by Dickey and Fuller (1979) and Phillip-Perron (*1988)* that have been widely used in countless studies. The stationarity test is done with the null hypothesis that the series is not stationary or it contains unit root and the alternate is the series is stationary or does not contain unit root. An accepted null hypothesis would require the series is differenced until stationarity is attained.

Next the long run relationship that exists between hydroelectricity generation, environmental degradation, alternate source of energy, trade openness, foreign direct investment and financial development is examined. This is informed by argument due Engel and Granger (1987) that although individual series may not stationary at levels, a linear combination between them may generate stationarity. In this case the variables are said to be cointegrated and a long run relationship established among them. The study employs the Engle-Granger (1987), Phillips-Ouliaris (1990) residual-based tests for cointegration and the Johansen (1995) system framework cointegration tests. The residual test is undertaken by examining whether the residual obtained from an OLS regression is stationary or not. If the residual is stationary then the variables are cointegrated. The difference between the two residual base tests is that Engle-Granger test uses a parametric augmented Dickey-Fuller (ADF) approach, while the Phillips-Ouliaris test uses the nonparametric Phillips-Perron (PP) methodology. In the light of this the null hypothesis of no cointegration is tested against the alternate of cointegration. The system cointegration by Johansen approach tests for the number of cointegrating vectors among variables.

To identify the effects of the drivers of hydroelectricity generation the study then employs the Fully Modified OLS (FMOLS) and Canonical Cointegrating Regression (CCR). Following closely Adom and Kwakwa (2013), the fully modified OLS estimator developed by Philips and Hansen (1990) is given in the equation below:

$$\Phi_{FME} = \left(\sum_{t=1}^{T} Z_t Z_t^{'} \right)^{-1} \left(\sum_{t=1}^{T} Z_t y_t^{+} - T\hat{J}^{+} \right) \qquad 6$$

where $y_t^+ = y_t - \hat{\lambda}_{ox}\hat{\lambda}_{xx}^{-1}\Delta x_t$ is the correction term for endogeneity, and $\hat{\lambda}_{qx}$ and $\hat{\lambda}_{xx}$ are the kernel estimates of the long-run covariances, $\hat{J} = \hat{\Delta}_{ox} - \ddot{\lambda}_{ox}\hat{\lambda}^{-1}{}_{xx}\Delta_{xx}$ is the correction term for serial correlation, and $\hat{\Delta}_{ox}$ and $\hat{\Delta}_{xx}$ are the kernel estimates of the one-sided long-run covariances.

The canonical cointegration regression by Park [1992], which is similar to the FMOLS deviates along the line that the FMOLS uses the transformations of both the data and estimates while the CCR uses only the data transformation and selects a canonical regression among the class of models representing the same cointegrating relationship. The CCR estimator is thus shown below:

$$\hat{\Phi}_{CCR} = \left(\sum_{t=1}^{T} Z_t^* Z_t^{*1} \right)^{-1} \sum_{t=1}^{T} Z_t^* Y_t^* \qquad 7$$

where $Y_t^* = (X_t^{*1}, D_t'), X_t^* = X_t - (\hat{\Sigma}^{-1} \hat{\wedge}_2) \hat{\vee}_t$ and $Y*_t = Y_t - \hat{\Sigma}^{-1} \hat{\wedge}_2 \hat{\beta} + [\hat{\eta}_{22}{}^{-1} \hat{\omega}_{21}]' \hat{\nu}_t$ denotes the transformed data, $\hat{\beta}$ is an estimate of the cointegrating equation coefficients, $\hat{\wedge}_2$ is the second column of $\hat{\wedge}$ and $\hat{\Sigma}$ denotes estimated contemporaneous covariance matrix of the residual.

3. Empirical Results and Discussion

This section presents and discusses the result of the unit root test of series, cointegration test, and long-run determinants of hydroelectricity generation for Ghana.

3.1 Unit root and cointegration results

The results of the unit root test is reported in Table 2. The results from both ADF and PP test indicate that none of the variable is stationary at levels but all becomes stationary at first difference. Thus all the variables are integrated of order one, I(1) at significant levels.

Having attained stationarity the long run relationship between hydroelectricity using the Engel-Granger test, Philip-Ouliaris test and Johansen test is examined. The generated results are reported in Tables 3 and 4. The results from both Engel-Granger test and Philip-Ouliaris tests in Table 3 shows that the null hypothesis of no cointegration is rejected by the tau tests while the z-test does not reject it. In addition, from the Johansen test 2 cointegrating equations at 5% level of significance is confirmed by the Trace test while the Max-eigenvalue test indicates 1 cointegrating equations at 5% level of significance. Thus on the balance it can be concluded that there is a long run relationship between hydroelectricity generation, environmental degradation, environmental degradation, trade openness, foreign direct investment and financial development.

Table 2: Unit root test

Variables	ADF- test	PP-test
	Series in levels	
LES	0.3314	-1.4359
LFDI	-0.7736	-0.6940
LFOS	0.1662	-0.4995
LMS	-1.1169	-1.2855
LEND	-1.0241	-0.7319
LTO	-0.8235	-1.0372
	Series at first difference	
DLES	-7.8986***	-8.0401***
DLFDI	-5.0992***	-5.1800***
DLFOS	-8.3409***	-9.1414***
DLMS	-5.9488***	-5.9602***
DLEND	-9.4106***	18.3057***
DLTO	-3.9616***	-3.7103***

*** and ** indicate significance level at 1% and 5% respectively

Table 3: Engel-Granger and Philip-Ouliaris unit root test

Cointegration Test	tau-test	z-test
Engle-Granger	-6.0911**	263.9811
Philip-Ouliaris	-6.8468**	-26.8337

Table 4: Johansen Unit root test

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.842597	153.4012	125.6154	0.0003
At most 1 *	0.669943	97.93285	95.75366	0.0351
At most 2	0.567501	64.67819	69.81889	0.1201
At most 3	0.452883	39.53293	47.85613	0.2397
At most 4	0.359101	21.44017	29.79707	0.3308
At most 5	0.234673	8.093658	15.49471	0.4555
At most 6	0.002334	0.070091	3.841466	0.7912

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.842597	55.46837	46.23142	0.0040
At most 1	0.669943	33.25465	40.07757	0.2392
At most 2	0.567501	25.14526	33.87687	0.3752
At most 3	0.452883	18.09277	27.58434	0.4874
At most 4	0.359101	13.34651	21.13162	0.4208
At most 5	0.234673	8.023567	14.26460	0.3763
At most 6	0.002334	0.070091	3.841466	0.7912

Trace test indicates 2 cointegrating equations at 5% level of significance
Max-eigenvalue test indicates 1 cointegrating equations at 5% level of significance

3.2 Long run determinants of hydroelectricity generation in Ghana

Table 5 presents the results of the long run estimations. Out of the six explanatory variables included in the estimation equation, financial development is found not be statistically significant to have any effect on hydropower generation in Ghana. Foreign direct investment (LFDI), trade openness (LTO), environmental degradation (LEND), availability of other source energy (LFOS) are found to have a significant effect on hydropower generation. FDI is found to be positive and statistically significant from all the three estimators. The results suggest that, all other things being equal, an increase in FDI in flows will increase hydroelectricity generation in Ghana. A 1% increase in the FDI inflows will lead to about 0.04% - 0.05% hydropower generation. Thus as Ghana attracts more FDI inflows, opportunities of having more resources and promoting investment activities become available which enhances hydropower generation. Similarly the effect of trade openness is found to be positive and statistically significant. From all the three estimators, a 1% increase in the level of trade openness will also increase hydropower generation by about 0.02% - 0.03%. This could be attributed to the transfer of knowledge and technology that Ghana gets from opening up its boarders to international trade. A study by Omuju (n.d) also found FDI and trade openness to increase renewable energy generation in China.

On the other hand, environmental degradation (LEND) measured by carbon emission is found to have a negative effect of hydropower generation at statistically significant levels. Thus a 1% increase in the deterioration of the environment will reduce hydropower generation by about 0.4%. Generating power from hydro sources is influenced by a number of or environmental or geographical factors such as precipitation, flow of river and topography. Degrading the environment in one way or the other affect precipitation, flow of river and the topography thereby reducing hydropower generation. Ghana has on many occasions suffered from this whenever the northern part of the country experience late rainfall as the Volta river on which the main hydro power plants the Akosombo plant and the Kpong plants have been built takes it source from northern Ghana. Carbon emission which also contributes to climate change could account for changes in the rainfall pattern which end up affecting the volume of water in the dam needed to generate power.

Availability of alternative source of energy (LFOS) has a negative and significant coefficient indicating a negative relationship between that and hydropower generation. The absence of other energy sources like oil and coal makes the country more dependent of hydro in generating power for its citizens as it is in the case of Japan and Switzerland. The availability of such energy resources could offer cheap or affordable alternative in generating power and this would make the country not to relent in developing its hydro project. Ghana does not rely solely on hydro to generate electricity but also on fossil source of fuel and the reliance on the latter has increased tremendously in recent times. This could therefore be associated with the decreasing hydropower generation in the country. So in the long run a one percent increase in alternate source of energy will reduce hydropower generation by approximately 0.32%.

A careful look at the estimated coefficients reveal the alternate source of energy (LFOS) and environmental degradation (LEND) have the stronger negative impact. LFOS ranges from negative 0.31-0.34 while LEND ranges from negative 0.3 – 0.4. On the other hand the positive coefficients of (foreign direct investment) LFDI ranges between 0.03-0.5 and 0.02-0.028 for trade (LTO). The implication is the negative effects of environmental degradation and availability of other sources of energy on hydropower generation outweigh the positive effects of trade openness and foreign direct investment.

Table 5: Long-run Estimate

Explanatory Variables	FMOLS	CCR	DOLS
LFDI	0.0461***	0.0437***	0.0304**
	(4.2441)	(3.1782)	(2.5377)
LFOS	-0.3249***	-0.3434***	-0.3193***
	(-4.9682)	(-3.6490)	(-4.1906)
LEND	-0.3885***	-0.3972***	-0.2971***
	(-7.5784)	(-6.3709)	(-6.5679)
LTO	0.0238**	0.0276**	0.0185*
	(2.7005)	(2.4335)	(1.8136)
LMS	-0.0025	-0.0146	0.0305
	(-0.0450)	(-0.2500)	(0.5414)
Constant term	8.7391***	8.3725***	8.3507***
	(13.3730)	(7.7884)	(11.4583)
Adj. R-squared	0.81	0.81	0.7976
Durbin-Watson stat	2.19	2.18	2.0288

*** and ** indicate significance level at 1% and 5% respectively

To investigate further into this the variance decomposition method is applied to delineate the actual contribution of foreign direct investment, trade, environmental degradation and alternate source of energy to hydropower generation in Ghana. In other words, the variance decomposition is used to estimate the percentage of every one standard deviation shock in hydropower generation explained by foreign direct investment, trade, environmental degradation and alternate source of energy. The variance decomposition result as shown in Table 6 indicates all the variables seems to increase their share of the shock in hydropower generation. However, like the results from the FMOLS, DOLS and CCR environmental degradation and availability of other source of energy take the greater share whiles trade and foreign direct investment take the smaller share. For instance environmental degradation increases its contribution from 17.67% in the second period to 17.83% in the sixth period and then to 21.70% in the tenth period. Also the contribution of alternate source of energy increases from 14.17% in the second period to 22.96% in the sixth period and to about 23% in the tenth period. For trade, its contribution increases from 2.30% in the second period to 4.42% in the tenth period whiles foreign direct investment share in the shock of hydropower generation increases from 2.57% in period two to 6.21% in the tenth period.

Table 6: Cholesky decomposition analysis

Period	S.E.	LEC	LFDI	LFOS	LCO	LTO
1	0.082447	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.109438	63.30216	2.566841	14.17166	17.66424	2.295095
3	0.124326	50.87755	3.197031	25.69113	18.12092	2.113369
4	0.125670	49.96011	3.130459	25.47919	17.75805	3.672191
5	0.130085	49.42172	5.410910	23.95424	16.57363	4.639499
6	0.132880	48.50745	6.257461	22.95862	17.82961	4.446858
7	0.135190	46.92182	6.149653	22.24943	20.16323	4.515857
8	0.136550	46.32686	6.070772	21.95448	21.21318	4.434716
9	0.137793	45.55449	6.177345	22.39635	21.44994	4.421879
10	0.139248	44.66597	6.208552	22.99862	21.70251	4.424346

4. Conclusion and policy implication

This paper has investigated the long run determinants of hydropower generation in Ghana since generation over the years has not only been low but also been reducing in the midst of growing demand for electricity in Ghana and efforts to deal with the global menace of climate change. Following from theoretical and empirical studies, hydropower generation is modeled as a function of trade openness, foreign direct investment, environmental degradation, alternate source of energy and financial development using time series data from 1975 to 2011. Unit root test by ADF and the PP tests showed all the variables integrated of the order one. Again, cointegration test indicated a long run relationship between the variables. Employing cointegration estimation techniques of FMOLS, CCR and DOLS it came to bear that Ghana's hydropower generation over the study period is positively influenced by trade openness and foreign direct investment at a statistically significance levels but negatively influenced by environmental degradation and alternate source of energy. A comparison of the estimated coefficients indicates the negative effects of environmental degradation and alternative energy source outweigh the positive effects of trade and foreign direct investment. A further investigation using the Cholesky impluse decomposition analysis showed a deviation in the hydropower generation is attributed more to environmental degradation and alternate source of energy than trade and foreign direct investment.

The findings of the study have some policy implications. First of all opening up the economy up to trade and attracting foreign direct investment inflows is crucial to enhance hydropower in Ghana. Also efforts should be made by government to reduce the negative influence of alternative source of energy. Thus conscious measures should be made to reduce reliance on such energy source as fossil fuel that the country partly relies on to generate electricity and also used for other industrial activities.

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