UDS International Journal of Development [UDSIJD]
Volume 4 No. 2, December, 2017
http://www.udsijd.org
ISSN: 2026-5336

DETERMINANTS OF HYDROPOWER GENERATION IN ETHIOPIA

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Abstract

Even though the share of hydropower in electricity has been increasing in recent times for the Ethiopian economy, less than 3% of the hydropower potential has been developed. Meanwhile, the country aims to achieving middle-income status by 2025 alongside a reduction in emission of gases that contribute to climate change. This requires the use of more renewable energy sources particularly hydro source. This study examined the drivers of hydro power generation in Ethiopia using annual time series data for the period 1981- 2014. Estimations from the Fully Modified Ordinary Least Square (FMOLS) and Canonical Cointegrating Regression (CCR) revealed that Ethiopia's hydropower generation is influenced positively by price, technology and environmental degradation while cost of production reduces it. Based on these findings the study suggests that, more technology investment is needed in the country's hydropower sector to enhance production.

Keywords: Renewable Energy, Electricity, Hydro Power, FMOLS, CCR, Ethiopia

INTRODUCTION

Since environmental degradation became the concern of policy makers, scientists, environmentalists and researchers over two decades ago. Studies have been conducted to examine the determinants of environmental degradation, through which it has come to light that macroeconomic factors namely trade, income, energy consumption, financial development, urbanization, population, foreign direct investment, water productivity and natural resources play crucial role (Jebli *et al.* 2016; Jebli and Youseff 2015a, 2015b; Kwakwa 2015; Hailu, *et.al*., 2014; Brock and Taylor, 2010; Frankel and Rose, 2005). Based on the empirical results from the numerous studies, policy implications and recommendations are provided accordingly. One of such policy outcome stemming from studies that found energy to significantly affect environmental degradation is the need for countries to rely upon renewable energy.

Renewable energy sources produce low level of carbon emission thereby contributing less to environmental degradation. In addition, their renewable nature guarantees sustainability of energy supply for the various sectors of the economy to function properly. They are also known to be associated with improving educational opportunities; creating jobs; reducing poverty; and increasing gender equality. However, non-renewable energy particularly fossil fuel source often generate more greenhouse gases which traps the sun heat. This development according to climate scientists have led to rising temperature on the earth for about ten decades now and has often led to floods, droughts and other bad weather conditions. If the emission trend of such greenhouse gases continues unabated worse conditions could occur from that. Emission of pollutants substances from burning fossil fuel apart from the effect it has on the environment also negatively affect the health of human population and the sustainability of animals (US Department of Energy, 2001). These reasons together with the price fluctuations of fossil fuels, reliance of energy from foreign source and the concern for the environment among others (Omri and Nguyen 2014) have contributed to making renewable energy the fastest growing energy source in the world (Energy Information Administration , 2009). According to a report by Renewable Energy Policy Network for the 21st Century (REN21) (2014) , the year 2004 saw the world's attention shifting immensely to renewable energy and since then, renewable energy has gained momentum as it provided about 19% of global final energy consumption in 2012. In 2013 over 56% of net additions to global power capacity came from renewable energy source.

At the moment the world has been relying on renewable energy from sources including the sun, wind, water, tides, waves, plants and geothermal heat to generate electricity. Of these sources, hydro is the dominant one accounting for about 16 percent of the global electricity generated. Generating power from hydro offers all the advantages renewable energy source have over non- renewable. Again, other pecuniary benefits have been identified to be associated with hydropower generation. These include water storage for drinking and irrigation, drought-preparedness, flood control protection and aquaculture among others (International Finance Corporation 2015). Developed countries have exploited their mid-sized large hydro resources, but opportunities for small hydro source still abound in such countries and other developing countries especially sub- Sahara Africa where less than 10% of the hydro potential is developed. Energy poverty in most sub-Sahara Africa countries is large but they have enough hydro potential to quadruple the current installed capacity of 80GW for the continent (International Finance Corporation, 2015) to reduce energy poverty as it has been suggested by many (Cole *et al.* 2014).

Despite this call, the sub- Saharan African countries seems to have slowed down in their hydro power development , with the share of hydro in electricity generation ranging between the lowest 14.9% (1997) and the highest 25.3% (1977) over the period of 1971 to 2012. However, the Ethiopian economy has for the past decade seen the share of hydro power increasing with an average of 83.53% of the nation's total electricity generated while the share of hydropower for countries like Ghana and Nigeria has been reducing. Although the Ethiopia's figure is far more greater than average for the sub region, the country has developed less than 3% of her 15,000 to 30,000 MW economically feasible potential for hydro power. With about 45% of population that has access to electricity, a figure considered low due to high connection cost. It is expected that by 2020 every Ethiopian will have access to electricity. The implication is, the current rate of electricity consumption at a little above 57 kWh per capita will increase. That will mean more power needs to be generated from the untapped potential to meet the needs of the population and industries.

Over the past two decades, the Ethiopian economy has grown at an average rate of 7.9% (Lighting Africa 2011) at the back of energy (US AID 2015). Despite the impressive economic performance in recent times the country is still one of the low income countries in Africa. The country's per capita GDP is below US 400 dollar (World Bank, 2015). To address this, the government has put mechanisms in place to achieve a middle income status by 2025, a target that cannot be done without energy (US AID 2015). Since virtually every economic activity thrives on energy, the country's Climate Resilient Green Economy (CRGE) strategy (MOFED, 2011) implies promoting climate change vulnerability and greenhouse gases reduction actions (Ministry of Water and Energy, 2012*)*. Accordingly renewable energy, particularly hydropower readily comes to mind to meet the energy needs of the economy.

The development of hydropower to meet both economic and environmental target in Ethiopia calls for identifying the driving forces behind the increasing share of hydropower in total electricity generation. It is acknowledged that empirical research has been conducted to appreciate the relationship between renewable energy and other macroeconomic variables (see Sadorsky 2009a; Marques *et al.,* 2010; Apergis and Payne 2011; Farhani 2013; Omri *et al.* 2015; Ackah and Kizys 2015; Kwakwa, 2015 and Jebli *et al.* 2016) to help deal with the problem of climate change. However, very little is known about the Ethiopian case.

Owing to the dearth of empirical studies on the subject matter for the Ethiopian economy, the present study is embarked upon to identify the determinants of hydropower generation in Ethiopia over the period 1981-2014 using annual time series data. By doing so the paper makes significant contribution to the literature on hydro energy. Firstly, this paper is novel for the study country in the sense that, although there are previous energy related studies for the Ethiopian economy including Hailu *et al.* 2014, Alem *et al.* 2013, Gebreegziabher 2009, Mekonnen and Köhlin 2008 and Mekonnen 1999, there is little evidence on the determinants of the development of hydropower and other renewable for the country to the best of the author's knowledge. Secondly, a review of the previous studies on renewable energy shows that their emphasis have been on drivers of the consumption side with little known about the generation side. Limited studies including Kwakwa (2015); Marques and Fuinhas, 2012; Menz and Vachon 2006 are the exceptions. Even with that Kwakwa (2015) seems to be the only study that provides the case study of hydropower development. As a result, this paper comes to fill the gap in the literature. Thirdly, the paper provides evidence from sub Saharan Africa (SAA) region where energy poverty is high and despite the fact that it is touted to be adversely affected by climate change, renewable energy has been low and little is known about the influential factors.

Empirically the study modeled hydropower generation as a function of price, cost of production, technology, trade openness, income and environmental degradation and our estimation from the Fully Modified Ordinary Least Squares (FMOLS) and Canonical Cointegrating Regression (CCR) revealed price of electricity, cost of production, technology and environmental degradation have been the drivers of hydropower generation in Ethiopia.

The rest of the study is organized as follows: Section 2 presents a brief literature review; Section 3 presents econometric methods and data; Section 4 discusses the results and section 5 concludes the paper with policy implication from the obtained results.

LITERATURE REVIEW

Empirical studies on the development of renewable energy abound. Such studies have focused on single countries or group of countries although majority comes from Asia and developed countries with little evidence from the African continent. Also majority of these studies have focused on the consumption side (Sadorsky 2009a, 2009b; Apergis and Payne, 2011; Salim and Rafiq 2012; Ackah and Kizys, 2015; Mehrara *et al*, 2015; Jebli and Youseff, 2015a, 2015b; Jebli *et al.* 2016) with few looking at the production side (Menz and Vachon 2006; Carley, 2009; Marques *et al.,* 2010 and Kwakwa 2015). In their previous studies, Sadorsky (2009a) found that for the G7 countries, renewable energy consumption in the long run is influenced positively by CO_2 emissions and income and negatively by oil price. In another study by Sadorsky (2009b), he used emerging countries as his case study and observed a positive relationship between income and renewable energy consumption. A subsequent study by Apergis and Payne (2010a) using the period of 1985-2005 for a number of OECD countries established a long run relationship between renewable energy consumption and real GDP, real gross fixed capital formation, and the labor force. Further, a bi-directional causality between renewable energy consumption and economic growth was noted by the author. For thirteen (13) Eurasia countries, Apergis and Payne (2010b) noted a long run relationship between renewable energy consumption and real GDP, real gross fixed capital formation and labor force. The authors recorded that in the short run renewable energy consumption and growth were found to granger cause each other likewise the long run. The authors used data for 1992–2007 periods. Similarly, Apergis *et al*. (2010) used data over the period of 1984- 2007 for 19 developed and developing countries and observed that renewable energy consumption is influenced by emissions and nuclear energy consumption while economic growth positively influences its consumption. In their other study, Apergis and Payne (2011) found there is a bi-directional causality between growth of an economy and renewable energy consumption for both the short- and long-run periods. The authors focused on six Central American countries using data for the period 1980–2006.

An analysis on the drivers of renewable energy consumption in Brazil, Philippines, India, Indonesia, Turkey and China by Salim and Rafiq (2012) revealed that emission of pollutants and income contribute to renewable energy consumption in the long-run for Brazil, China, India and Indonesia and income for Philippines and Turkey. In the short run however, bi-directional causality was noted between renewable energy and income; and between renewable energy and pollutant emission. Recently Rafiq *et al* (2014) did a comparative study on the determinants of renewable energy adaption by China and India for the 1972 to 2011 period. They found for the Indian economy that, in the short run carbon emission granger cause renewable energy generation and renewable energy granger cause output. A long run bi-directional causality was found among the variables. For the Chinese economy it was found that both output and carbon emission granger cause renewable energy in the short run. In the long run however, they observed carbon emission and renewable energy generation granger cause each other and uni-directional causality from output to renewable energy generation. Mehrara *et al.* (2015) found socio-economic environment, institutional environment proxies, urban population and human capital significantly influence renewable energy consumption for Economic Cooperation Organization (ECO) countries. The author used data for the period 1992-2011.In their study, Ackah and Kizys (2015) observed 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 in oil-producing countries in Africa for the 1985-2010 period. Also, Jebli and Youssef (2015a) for the Tunisian economy over the period 1980–2009 established that, in the short run renewable energy is granger caused by trade, GDP, CO_2 emission and non-renewable energy. Another study by Jebli and Youssef (2015b) for a sample of 69 countries noted a bi-directional causality between non-renewable energy and trade in the short run and long run for the period of 1980–2010. Moreover, for sub-Saharan African countries, Jebli *et al.* (2015) found import and export granger cause renewable energy consumption for the period of 1980-2010. In a much recent paper by Jebli *et al.* (2016) which investigated the role of trade, renewable and non-renewable energy towards environmental degradation for OECD countries over the period 1980–2010 , revealed renewable energy consumption and import granger cause each other on one hand, while renewable and non-renewable energy consumption also granger cause each other on another hand. In the short run uni-directional causality from export and output to renewable energy was noted. Marques and Fuinhas (2012) also established that public policy measures contribute, as a whole or disaggregated, to wider use of renewable in Europe.

On the development of renewable energy side, Menz and Vachon (2006) empirically found that state-level policies (renewable portfolio standards) requiring electricity suppliers to provide green power options to customers positively increased wind power development while retail choice reduces that in several states of America. Aguirre and Ibikunle (2014) analyzed the determinants of renewable energy development for 31 countries and noted that renewable energy development is positively affected by CO_2 emissions, Kyoto protocol, biomass and solar potential while participation of coal, oil, natural gas and nuclear power in electricity generation negatively affects renewable energy development. Carley (2009) found that political institutions, natural resource endowments, deregulation, gross state product per capita, electricity use per person, electricity price, and the presence of regional renewable portfolio standard (RPS) policies have significant effect on renewable energy deployment in USA. In their study on European countries, Marques *et al*. (2010) established that lobby of the traditional energy sources namely oil, coal, and natural gas and CO_2 emissions do not enhance renewable energy deployment. Omoju (nd) also noted for the Chinese economy that income, trade openness, FDI increases renewable energy development while carbon emission and fossil use reduce it , while Kwakwa (2015) observed trade openness and foreign direct investment increases while environmental degradation and fossil fuel use reduce hydro power generation.

METHODOLOGY

Economic Motivation and Model Specification

The starting point of our model specification is the theory of supply which suggests that the supply of a good and service is determined primarily by the price of the good, cost of production and technology. From this economics argument the generation of hydropower can be expressed in the mathematics form as:

$$HYS = \alpha + \beta i X \qquad (1)$$

Where HYS is the quantity supplied, α is a constant term, βi is the coefficient of the explanatory variables, X which in this case is price of the good, cost of production and technology. Following empirical works by (Omuju n.d) and Ubi *et al.* 2013 and arguments due Cole *et al*. (2014) environmental degradation is included in the explanatory variables. While Omuju (n.d) found environmental degradation element of carbon emission to increase renewable energy production Cole *et al.* (2014) argue it has negative effect. 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. The literature on trade liberalization reveals specialization and efficiency are enhanced through trade (Sakyi *et al.* 2015) and also increases stock of knowledge or transfer of ideas and technology (Asiedu 2013). Accordingly, trade openness can in this regard increase power generated from hydro source for an economy. We also include in our model income to capture the economic strength of the country to invest into hydro power.

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

$$HYS = \alpha + \beta_1 PR + \beta 2CO + \beta 3TEC + \beta 4END + \beta_5 TO + \beta 8Y + \mu \qquad (2)$$

Where *HYS* and α remain as explained earlier on. *PR* is price of electricity, *CO* is the cost of production, *TEC* is level of technology, *END* environmental degradation, *TO* represents trade openness and *Y* is income. The natural logarithm forms of all the variables are used in the final estimations.

Data and econometric technique

Except cost of production which was sourced from the statista.com (https://www. statista. com/statistics/262858/change-in-opec-crude-oil-prices-since-1960/) all the study relied on annual time series from WDI (2017) to estimate the effects of price, cost of production, technology, trade openness, income and environmental degradation on the generation of hydroelectricity for the Ethiopian economy. Hydroelectricity supply in this current study is measured as the electricity production from hydroelectric sources (% of total). Following the argument by Adom (2016) that electricity system losses has a strong correlation with technological investment, our technology variable is measured by electric power transmission and distribution losses (% of output) while cost of producing hydroelectricity is represented by the price of crude oil since oil is needed to ensure effective functioning of the machines and equipment for hydropower generation. Trade openness is measured as the sum of import and export as a share of GDP; environmental degradation is measured as emission of carbon dioxide; income is measured as gross domestic income (constant 2010 US$); and price is measured as the consumer price index. The a priori expectation is that all the variables would positively affect hydropower generation except cost of production which is expected to have negative effect, and environmental degradation whose effect can be both positive and negative. The study period was from 1981-2014 and this was based on data availability. Table 1 below gives a summary statistics of the variables.

Table 1: Summary statistics of the variables

Statistics	HYS	PR	CO	TEC	END	Y	TO
Mean	90.44079	50.15462	38.74906	10.23495	4285.860	1.62E+10	5.89E+09
Median	93.85754	32.16795	27.30500	9.986710	3104.116	1.20E+10	2.49E+09
Maximum	99.69410	189.8399	109.4500	22.87066	11598.72	4.41E+10	2.45E+10
Minimum	70.31900	12.77640	12.28000	1.233184	1481.468	7.76E+09	1.19E+09
Std. Dev.	9.231899	48.46920	29.60453	4.589988	2531.849	9.99E+09	6.56E+09
Skewness	-0.841555	1.762222	1.327601	0.657449	1.282871	1.440089	1.521132
Kurtosis	2.334277	4.967231	3.479985	4.533185	4.071516	3.948796	4.041198

Observations	34	34	34	34	34	34	34

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. Variables that are not stationary at levels are differenced until it becomes so. 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) test by Dickey and Fuller (1979) and Phillip-Perron (1988) test 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 between hydroelectricity generation, price, cost of production, technology, trade openness, income and environmental degradation is examined. According to Engel and Granger (1987) although individual series may not be 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) parametric, Phillips-Ouliaris (1990) non parametric 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 Engle-Granger (1987) and Phillips-Ouliaris (1990) tests work with the null hypothesis of no cointegration and the alternate of cointegration while the system cointegration by Johansen approach tests for the number of cointegrating vectors among variables.

To identify the drivers of hydroelectricity generation the study then employs the Fully Modified OLS (FMOLS) and Canonical Cointegrating Regression (CCR). Following closely Adom and Kwakwa (2014), the fully modified OLS estimator developed by Philips and Hansen (1990) is given in the equation 5 below:

$$\hat{\varphi}_{FME} = (\textstyle\sum_{t=1}^{T} z_t z_t')^{-1}\left(\sum_{t=1}^{T} z_t y_t^{+} - T\hat{J}^{+}\right) \qquad (5)$$

Where $y_t^{+} = y_t - \hat{\lambda}_{0x}\hat{\lambda}_{xx}{}^{-1}\Delta x_t$ is the correction for endogeneity, and $\hat{\lambda}_{0x}$ and $\hat{\lambda}_{xx}$ are the kernel estimates of the long-run covariances, $\hat{J}^{+} = \hat{\Delta}_{0x} - \hat{\lambda}_{0x}\hat{\lambda}_{xx}{}^{-1}\hat{\Delta}_{xx}$ is the correction term for serial correlation, and $\hat{\Delta}_{0x}$ and $\hat{\Delta}_{xx}$ are the kernel estimates of the one-sided long-run covariance.

The canonical co-integration 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 co-integrating relationship. The CCR estimator is thus shown below:

$$\hat{\varphi}_{CCR} = (\textstyle\sum_{t=1}^{T} Z_t^{*} Z)^{-1}(\sum_{t=1}^{T} Z_t^{*} Y_t^{*}) \qquad (6)$$

Where $Y_t^{*} = (X_t^{*1}, D_t')$, $x_t^{*} = X_t - (\hat{\Sigma}^{-1}\hat{\Lambda}_2)\hat{\nabla}_t$ and $Y_t^{*} = Y_t - \hat{\Sigma}^{-1}\hat{\Lambda}_2\hat{\beta} + [\hat{\eta}_{22}^{-1}\hat{\omega}_{21}]'\,\hat{\upsilon}_t$ denotes the transformed data, $\hat{\beta}$ is an estimate of the co-integrating equation coefficients, $\widehat{\Lambda}_2$ is the second column of $\widehat{\Lambda}$ and $\widehat{\Sigma}$ denotes estimated contemporaneous covariance matrix of the residual. To check for robustness, the dynamic ordinary least square (DOLS) estimator is also run alongside the FMOLS and CCR.

PRESENTATION AND DISCUSSION OF EMPIRICAL RESULTS

Meeting the stationarity condition requires that the unit root test is done using the ADF and PP unit root tests and the results are presented in Table 2. The results from both ADF and PP test give similar results. In the sense that they both show all the variables are not stationary at levels under the assumptions of intercepts and intercept and trend except for END under the second assumption. However, on the balance we can say that at levels the null hypothesis that each of the series HYS, END, TO, Y, PR, CO and TEC contains unit root is not rejected rendering it difficult to use that for analysis. Consequently each of the variables is differenced, after taking the first difference of all the variables the null hypothesis of no unit root problem is rejected at 1% level of significance. Thus, all the series are concluded to be I (1) variables.

Table 2: Unit root test results

Variables	Levels Intercep	Intercept and trend	First difference	Intercept and trend
		ADF TEST		
HYS	-2.2336	-1.7459	-4.7432***	-4.9016***
CO	-2.0151	-1.7757	-6.5160***	-6.9424***
TO	-0.7340	-2.1654	-6.1164***	-6.0236***
Y	1.2590	-0.2446	-3.3931***	-4.5569***
END	-1.0516	-1.2258	-5.5754***	-5.4950***
PR	3.3016	0.9438	-6.1399***	-4.5569***
TEC	-2.9124	-1.1242	-5.7183***	-5.6514***
		PP TEST		
HYS	-2.2072	-1.5339	-4.6957***	-8.1259***
CO	-0.5579	-1.5093	-10.1750***	17.8123***
TO	-0.7273	-2.1338	-6.0869***	-6.0006***
Y	1.1072	0.4164	-3.8605***	-5.2931***
END	-1.9231	-3.0454	-6.6871***	-11.4310***
PR	7.5100	-0.1432	-6.1164***	-11.0832***
TEC	-2.2200	-2.3679	-9.6433***	-10.817***

*** indicate significance level at 1%

Table 3:Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.879221	192.5194	125.6154	0.0000
At most 1 *	0.726297	124.8781	95.75366	0.0001
At most 2 *	0.608213	83.41526	69.81889	0.0028
At most 3 *	0.542394	53.43005	47.85613	0.0137
At most 4	0.413433	28.41419	29.79707	0.0715
At most 5	0.287792	11.34323	15.49471	0.1913
At most 6	0.014977	0.482888	3.841466	0.4871

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.879221	67.64132	46.23142	0.0001
At most 1 *	0.726297	41.46279	40.07757	0.0347
At most 2	0.608213	29.98521	33.87687	0.1360
At most 3	0.542394	25.01586	27.58434	0.1030
At most 4	0.413433	17.07096	21.13162	0.1687
At most 5	0.28779	10.86034	14.26460	0.1613

Trace test indicates 4 cointegrating eqn(s); Max-eigenvalue test indicates 2 cointegrating eqn(s)
* denotes rejection of the hypothesis at the 0.05 level

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. The results from the Johansen cointegration approach reported in Table 3 confirms there is a long run relationship among the variables as the Trace Statistics and the Maximum Eigenvalue indicate 2 and 4 cointegrating equations respectively at 5% level of significance. In light of this, it can be concluded that there is a long run relationship among hydropower generation, price, and cost of production, technology, trade openness, income and environmental degradation.

Table 4: Long-run Estimate of hydropower generation in Ethiopia

Explanatory Variables	FMOLS	CCR	DOLS
PR	0.1066**	0.1081**	0.1235
	(2.7028)	(2.1500)	(1.5808)
CO	-0.06720***	-0.6056*	-0.1324***
	(-2.9232)	(-1.9871)	(-3.2960)
TEC	0.0348**	0.0316*	0.0540**
	(2.4292)	(1.7376)	(2.2296)
ENV	0.2499***	0.2508***	0.2227***
	(5.8101)	(5.8251)	(3.9870)
Y	-0.1320	-0.1245**	-0.0591
	(-1.3771)	(-0.9795)	(-0.2395)
TO	-0.0638	-0.0734	-0.0504
	(-1.5320)	(-1.2831)	(-0.6833)
Constant term	6.7083***	6.6886***	5.0153
	(4.2730)	(3.2067)	(1.4515)
Adj. R-squared	0.61	0.61	0.86

Next, the long run effects of price cost of production, technology, trade openness, income and environmental degradation on hydropower generation in Ethiopia is estimated with results presented in Table 4. The outcomes from the three estimators are similar. With the exception of income and trade which have insignificant effect, and cost which has negative effect, all the other variables have positive effects on hydro power generation.

The effect of price is positive in this study and it confirms the law of supply. Increase the price of electricity is thus seen to increase hydropower generation in Ethiopia. From the results, an increase in electricity price by 1% will increase hydropower generation by about 0.11%. The finding in this study confirms previous studies including Adom (2016), Ubi *et al* (2012), Sihombing (2010) and Nababan (2016). The cost of production has the expected sign from all the three estimators. As it can be seen, there is a negative relationship established between cost of production and hydropower generation in Ethiopia. A 1% increase in the cost of producing hydropower will reduce hydropower supply by 0.1-0.6%. A higher cost of production leads to lower supply since the resources allocated for production is fixed; hence increase cost of production will reduce hydropower generation. This corroborates with the findings by Nababan (2016) and Sihombing (2010). Technology is seen to have a positive and significant effect on hydropower generation. The reported results indicate that an improvement in technology for hydropower generation will increase supply by about 0.03-0.05%. This is reasonable because an improve technology increases efficiency.

Environmental degradation (END) is found to have a positive effect on hydropower generation. Specifically, a 1% increase in the deterioration of the environment via carbon emission increases hydropower generation by about 0.2%. This is reasonable because as environment degrades more attention is given to cleaner alternative means of electricity production such as hydro. This result contradicts Kwakwa (2015) paper on Ghana that reported a negative effect of environmental degradation on hydropower generation. In the study the author alluded to how bush fires, deforestation and changes in rainfall have reduced the volume of water in the dams needed to generate power. The current paper however collaborates Omuju (nd) research on China.

The study takes a further look at the variance decomposition analysis to outline the actual contribution of each of the variables to a shock in the Ethiopian hydropower generation and the result is presented in Table 5.

Table 5: variance Decomposition Analysis

Period	S.E.	HYS	PR	CO	TECH	END	TO	Y
1	0.028495	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.036054	90.65595	0.001724	1.085980	2.107712	0.056497	4.913382	1.178756
3	0.039787	75.15064	0.739724	13.27505	3.041266	1.372089	4.661520	1.759713
4	0.047075	64.30460	0.541162	22.54653	2.463554	1.947299	6.929315	1.267549
5	0.052756	58.79446	1.053281	24.20962	2.506039	3.441498	8.515101	1.480001
6	0.056527	57.52696	0.922960	23.89100	2.783077	3.802490	9.638317	1.435196
7	0.061473	57.91599	2.386354	22.82912	2.921499	3.434894	9.050852	1.461285
8	0.066142	58.18351	4.272783	21.49159	3.079163	3.166407	8.199667	1.606885
9	0.069519	57.80850	6.465697	19.86736	3.425809	3.107004	7.719431	1.606203
10	0.072159	56.73741	9.170095	18.50739	3.616754	3.121710	7.243101	1.603544

From the decomposition analysis, the contribution of the variables price, technology and environmental degradation to a shock in the generation of hydropower seems to increase over the period. For every shock in hydropower generation, environmental degradation for instance increases its share from 0.057% in the second period to 3.6% in the tenth period. Also, the share of price increases from 0.001% in the second period to 0.92% in the sixth period and then to 9.17% in the tenth period. However, the share of cost of production seems to fluctuate over the years from 13.27% in the third period to 23.89% in the sixth period and then finally to 18.50% in the tenth period.

Conclusion and Policy Implication

Following the concern for environment, the world's attention to renewable energy has gained momentum particularly hydropower. Meanwhile many sub Saharan African countries with many hydropower resources have not fully utilized the available resources while others even have their hydropower share of total electricity generated reducing. Although the Ethiopian economy has many hydropower sources, less than 3% has been developed notwithstanding the fact that the nation has seen a rising trend in the share of hydropower to the electricity generated.

Owing to the fact that the country aims at reaching middle-income status by 2025 while ensuring that climate change vulnerability is reduced significantly, it has become important that more renewable energy is generated particularly hydropower. Accordingly, this paper examined the long run determinants of hydropower generation in Ethiopia. Based on theoretical and empirical studies, hydropower generation is modeled as a function of price, cost of production, technology, trade openness, income and environmental degradation for the period of 1981 to 2014. Our results indicated all the variables are integrated of the order one and a long run relationship exists between hydropower generation and the selected explanatory variables. Estimation from FMOLS, CCR and DOLS revealed Ethiopia's hydropower generation over the study period is positively influenced by price of electricity, technology and environmental degradation but negatively influenced by input cost of production. A further investigation using the Cholesky impulse decomposition analysis showed that over the period, the share of technology, price and environmental degradation increases.

Based on these findings the study suggests that, more technology investment is needed in the country's hydropower sector to enhance production. This calls for conscious effort on the part of the authorities of the country to channel resources into the hydropower sector.

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