

Effect of Geothermal Generation on Energy Costs and GDP

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ABSTRACT

The paper is a three step analysis; it seeks to look at the impact of geothermal generation on the economy whether there is a bi-directional causality between economic growth, electricity consumption and electricity generation. Emphasis is being placed on specific source of energy-geothermal- to show that it being renewable energy and a comparative least cost source of energy, it will have a significant impact on tariff reduction. By use of Vector Error Correction Model and Granger Causality Test on the data available- for the period ranging from 1990 to 2016. Assessment is done against the different sectors of the economy to ascertain any correlation/causality between electricity tariff, electricity consumption/electricity generation and the various GDP components/sectors. The results show that reduced energy tariffs results to economic growth in the Construction sector and the Manufacturing sector specifically-bundled up to represent the goods industry and geothermal being the comparative least cost of energy source plays a significant role in increasing electricity consumption resulting from reduced costs and consequently economic growth through the Construction sector, Manufacturing sector, Wholesale and Retail-Goods Industry. Noting the findings, the government should undertake expansion focusing the least cost energy source; consider price discrimination for the low income and the manufacturing industries in order to accelerate electricity access from the current estimate of 48% of the population in both urban and rural areas so as to increase electricity consumption.

1. Introduction

This paper looks at relationship between Energy Costs and GDP- Kenya being the country of interest. The empirical model is to ascertain how energy pricing is affected or affects various variables; domestic consumption of electricity, specific use of a different energy sources- geothermal, and the different sectors of the economy which have been individually assessed then further categorized based on the output;

No	Categorization	GDP Output Source
1	Goods Industry	Manufacturing, Construction, Wholesale and Retail Trade
2	Service Industry	Public Administration, IT, and other Services
3	Resources	Quarry and Mining, Electricity and Water Supply

The subject area is of interest majorly because Kenya is an emerging economy at the verge of industrialization hence its take off is highly dependent on electricity as a major input. If the electricity cost is relatively priced/cheap it will encourage investors and equally if the electricity supply is stable and not spasmodic due to power outages, it will play a major role in attracting investment.

The model analysis will commence with conducting Unit root test on the data to ascertain stationarity. Upon establishment of non-stationarity of some of the variables, it is presumed that long term relationship exists therefore the Vector Error Correction Model is the model of choice for the analysis. Equally proceeding on the presumption that electricity cost is a major determinant of electricity consumption which plays a major role in economic development, adopting a model that would estimate the speed of its return to the equilibrium upon change on the dependent variable is of high importance. Following the Stationarity test, the identification of optimal length of the number of lags that need to be included for the VEC Model is done, following which the co-integration test is performed, the VEC and the Granger Causality test is conducted. The data used is unique in nature since the unit of measure unlike most economic papers is composed of both monetary and Kilowatts per hour.

The findings are relatively different from some of the other papers, since while significance is noted in the long run and the short run, bi-causality is not observed.

The paper commences with the Abstract which details in brief the content of the paper and the outcome following which is the introduction, thereafter the background gives an outline of the energy sector specific to Kenya and further expounds on the needs that have necessitated the paper. The Literature review follows by outlining the various authors who have dealt with the same subject matter, the different methods employed and what their finding were and the reasons for variance in findings if any. The Data and Model follows detailing the data used, the source *et al.* Thereafter follows the different regressions and the analysis thereto. The paper is concluded with a summary of what has been done, the findings, the limitations that if adjusted, may give better results and the policy implications thereto

1.1 Objective

The objective is to ascertain if electricity generation mode and consumption of electricity and/or impacts on electricity cost and consequently does reduced electricity cost have any impact on the economy in terms of growth. This will be achieved through the following means; Review of the tariff computation model (components) adopted in Kenya; Look into the electricity consumption behavior and estimate a demand trend for electricity consumption thereto; Assessing and estimate the level of price elasticity of demand for electricity for various categories as mentioned herein; Develop a further model for purposes of looking into

the impact of electricity tariff changes with the source of energy being a major contributory factor in the pricing which will be done by creation of an interaction term between the energy pricing and energy source by generation-reduction in cost- on the consumer (categorize the the various GDP contributory elements i.e. Domestic consumption and Rural Electrification are the variables that will be used to assess increase in electricity consumption specific to different income brackets. The Manufacturing Sector, Service Industry and the Agricultural sector components of GDP will be used as proxy for measuring increase in foreign direct, investment and local investment.); Finally Putting into consideration the reduced tariff rates, do a comparative analysis of the level and competitiveness of commercial electricity tariffs in Kenya relative to the neighboring countries, this is to prove the influx of foreign investments due to reduced electricity tariff. To reiterate the impact of both increase of local and foreign firms, conduct a comparative analysis on the impact of imported and exported energy on consumption and subsequently the local industries.

As a result of the above models and approaches, depending on the impact to GDP, the analysis will seek to show that the reduced energy costs as a result of geothermal generation play a major role in economic growth. The findings will play a major role in policy making, that is, the planning of electricity expansion in terms of the different generation sectors and the country's electricity distribution network.

2. Background

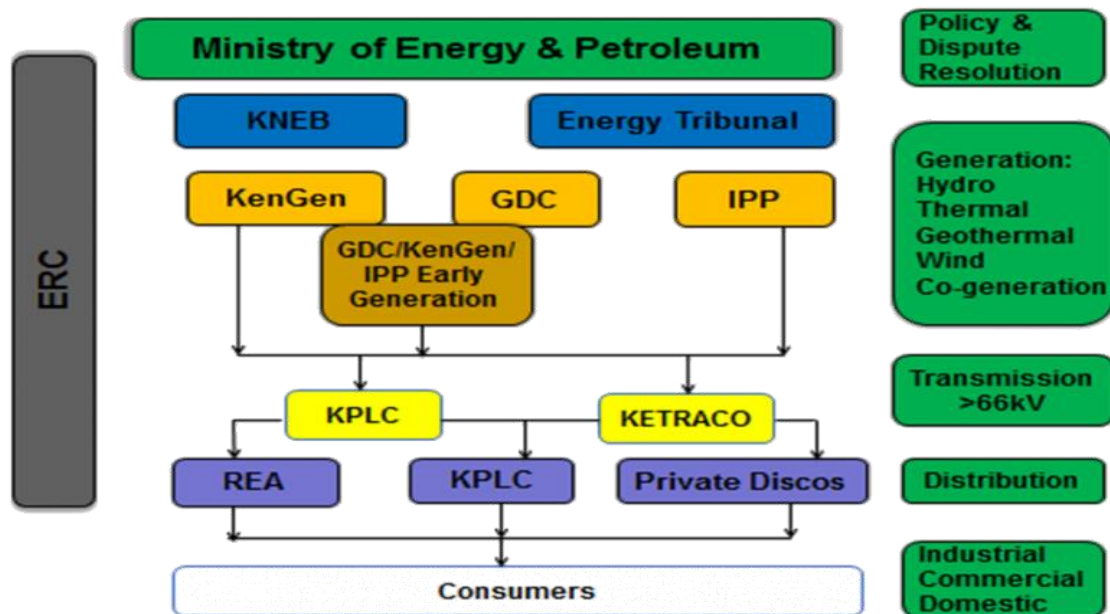
Electricity is an essential input in production. Kenya being an emerging economy at the verge of takeoff significantly requires electricity for industrialization. Therefore, consistent/stable supply of electricity is of high importance for takeoff or continued industrialization.

The government of Kenya has realized the essentiality of electricity on economic development i.e. increase in output through FDI and domestic investment, increase in employment opportunities and consequently reduction of poverty, this can be seen from the government development plan 'vision 2030' which highlights the intend of achievement of a certain level of industrialization by then to improve the economic welfare of the population and the continued effort of realization of the Sustainable Development Goals-Goal 7; Cheap, clean, stable, sustainable and increased accessibility to electricity . At the same time it is acknowledged that energy will play a very major role in the industrialization as an input. To the effect, a target of 10,000MW was set of which 5000MW is to come from geothermal. To achieve this, various measures have been laid forth;

2.1 Institutional Reforms

The Vision 2030 is structured in line with the SDG, and to the effect, the government made various reforms on the existing institution to ensure accomplishments of the goals i.e. increase accessibility of electricity, provision of comparatively less priced electricity, use of clean energy.

Figure 1.1 Energy Sector Institutional Structure



Emphasis was placed on renewable energy to ensure protection of the environment. It was great of great importance that the energy source be comparatively less costly as compared to other sources of energy, therefore emphasis was placed on geothermal energy. Through Kenya Electricity and Generating Company (KenGen) geothermal capacity increased to almost 50 percent of the total capacity on the grid.

2.2 Efficiency and Financing Gap

To bridge the technical know-how and the financing gap, Independent Power Producers (IPPs) were allowed to come in and do the generation through Public Private Partnership (PPP). Various incentives were offered by the government issue of guarantees and insurance to cover both political and commercial risks, attractive tariff rates to ensure return for investment.

2.3. Regulatory Reforms

Various regulatory reforms were equally made to support the plan including the enactment of the National Environmental Coordination Act in 1999 to safeguard the environment through all forms of development and incorporation of a statutory body and courts to ensure enforcement of the law.

The Energy Act was enacted in the year 2006 to make provision for better and more comprehensive regulations for the energy sector in line with the recent changes.

The Feed in Tariff Policy was adopted for renewable energy to encourage use of clean energy, and to offer guarantee to IPPs ensuring returns for their investment

Tax statutes were revised to allow for tax exemptions for geothermal equipment imported for purposes of geothermal development.

All the hereinabove measures illustrated the then government's intention and commitment to provide reliable, least cost and environmentally friendly source of energy.

The study will assess how energy cost impact on the GDP of the country through the following components: Increased consumption of electricity; Increase in access of electricity;

Increase in electricity exports and decrease in imports; Increase in investment both foreign direct investment and local investment as a result of cost energy supply-increase in taxes and trading characterized by the different GDP Sectors shall be the proxy for this analysis; and Increased employment opportunities.

3. Literature Review

Various authors have conducted an empirical study on similarly related subject area. Some have reviewed the impact of electricity of consumption on the economy, the impact of electricity prices on the economy and a combination of both the consumption rate and price on the economy for different countries. The studies have predominantly shown proof that electricity is a major causality for economic growth, however the direction of causality has differed from author to author based on the time period under analysis, data set duration, and the model used for the analysis. The first authors to conduct an analysis on the same, Kraft and Kraft (1978) using USA as the subject area of study found a unidirectional causality from Gross National Product to Energy Consumption. It can be noted that the method of analysis significantly affected the findings. Various authors undertook to expand the analysis beyond the USA. Glasure and Lee (1997) did conducted an analysis on the Impact of Energy consumption on the Asian economy-South Korea and Singapore through co-integration and Error Correction model which showed a bi-directional causality while a granger causality test resulted to a unidirectional relationship from energy consumption to GDP. Alice Shiu, Pun-lee (2004) expanded the analysis further to a country at the industrialization phase. The paper used a vector error correction model on data of a 30 year period to assess the causality of electricity consumption on electricity growth, a unidirectional causality was established from electricity consumption to GDP. In the analysis, a point to note, distinction should be made between the electricity consumption tendencies in the developed countries and the developing economies. This will in turn affect the direction of causality to some extent. Chang and Lai (1997) undertook a study on Taiwan electricity consumption and its impact on the economy. The causality relation was from GDP to electricity consumption while Yang (2000) on the same country had different findings; bi-directional causality, the difference in findings was attributed to difference in the time period of analysis and the price index difference used in the assessment. Masih and Masih (1998) assessed electricity consumption and the economy and went ahead to include a new variable of prices of products. The analysis was done on relatively less developed countries-Thailand and Sri-Lanka- through use of johansen's multivariate test to check the co-integration of consumption on of energy, real income and product pricing. The resulting results show that consumption play a major role on income and product prices. Shyamal Paula, Rabindra N. Bhattacharyab (2004) looked at the bi-directional causality between energy consumption and the impact on growth on Indian economy through use of Engle-Granger cointegration together with standard Granger causality for a period of about 46 years. The results proved that there is a bi-directional causality. He further used Johansen multivariate cointegration and found the same results. Studies on developing countries including Kenya have equally been undertaken. Chien-Chiang Lee looked at the causal relationship and the co-movement between energy consumption of 18 developing countries and their GDP including Kenya. The paper used 26 year panel data. The results indicated there is both a long run and short run relationship between energy consumption and GDP

Consequently, this paper seeks to see not only the impact of electricity consumption rate on the economy but also how increase of geothermal energy on the electricity grid would impact on electricity cost. The sectorial analysis of the impact of the tax on the economy equally

helps in understanding the specific areas of the economy that will be affected for better policy making.

Kenya is a good target area for the study of this topic since comparatively its input of geothermal energy in the electricity grid /generated capacity is comparatively higher as compared to the neighboring countries.

4. Data

4.1 Data Source

The data used is time series quarterly data for varied variables-sectorial GDP, Energy Generation, Energy Consumption and the Energy Cost-for a period of 16 years ranging from the year 1990 to 2016.

The data was obtained from Kenya National Bureau of Statistics annual CPI, GDP reports and leading Economic Indicators; Kenya Power and Lighting Company annual Reports; and The Energy Regulatory Commissions of Kenya.

4.2 Description of the Data

Energy Cost-Categories of Energy Consumers and Tariffs thereto

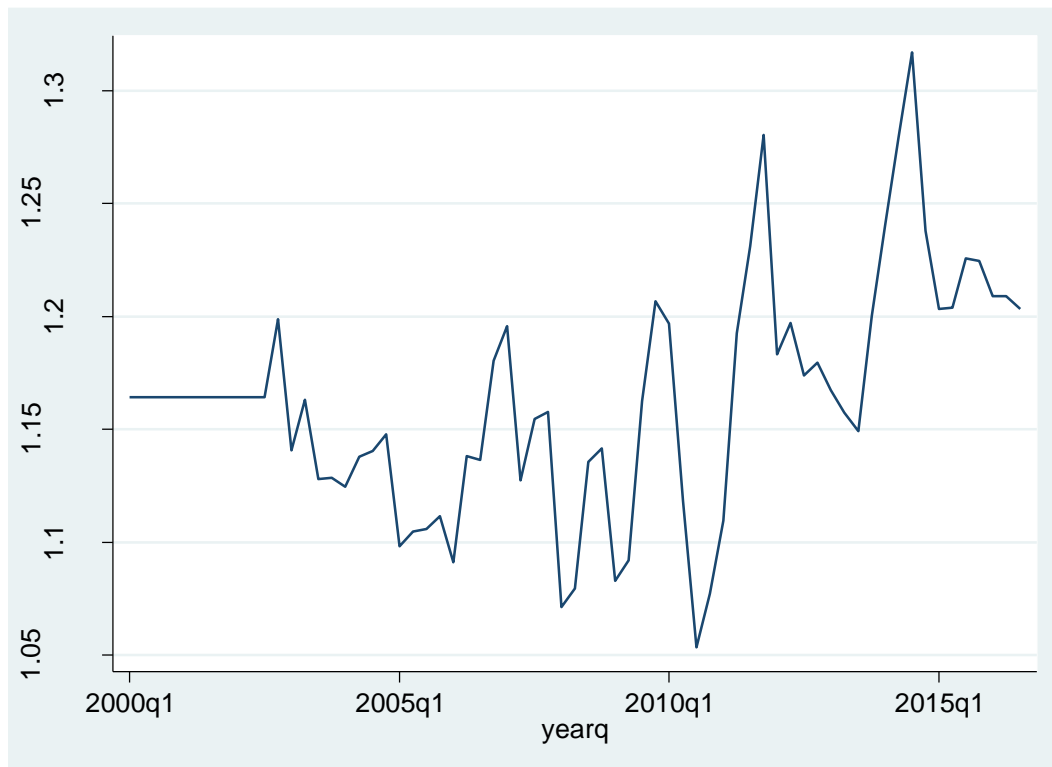
Energy consumers are categorized into; Small Scale consumers, House hold consumers, Commercial consumers I-, Commercial consumers II-, Commercial consumers III-, Commercial consumers IV- and IT

Table 4.2.1 Customer Electricity Voltage use

NO	Consumer Categories and Tariffs Thereto	Maximum Voltages
1	Domestic	The maximum installed voltage for use is 240 Voltages
2	Small Scale consumers	The maximum installed voltage for use is 240 Voltages
3	Commercial consumers I	The maximum installed voltage for use is 415V
4	Commercial consumers II	The maximum installed voltage for use is 11 kilo Voltage
5	Commercial consumers III	The maximum installed voltage for use is 33kV
6	Commercial consumers IV	The maximum installed voltage for use is 66kV
7	Commercial consumers V	The maximum installed voltage for use is 132kV
8	IT (Household Heating)	Electricity usage for heating of water

Due to limitation of data availability, from the year 2006, the data used is rotating average on a quarterly basis based on the previous year data. Since different consumption capacities for the aforementioned categories could not be obtained, the respective tariffs were summed up and the average obtained titled 'Total Tariff. It is measured in Kilowatts per hour. The trend of the series over the years is as observed below;

Figure 4.2.1 Electricity Cost Trend



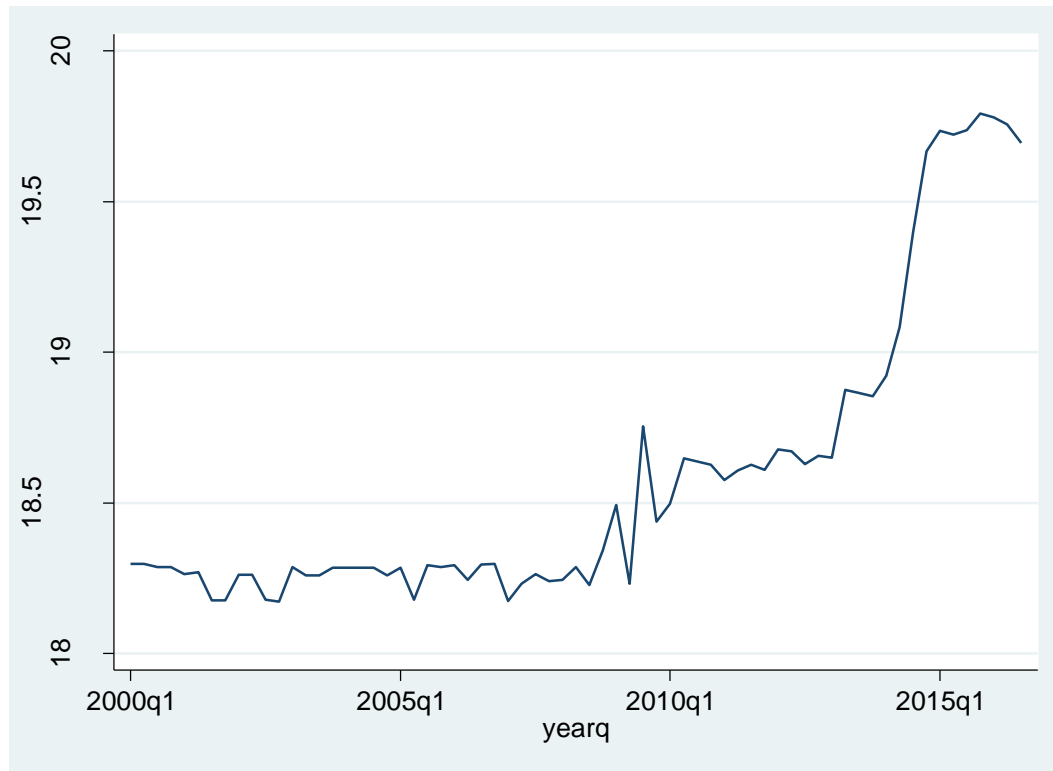
The constant amount represents from year 2000 to 2003 is due to the rotating average effect. Since Kenya was heavily reliant on Hydroelectric Power and Thermal energy and considering the instability of hydroelectric power, the electricity cost tends to fluctuate a lot due to the fuel cost attached to thermal power. The extra surcharge resulting from fixed fuel cost depending on the period example year 2009 to 2014, ranged from KES 7.83 to KES 9.03 for each kilowatt per hour. This explains the significant rise on the significant rise in electricity cost.

4.3 Energy Generation Sources

This is the characterization of energy generated on the electricity grid according to the source. The focus is in the renewable energy sector, limited to geothermal energy, Solar Energy and Hydroelectric power. This is equally supplemented through energy sourced through importation and reduced in capacity through energy exports and losses occasioned during transmissions. This as further detailed below;

Total available energy for Consumption= Geothermal Generation + Solar Generation + Hydroelectric Power Generation + Electricity Imports – Electricity Exports- Transmission Losses

Figure 4.2.2 Geothermal Generation Trend

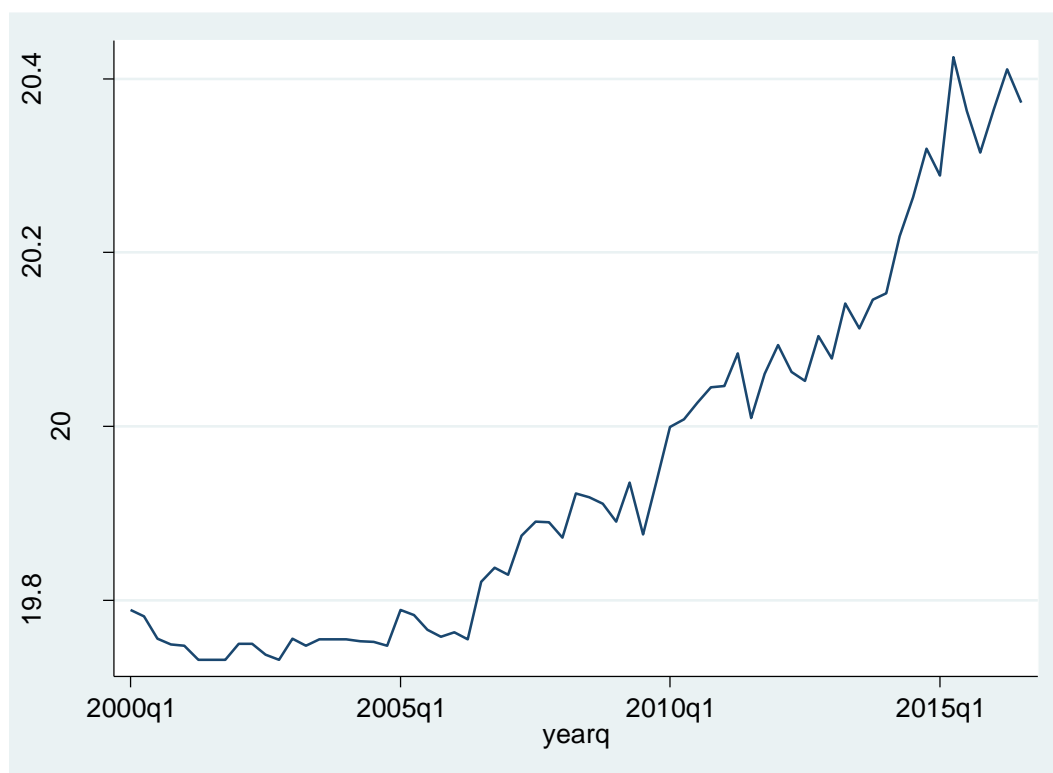


The significant increase in 2014 is as a result of an extra 280MW injected to the grid, and the decreased amount as per the graphs is due to the scheduled maintenance of the power plants or failure experienced at the power plants.

4.4 Domestic Energy Consumption

The Energy consumption is measured through the following variables; Domestic consumption; which characterizes all local consumption of electricity by the different consumers. Rural Electrification; pursuant to an initiative adopted by the government to increase access to electricity by the population targeting the rural population a certain percentage is used to achieve the same. The focus for the purposes of this paper shall be on domestic consumption exempting rural electrification whose trend is as illustrated in the figure below;

Figure 4.2.3 Geothermal Generation Trend

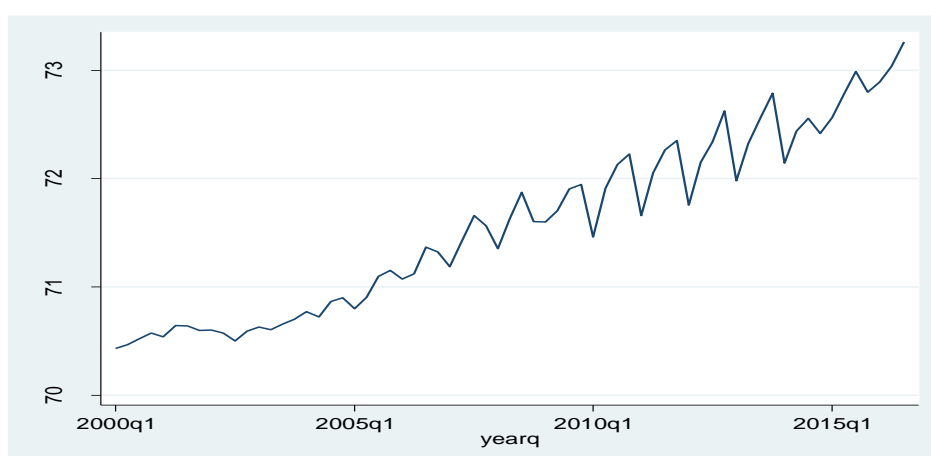


4.5 Gross Domestic Product

The GDP used for analysis is in Kenya Shillings, constant at base year 2001. It is divided into various sectors of output of which for analysis purposes the sectors have been grouped into;

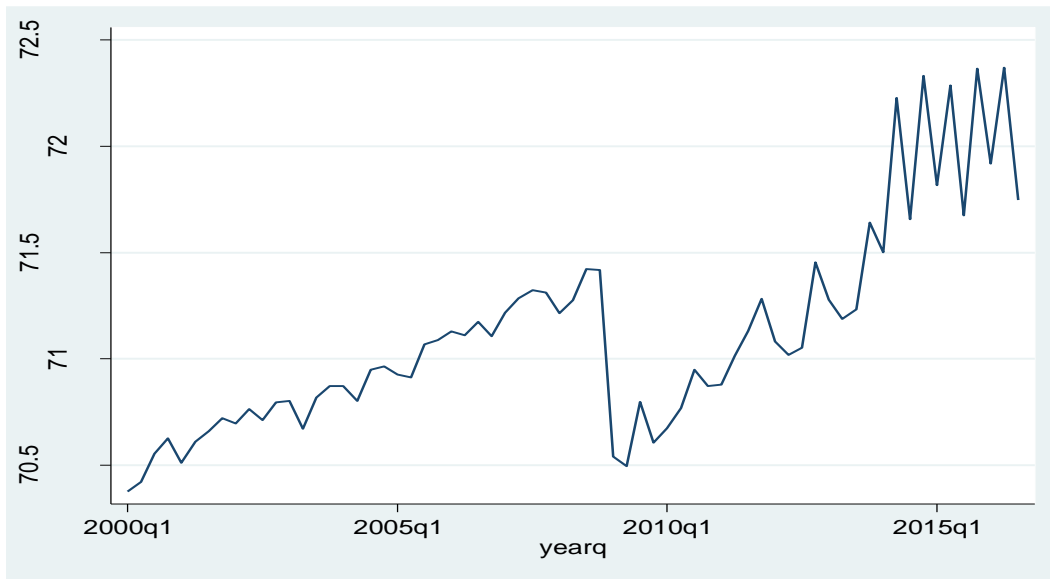
The **Goods industry**, comprising of Manufacturing, Construction and Wholesale and Retail as illustrated in the below figure.

Figure 4.2.4 Industry 1 Trend-Goods



The **Service Industry**, comprising of Restaurant and Accommodation, Public Administration, IT and Other Services as illustrated in the below figure.

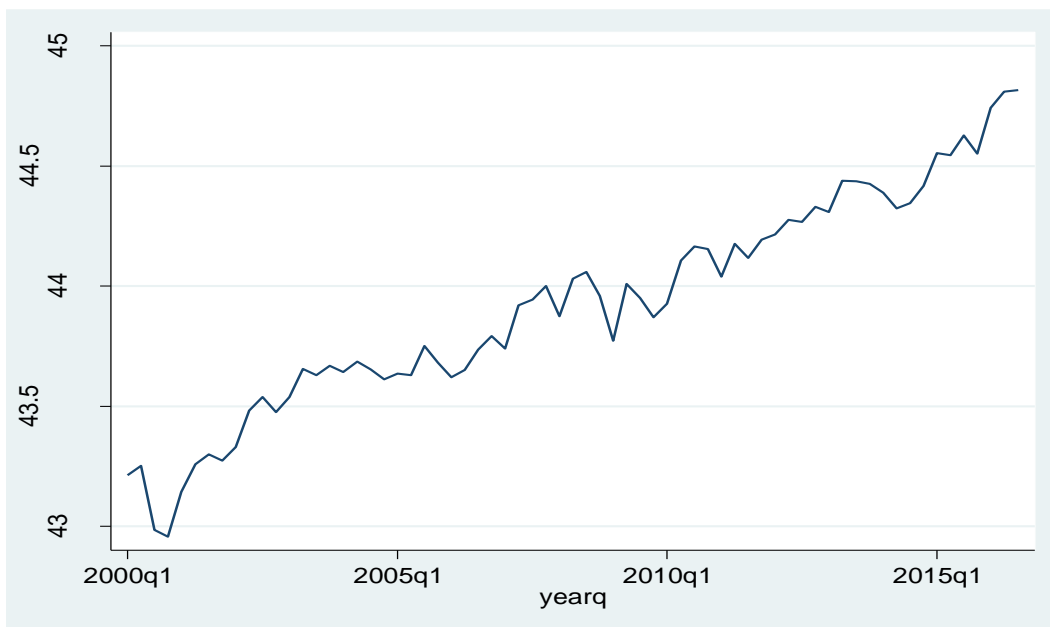
Figure 4.2.5 Industry 2 Trend-Services



A significant drop in output is noted around the year 2008-2009, this resulted from the impact of the election violence that took place after the 2007 elections and a series of terrorism attacks in the country which greatly affected the service industry more specifically, Restaurant and Accommodation and the inflow of expatriates.

The **Resource Industry**, this comprises of output from Mining and Quarrying and Electricity and Water Supply as illustrated in the below figure.

Figure 4.2.6 Figure 3.3.5 Industry 3 Trend-Resources



5. Methodology

This chapter represents the data test and analysis thereto which was conducted on the herein below models through the steps detailed below;

$$\Delta Z_t = \alpha_1 + \alpha_z \mu_{t-1} + \sum_{i=1}^l \alpha_{11} (i) \Delta Z_{t-l} + \sum_{i=1} \alpha_{12} (i) \Delta X_{t-l} + \sum_{i=1} \alpha_{13} (i) \Delta Y_{t-l}$$

$$\Delta Y_t = \alpha_1 + \alpha_y \mu_{t-1} + \sum_{i=1}^l \alpha_{11} (i) \Delta Y_{t-l} + \sum_{i=1} \alpha_{12} (i) \Delta X_{t-l} + \sum_{i=1} \alpha_{13} (i) \Delta Z_{t-l}$$

1

$$\Delta X_t = \alpha_1 + \alpha_x \mu_{t-1} + \sum_{i=1}^l \alpha_{11} (i) \Delta X_{t-l} + \sum_{i=1} \alpha_{12} (i) \Delta Y_{t-l} + \sum_{i=1} \alpha_{13} (i) \Delta Z_{t-l}$$

Where l is the no of lag.

Z Total Tariff/Electricity Cost in Kenya Shillings (natural logarithm)

X=Domestic Consumption of Electricity measured in Kwh (natural logarithm)

Y represents different outputs; Y1=refers to output from the Goods Industry; Manufacturing, Construction, Wholesale and Retail in Kenya Shillings (natural logarithm); Y2= refers to output from the Service Industry; Public Administration, IT and Other Services in Kenya Shillings (natural logarithm) and Y3=refers to output from Resource Industry; Mining and Quarrying, Electricity and Water Supply in Kenya Shillings (natural logarithm)

α and μ is the coefficient and error term respectively.

$$\Delta Z_t = \alpha_1 + \alpha_z \mu_{t-1} + \sum_{i=1}^l \alpha_{11} (i) \Delta Z_{t-l} + \sum_{i=1} \alpha_{12} (i) \Delta G_{t-l} + \sum_{i=1} \alpha_{13} (i) \Delta Y_{t-l}$$

$$\Delta G_t = \alpha_1 + \alpha_g \mu_{t-1} + \sum_{i=1}^l \alpha_{11} (i) \Delta G_{t-l} + \sum_{i=1} \alpha_{12} (i) \Delta Y_{t-l} + \sum_{i=1} \alpha_{13} (i) \Delta Z_{t-l}$$

2

$$\Delta Y_t = \alpha_1 + \alpha_y \mu_{t-1} + \sum_{i=1}^l \alpha_{11} (i) \Delta Y_{t-l} + \sum_{i=1} \alpha_{12} (i) \Delta G_{t-l} + \sum_{i=1} \alpha_{13} (i) \Delta Z_{t-l}$$

Where l is the no of lag

G=Geothermal in Kwh (natural logarithm)

Y1=refers to output from the Goods Industry; Manufacturing, Construction, Wholesale and Retail in Kenya Shillings (natural logarithm)

Z Total Tariff/Electricity Cost in Kenya Shillings (natural logarithm)

α and μ is the coefficient and error term respectively.

The analysis is divided into two sections: Descriptive analysis which looks at the current tariff rates for purposes of comparative analysis of the cheaper and/or cheapest source of energy, thereafter a look into the surcharges applicable on the tariffs will be done to ascertain which energy source is or continues to be the least cost. The second bit will focus on empirical analysis of factors that determine energy cost or vice versa including, capacity of consumed electricity, capacity of generated electricity and the GDP. The empirical analysis will commence with conducting the unit root test to establish stationarity of the variables, this will be followed by assessment of the appropriate lag length and thereafter checking the co-integration of the variables to ascertain existence of long term relation and usage of VECM

model. This will be followed by running the error correction model, thereafter checking the impulse and response and finally the direction of causality through granger causality test.

6. Model, Empirical Results and Discussion

6.1 Descriptive Analysis

The analysis commences with assessment of the current tariff rates to ascertain the comparative least cost source of energy upon assessment its established to be hydroelectric and geothermal, but considering the issue of stability, geothermal becomes the most reliable choice. The table below details the results;

Table 6.1.1 Feed in Tariff Rate¹

Energy Source	Duration	Installed capacity (MW)	Standard Fit (USD \$/kWh)	Percentage Escalable portion of the Tariff	Cumulative capacity (MW)
Wind	20 years	10.1-50	0.11	12%	500
Geothermal	-	35-70	0.088	20% for first 12 years and 15% after	500
Hydropower	-	10.1-20	0.0825	8%	200
Biomass	-	10.1-40	0.1	15%	200
Solar (Grid)	-	10.1-40	0.12	12%	100

We further look at the surcharges applicable on different energy sources which further reiterates geothermal as the less costly energy source as shown below;

Table 6.1.2 Surcharges applicable to Electricity Tariffs

Surcharge	Rate / Notes	Applicable Energy Source
Cost of the Plant	Purchase price including all taxes The actual cost as tabulated by an audited financial model	ALL
The Operations and Maintenance		ALL

¹ Kenya Feed in Tariff Policy of 2012

Financing cost- Interest on loan	The actual interest	ALL
Fuel Cost Charge (FCC)	The value is published by KPLC at the rate per kWh, based on the generating cost of the previous month.	Thermal
Foreign Exchange Rate Fluctuation Adjustment (FERFA)	The value is published by KPLC at the rate per kWh, this includes the foreign currency cost incurred by the generating companies-KENGEN, GDC and Independent Power Producers- and KPLC. This is significantly affected by the purchase of fuel	Thermal and diesel powered generators
Inflation Adjustment (IA)	The value is published by KPLC at the rate per kWh to address various factors including CPI variations that results to inflation	All
WARMA Levy	Variable rate per kWh, determined from the amount of energy supplied from hydroelectric facilities in the previous month.	Hydroelectricity Power
Energy Regulatory Commission Levy	KES 0.03 cents per kWh	ALL
REP Levy	5% of the base rate	ALL
Power Factor Surcharge	A surcharge applied if the consumer's power factor falls below 0.9. The surcharge applied is 2% of the base rate and the demand charge for every 1 per	ALL

cent by which the Power Factor is below 0.9.

VAT	16% of the total cost excepting WARMA, ALL ERC and REP levies
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Upon analysis it can be seen that the tariff offered for hydroelectric power is the least in comparison to all followed by geothermal i.e. USD \$/kWh)0.0825 and USD \$/kWh) 0.088 respectively. This implies that hydroelectric power is cheaper comparatively, however as earlier discussed in the introduction, hydroelectric is dependent on rainfall and due to the spasmodic nature of the rain, this makes it unreliable hence the cheaper and reliable alternative become geothermal.

The next phase further analyses how electricity cost goes a long way to affect economic growth, thereafter geothermal being a least cost source of energy will be reiterated through looking at the effect of its decrease and/or decrease on electricity price.

6.2 Empirical Analysis and Results

6.2.1(a) Unit Root Test

This was done to ascertain if the data was stationarity or lack of, of the variables to avoid spurious results, the null hypothesis being;

H0: variable has Unit Root /Not stationery)

H1: Variable does not have Unit Root/Stationery)

Once it's determined that the variable is non-stationery, a further application of differentiation was done to make the variable stationery. In determining how to make a variable stationery first it is of importance to determine whether the cause of the non-stationarity feature is due to a deterministic or a stochastic trend before applying the proper transformations i.e. a stochastic trend, is eliminated by differencing the series

The results are as further detailed in the appendix 6.2.1

6.2.1(b) Unit Root Test Results at Level

Variable	Test Statistic	Critical Value		p-value for Z(t)
Domestic	-1.866	1%	-4.124	0.6719
		5%	-3.488	
		10%	-3.173	
Total Tariff	-2.819	1%	-4.124	0.1902
		5%	-3.488	

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		10%	-3.173	
Geothermal	-1.270	1%	-4.124	0.8952
		5%	-3.488	
		10%	-3.173	
Industry1Goods	-0.666	1%	-4.124	0.8553
		5%	-3.488	
		10%	-3.173	
Industry2service	-1.842	1%	-4.124	0.6839
		5%	-3.488	
		10%	-3.173	
Industry3Resources	-3.518	1%	-4.124	0.0375
		5%	-3.488	
		10%	-3.173	

Where the absolute test static > Critical Value = reject null hypothesis (variable is stationery.)

When the absolute test static < critical value = accept null hypothesis (variable is not stationery or has unit root)

Variable Industry3Resources is stationery at 5% confidence interval therefore we reject the hypothesis while the remainder of the variables have unit root therefore we accept the hypothesis. The lack of stationarity on some of the variables indicates existence of a long term relation on the models.

6.2.1 Unit Root Test Results at first difference

Variable	Test Statistic	Critical Value		
DDomestic	-4.372	1%	-4.124	0.0024
		5%	-3.486	
		10%	-3.173	
DTotal Tariff	-5.744	1%	-4.124	0.0000
		5%	-3.486	
		10%	-3.173	
Industry1Good	-3.961	1%	-4.124	0.0100

			5%	-3.486	
			10%	-3.173	
Industry2service	-3.533		1%	-4.124	0.0360
			5%	-3.486	
			10%	-3.173	
DGeothermal	-4.081		1%	-4.124	0.0067
			5%	-3.486	
			10%	-3.173	

6.2.2 Lag Test

This test is conducted to check the optimal lags that need to be included for the Error Correction Model.

6.2.2(a) Lag Test Results and Analysis

		LR	FPE	AIC	HQIC	SBIC
Model 1	L0	-	-	-	-	-
	L1	-	-	-	-	-7.54274*
	L2	-	-	-	-	-
	L3	-	-	-	-	-
	L4	73.014*	2.5e-08*	-8.99136*	-8.46956*	-
Model 2	L0	-	-	-	-	-
	L1	-	-	-	-	-
	L2	-	-	-	-7.57134*	-7.13793*
	L3	-	7.5e-08*	-	-	-
	L4	18.335*	-	-7.90559*	-	-
Model 3	L0	-	-	-	-	-
	L1	-	-	-	-	-9.52613*
	L2	-	7.6e-09*	-10.1854*	-9.90445*	-
	L3	-	-	-	-	-
	L4	19.529*	-	-	-	-
Model 4	L0	-	-	-	-	-
	L1	-	-	-	-	-5.07954*
	L2	14.837*	.000016*	-5.39218*	-5.25838*	-
	L3	-	-	-	-	-
	L4	-	-	-	-	-

Model 1

LR, HQIC, FPE and AIC has selected a model with 4 lags while SBIC has selected a model with 1 lag

Model 2

HQIC and SBIC, has selected a model with 2 lags while FPE, has selected a model with 3 lags, LR and AIC has selected a model with 4 lags.

Model 3

SBIC has selected a model with 1 lag, HQIC, FPE and AIC has selected a model with 2 lags and LR has selected a model with 4 lags

Model 4

HQIC, LR, FPE, and AIC has selected a model with 2 lags while SBIC has selected a model with 1 lag.

6.2.3 Co-Integration

This is used for checking rank of co-integration of the models.

Since most of the variables are not stationery with the first analysis, the combination of either of this variables may result in a long run relationship.

So as to illustrate the level of co integration, the command uses three ways in finding the aggregate number of co integrated equations in a VEC Model. The Johansen's "trace" statistic method. The maximum Eigenvalue statistic method and the last way is by choosing r to minimize an information criterion

The Number of co integrated data is illustrated in the below table at 5% confidence level;

The null hypothesis being; H0: there are no more than r co integrating relations. The findings are as detailed below;

Model	Trace statistic (λ_{trace})				Critical Value			Maximum eigenvalue statistic (λ_{max})			
	r=0	r≤1	r≤2	r≤3	R=0	R-1	R=2	r=0	r=1	r=2	r=3
Model 1	40.1732	16.9610	2.0302*	-	29.68	15.41	3.76	.	0.30819	0.21101	0.03171
Model 2	22.3010*	5.3754	2.3495	-	29.68	15.41	3.76	.	0.23560	0.04690	0.03661
Model 3	39.0309	18.6655	4.1484	-	29.68	15.41	3.76	.	0.27621	0.20581	0.06373
Model 4	38.9135	12.8700*	3.8371	-	29.68	15.41	3.76	.	0.33860	0.13357	0.05909

Model one

Since the trace statistic at $r = 0$ 40.1732 is greater than the critical value 29.68 we reject the null hypothesis that there is no co integrating equation, at $r=1$ 16.9610 > 15.41 therefore we reject the null hypothesis that there is 1 or fewer co integrating equation, at $r=2$ 2.0302 < 3.76, therefore we fail to reject the null hypothesis that there is 2 or fewer co integrating equations and proceed to VECM analysis.

Model 2

Since the trace statistic at $r = 0$ of 22.3010 is less than 29.68 the critical value we fail to reject the null hypothesis that there is no co integrating equations. Model 2 is therefore not good for VECM analysis. Granger causality test to be conducted to ascertain the direction of causality

Model 3

The trace statistic is greater than the critical value at all levels. Granger causality test to be conducted to ascertain the direction of causality

Model 4

Since the trace statistic at $r = 0$ 38.9135 is greater than the critical value 29.68 we reject the null hypothesis that there is no co integrating equation, at $r=1$ 12.8700 < 15.41 therefore we fail to reject the null hypothesis that there is 1 or fewer co integrating equation and proceed to VECM analysis.

6.2.4 Vector Error Correction Model**Short term relation**

	Model 1		Model 4	
	Coefficient	5%	Coefficient	5%
Error Term	-.3724887	0.001	-.4645451	0.000
TotalTariff	.3264702	0.025	.3262616	0.017
Domestic	-.0730409	0.553	-.0507999	0.715
Geothermal			-.0095185	0.800
Y1	.0253565	0.190	.0035615	0.848

Long term relation Johanssen Normalization Restriction

Variable	Model 1		Model 4	
	Coefficient	5%	Coefficient	5%
TotalTariff	1	.	1	.
Domestic	-.6282453	0.000	-	-
Geothermal Generation	-	-	-.0791326	0.005
Y1	.1404151	0.000	-.0544531	0.010
Constant	1.290698	.	2.760333	.

Analysis**Model 1-Short Term Relation**

The error term is negative and significant at 5% confidence level (-.3724887) which indicates that when there is a deviation from the equilibrium by the electricity cost, it adjusts at 37% on a quarterly basis to clear the disequilibrium.

Of the variables, only “TotalTariff” is significant in the short run at 5% confidence level.

Long Term Relation

$$1 = -.6282453 D - .033611 Y1 + 1.264973 \quad (5)$$

(0.1077911) (0.0280096)

The increment of the Electricity Tariff is related to increasing of output from Industry 1 and decrease in Domestic Consumption of Electricity. One percent increase of Y1 will decrease Electricity Tariff by 0.033611 %, and 1% increase in domestic consumption will decrease Electricity Tariff by 0.6282453 % significant at 5% confidence level

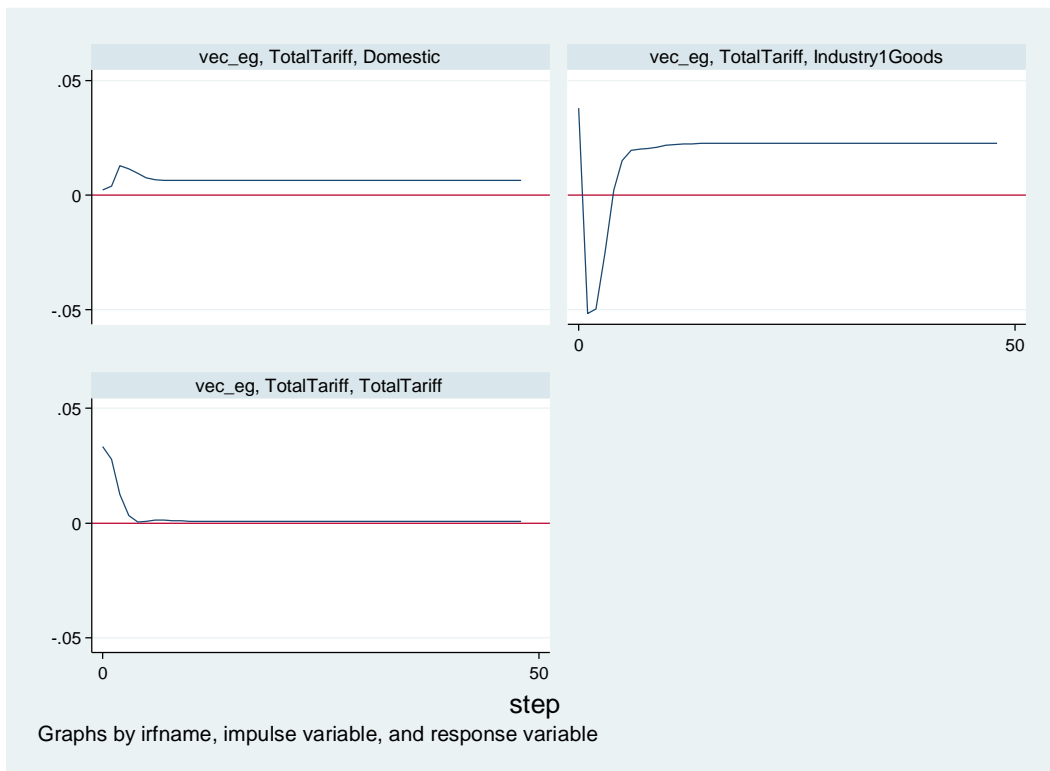
This situation will apply since production of Y1 is heavily dependent on Electricity cost, therefore to encourage increase of Industries for industrialization, the electricity cost has to be reduced, on the other hand, as much as Consumption of electricity is inelastic especially in the long run, reduction in consumption will cause cost reduction for purposes of inducing increase in consumption.

The R square for the “TotalTariff”, “Domestic” and “Industry1Trading” variables is 0.1756, 0.3143 and 0.3244 meaning 18 %, 31% and 32% of the aggregate variations on the dependent variable is as a result of the explanatory variables while the remainder percentage is resulting from variables out of the model-exogenous variables which are covered in the error term

6.2.5 Impulse Response Test

Figure 4.2.5.1 shows the responses of Domestic Consumption of Electricity (natural log), Output2 –Y1 (natural log) and Electricity Cost (natural log) to exogenous change on Electricity Cost-TotalTariff. The blue line represents the response, the horizontal axis measures the numbers of quarters following the initial shock while the Y axis measures the response in Kwh, KES and KES for Domestic Consumption of Electricity, Output 2 and Electricity Cost respectively.

6.2.5(a) Impulse Response Model 1



A shock on electricity tariff will result to a very minimal increase of Domestic Consumption to slightly over about 0.00 and it will remain constant at the same point thereafter, this is characterized mostly due to the inelasticity of consumption of electricity. On the other hand Y1 will drop significantly to about -0.03 since its heavily reliant on electricity as an input for production thereafter an increase in electricity cost amounts to increase on cost of production.

6.2.5(b) Impulse Response Model 2

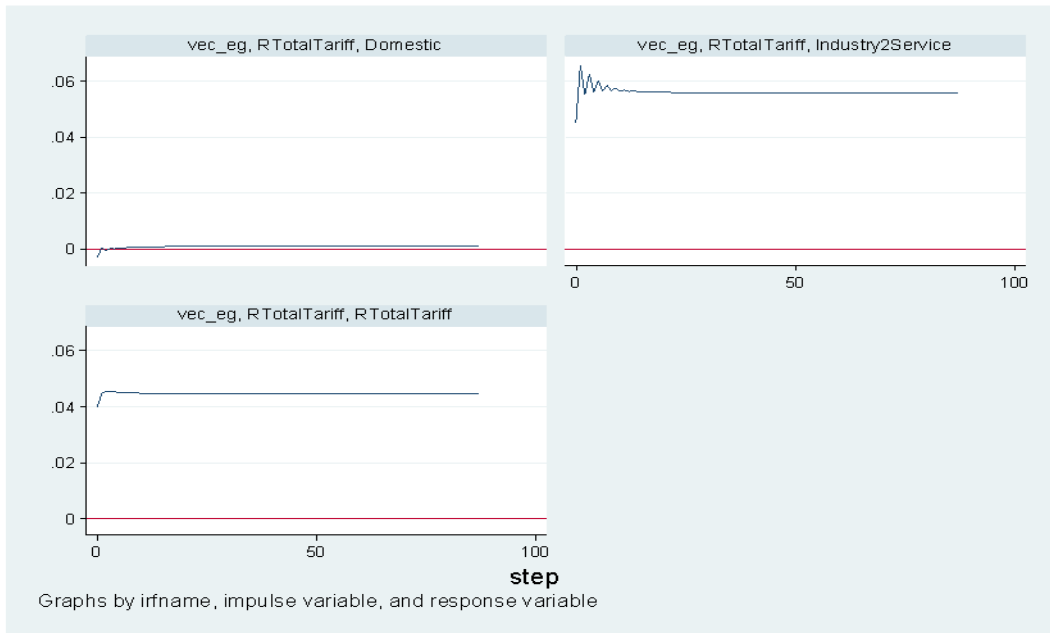


Figure 4.2.6.1 shows the responses of Domestic Consumption (natural log), Output 2 -Y2 (natural log) and Electricity Cost (natural log) to exogenous change on Electricity Cost-TotalTariff. The blue line represents the response, the horizontal axis measures the numbers of quarters following the initial shock while the Y axis measures the response in Kwh, KES and KES for Domestic Consumption of Electricity, Y2 and Electricity Cost respectively.

A shock on electricity tariff will result to an immediate very minimal increase on Domestic Consumption to 0 and it will remain constant at that level thereafter, this is due to the inelasticity of Domestic Consumption, mostly because the service industry consumes relatively minimal electricity, which will further be reiterated by the response of the Industry which will not be affected negatively by the change; a slight increase from 0.042 to 0.06 is noted in the 1st and the 2nd quarter.

6.2.5(c) VECM Analysis and Impulse Response Model 4

Short Term Relation

The error term is negative and significant at 5% confidence level (-.4645451) which indicates that when there is a deviation from the equilibrium by the electricity cost, it adjusts at 46% on a quarterly basis to clear the disequilibrium.

Of the variables, only “TotalTariff” is significant in the short run at 5% confidence level.

Long Term Relation

$$1 = -0.0791326 G - 0.0544531 Y1 + 2.760333 \quad (5)$$

(.0283287) (.0212641)

The increment and/or of the Electricity Tariff is related to decreasing of Y1 and decrease in Geothermal Generation, therefore, the above model was able to produce result as expected. One percent increase of Y1 will decrease Electricity Tariff by 0.0544531 %, and 1% increase

in Geothermal Generation, will decrease Electricity Tariff by 0.0791326 % significant at 5% confidence level

This situation will apply since production of Y1 is heavily dependent on Electricity cost, therefore to encourage increase of Industries for industrialization, the electricity cost has to be reduced, on the other hand considering the geothermal generation relatively low tariff rate, and increase in geothermal quantity on the grid will significantly reduce electricity cost.

The R square for the Total Tariff, Domestic and Industry1Trading variables is 0.2307, 0.2503 and 0.2565 meaning 23 %, 25% and 26% of the aggregate variations on the dependent variable is as a result of the explanatory variables at respective percentages while the remainder percentage is resulting from variables out of the model-exogenous variables which are covered in the error term

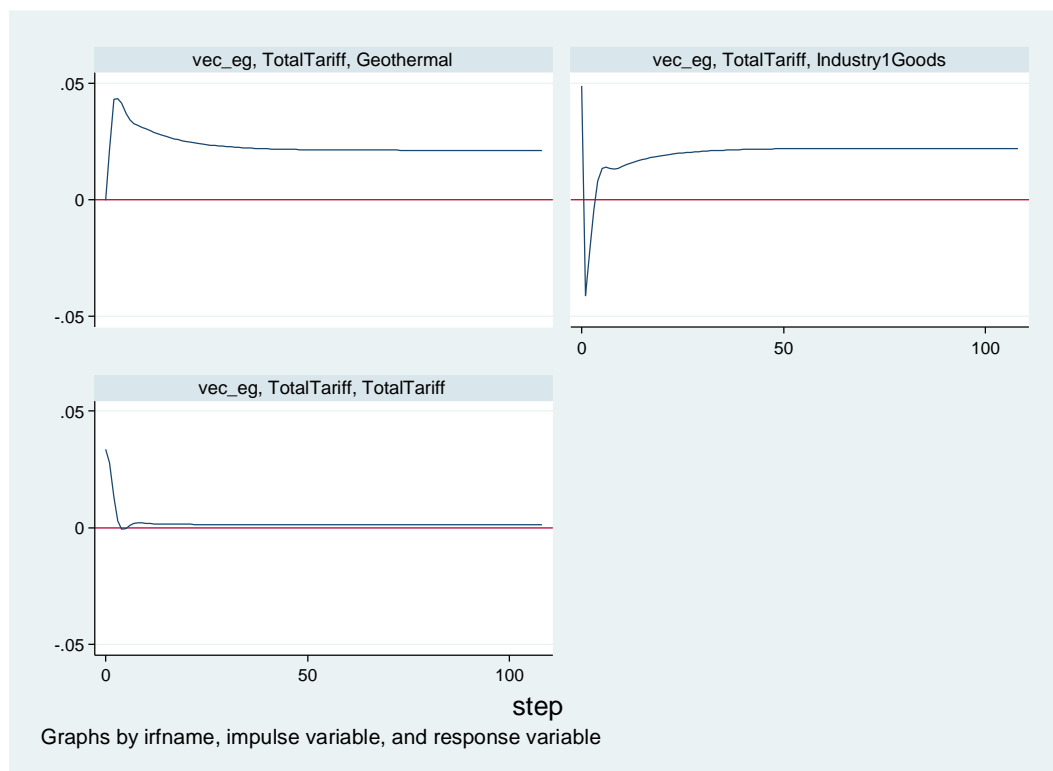


Figure 4.2.8.1 shows the responses of Geothermal Generation (natural log), Output 2 -y2 (natural log) and Electricity Cost (natural log) to exogenous change on Electricity Cost-TotalTariff. The blue line represents the response path, the horizontal axis measures the numbers of quarters following the initial shock while the Y axis measures the response in Kwh, KES and KES for Geothermal Generation, Output 2 and Electricity Cost respectively.

A shock on electricity tariff will result to an immediate increase on Geothermal Generation to slightly over 0.05, followed by an immediate decrease to 0.05 and remain constant at that level thereafter, this will result from an initiative by the government to increase geothermal generation to curb the increasing cost which is further reiterated by the response of Total tariff by its decrease from 0.004 after the initial response to shock, down to slightly about 0.01, Y1 will respond by an immediate increase to 0.04 over the 1st quarter which may be an immediate response in anticipation of further increase of tariff cost over the long run, but thereafter considering the high tariff cost, an immediate significant decrease to -0.05 is noted

, this is due to the fact that electricity being an input for Y1 ,and its increment is detrimental to Y1 hence the significant decrease.

6.5 Granger Causality Test

Null hypothesis; Electricity Cost (Z), does not Granger-cause Domestic Electricity Consumption (X) and Output (y1, y2, y3); and

Null hypothesis’; Domestic Electricity Consumption (X) and Output (y1, y2, y3) does not Granger-cause Electricity Cost (EZ), and Output

The models are said to have unidirectional causality if either of the null hypothesis is rejected, Bidirectional Causality; if both null hypothesis are rejected and no causality occurs if neither is rejected. The findings are as detailed below;

6.5.1 Granger Causality Findings

NO	Hypothesis	Chi2(2)	significance	Finding
1	Z does not Granger-cause X and Y1	6.3004	0.70952	Fail to reject
	X and Y1 does not Granger-cause Z	18.9564	0.02557	Reject
2	Z does not Granger-cause X and Y2	20.6649	0.06467	Fail to reject
	X and Y2 does not Granger-cause Z	15.8484	0.34765	Fail to reject
3	Z does not Granger-cause D and Y2	9.6966	0.37560	Fail to reject
	X and Y3 does not Granger-cause Z	10.1257	0.34041	Fail to reject
4	EC does not Granger-cause Y1 and G	17.1324	0.06282	Fail to Reject
	Y1 and G does not Granger-cause Z	37.7975	0.00003	Reject

Model I

Null hypothesis; Electricity Cost (Z), does not Granger-cause Domestic Electricity Consumption (X) and Output (Y1); and

Null hypothesis'; X and Y1 does not Granger-cause Z

At 5% significance level 0.70952 is insignificant hence fail to reject the first null hypothesis and reject the 2nd null hypothesis since 0.02557 is significant at 5% confidence level. This implies changes in Electricity Cost (z) is caused by a change(s) in Output1 (Y1) and Domestic Consumption of Electricity (Z). Hence a unidirectional causality is observed. In reiteration of the earlier stated, Y1 uses electricity as input, therefore to encourage FDI, industrialization and/or exports, the electricity prices ought to be adjusted to encourage competitiveness of manufactured goods,

Model 2:

Null hypothesis; Electricity Cost (Z), does not Granger-cause Domestic Electricity Consumption (X) and Output (y2); and

Null hypothesis'; Domestic Electricity Consumption (X) and Output (Y2,) does not Granger-cause Electricity Cost (Z)

At 5% significance level 0.06467 is insignificant hence fail to reject the first null hypothesis and equally fail to reject the 2nd null hypothesis since 0.34765 is not significant at 5% confidence level. This implies changes in Electricity Cost will not occasion any change(s) in domestic consumption of electricity and Output2 (Y2) and the reverse relation does not exist as well. This may result from the fact that the service Industry does not require electricity as an input irrespective of Accommodation and Restaurant being included, their percentage contribution is minimal hence the impact. However cheaper electricity cost is a key factor in the hotel industry hence it will may play a major role in policy making for restaurant and accommodation set up or continuity if the economy is reliant on the Industry or wishes to promote the Industry.

Model 3:

Null hypothesis; Electricity Cost (Z), does not Granger-cause Domestic Electricity Consumption (X) and Output (Y3); and

Null hypothesis'; Domestic Electricity Consumption (X) and Output (Y3) does not Granger-cause Electricity Cost (Z).

At 5% significance level 0.37560 is insignificant hence fail to reject the first null hypothesis and fail to reject the 2nd null hypothesis since 0.34041 is insignificant at 5% confidence level. This implies changes in Electricity Cost may not occasion change(s) in domestic consumption of electricity and Output3 (Y3) and the reverse relation does not exist either. This may result from the fact that Output3 comprises of Electricity hence increase in electricity cost implies more income for the industry, on the other hand the existence of water industry, mining and quarrying which is not reliant on electricity may water down the effect hence the lack of causality relation.

Model 4:

Null hypothesis; Electricity Cost (Z) does not Granger-cause Output1 (Y1) and Geothermal Generation (G); and

Null hypothesis'; Output1 (Y1) and Geothermal Generation (G) does not Granger-cause Electricity Cost (Z).

At 5% significance level 0.06282 is insignificant hence reject the first null hypothesis and reject the 2nd null hypothesis since 0.00002 is significant at 5% confidence level. This implies changes in Electricity Cost may occasion change(s) to the source of generation i.e. increasing or reducing geothermal generation to curb cost increment and vice versa. change(s) in Output1 (Y1) and Geothermal Generation may occasion changes in Electricity Cost hence unidirectional causality is established. This may result from the fact that output1 depends on electricity as a major input hence changes on the electricity cost affect prices of good and geothermal is comparatively a cheaper mode of generation hence it tends to reduce the electricity cost if its input on the grid is significant.

7. Policy Implications

The analysis focused on reiteration of the importance of geothermal generation as a major factor of cost reduction and economic growth. A two-step analysis approach was used to the effect; Descriptive analysis which indicated that beforehand the tariff rate of geothermal is comparatively less, following which an analysis to confirm that electricity tariff is in fact relatively affected by electricity consumption and significantly affected by output(s) from different sectors whose findings signified the goods industry is of high importance since electricity is an input in the production hence the cost of electricity is a key player in decision making. Thereafter, a further in look of how electricity cost will be affected by different generation sources and outputs, the focus being geothermal generation and output 1(y1), the results signified a unidirectional causality.

Noting the above, when the prices for electricity goes up, the response will be to increase the amount of geothermal generation in the long run so as to reduce the cost of electricity since it is the least cost source of energy. Domestic consumption is none responsive in most of the models due to its inelasticity after installation, but in small margins that may not be significantly be detected, in the long run as an input for production, due to the high costs, it will reduce relatively. The different outputs respond by decreasing other than services which are mostly not dependent on electricity as an input.

The less cost resulting from use of geothermal will increase economic growth significantly through the manufacturing component of the GDP as analyzed previously. Relatively cheaper electricity will equally encourage accessibility of electricity by many.

Kenya being an emerging economy on the verge of takeoff through industrialization, electricity is a very major input for production. The impact of electricity consumption and increase in investment is summarized as below;

Before installation, electricity demand can be characterized as being very elastic, any slight change in price and/or installation charges will significantly affect the demand and subsequently the economy. i.e. If the price goes up, the consumers may generally refuse/be unable to install the electricity usage.

After installation, electricity demand is comparatively less elastic depending on the consumer, hence; Domestic consumption may relatively decrease; Commercial consumption may not respond immediately however in the long run considering it is an input for production, the cost of production will increase making the products to be non-competitive, this will result in movement of the investors to a less costly market-neighboring countries.

In the long run, once the economy is more developed, the demand elasticity of electricity becomes less i.e. a slight increase in the tariff will result to a lesser response in the shift of the

quantity demanded since electricity becomes a necessity. But it is equally important to encourage competitiveness of output to act as incentive to foreign and local investors, therefore adopting the reliable, least cost energy source-geothermal-is reasonable.

As detailed earlier in the literature review, the database duration affects the findings of the model, an analysis done with a longer duration dataset may bring forth more significant findings. Use of a different model which may put emphasis on the years that significant increase of geothermal energy on the greed was observed will equally give more significant results.

REFERENCES

- Abul M.M. Masih, Rumi Masih “Energy Consumption, Real Income and Temporal Causality: Results from a Multi-Country Study Based on Cointegration and Error-correction Modelling Techniques” *Energy Economics* 18(1996) 165-183
- Silas Masinde Simiyu “Status of Geothermal Exploration in Kenya and Future Plans for Its Development” *Proceedings World Geothermal Congress 2010 Bali, Indonesia, 25-29 April 2010*
- Dhungel, Kamal Raj. "Estimation of Short and Long Run Equilibrium Coefficients in Error Correction Model: An Empirical Evidence from Nepal." *International Journal of Econometrics and Financial Management* 2.6 (2014): 214-219.
- Watson, M. W. Vector auto regression and co-integration. In Vol. 4 of *Handbook of Econometrics*, ed. R. F. Engle and D. L. McFadden. Amsterdam: Elsevier (1994)
- Alice Shiu*, Pun-Lee Lam “Electricity consumption and economic growth in China” *Energy Policy* 32 (2004) 47–54
- Chien-Chiang Lee, “Energy consumption and GDP in developing countries: A co-integrated panel analysis” *Energy Economics* 27 (2005) 415 – 427
- Ugur Soytaska, Ramazan Sari “Energy consumption and GDP: causality relationship in G-7 countries and emerging markets” *Energy Economics* 25 2003 33 Ž -37
- Phillips, P.C. and P. Perron, 1988. Testing for a unit root in time series regression. *Biometrika*, 75(2): 335-346.
- Institute of Economic Affairs (IEA), “Situational Analysis of Energy Industry, Policy and Strategy for Kenya,” (2015)