RELATIONSHIP BETWEEN ENERGY CONSUMPTION AND ECONOMIC GROWTH IN TANZANIA

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DECLARATION

I hereby declare that this research paper is my own work and has not been presented for the award of a degree in any other University.

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We confirm that this work has been submitted for examination with our approval as University supervisors.

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Date………………………………….

DEDICATION

This work is dedicated to my late father, Mr. Callystus Nyoni, my late mother Mrs Acquina Nyoni; my late brother Marcellino Nyoni; my family; my brothers and my sisters and to my beloved partner Bertha Bihondo for her moral and emotional support throughout the study.

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LIST OF ABBREVIATIONS

ADF- Augmented Dickey Fuller

CES-Constant Elasticity of Substitution

C-D-Cobb-Douglas

EWURA-Energy and Water Utilities Regulatory Authority

GDP-Gross Domestic Product

GW-Giga Watts

IPP's-Independent Power Producers

IPTL-Independent Power Tanzania Limited

ILS-Indirect Least Squares

KLEM-Capital-Labour-Energy-Materials

MENI-Non-energy imports

ME-Energy Imports

MW-Mega Watts

OMP-Oil Import Price

OPEC-Organization of the Petroleum Exporting Countries

OECD-Organization for Economic and Co-operation Development

SADCC-Southern African Development Co-ordination Conference

TOE-Tonnes of Oil Equivalent

U.S-United States

2SLS-Two stage Least Squares

3SLS-Three Stage Least Squares

ABSTRACT

Energy consumption and economic growth modeling had received a lot of attention following the oil crisis of the 1970's. This event led to a new approach of economic growth modeling that included energy as one of the economy's input. This study seeks to analysis the relationship between energy consumption and economic growth in the context of Tanzania. The main objective of this study is to understand the nature of relationship between energy consumption and economic growth. Economic growth is represented by production function and proxied with real GDP determined by capital, labor and energy. Energy consumption is determined by income level (GDP), lagged energy-consumption, urbanization and energy price. The specific objectives were to examine the effects of energy price changes on aggregate output and to examine the direction of causality between energy consumption and economic growth. The study was carried using the annual time series data for the period 1980 to 2010. The model adopted the Cobb-Douglas production function and used the Two Stage least squares (2sls) to estimate the simultaneous equations of economic growth and energy consumption. Granger-causality test was also run to test for the direction of causality. The results suggest that an increase in price of energy leads to a fall in output, however the output responded weakly to increase in price of energy. The causality test supports the unidirectional causality that run from economic growth to energy consumption, hence supporting the conservation hypothesis. This implied that as the economy grows the more the energy consumption. Therefore, the results suggest that a reduction in energy use does not have a significant impact on the total output of an economy.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Energy as an input in production has been of great concern to business and financial economists. In particular the effects of oil prices on economic activities have attracted most attention. However, traditional economic theories of production give energy less weight since the focus is on three inputs namely capital, labor and land. Materials and fuel are treated as intermediate inputs. (See Dunkerley, 1981; Stern, 2003).

Since the 1970’s oil crisis that adversely affected developing countries who are largely net oil importers, energy has gained more attention. Scholars modeling growth now incorporate energy as one of the explanatory variables. Since the oil cartel action of 1967 where Arab oil-producing countries decided to limit oil supply to United States and United Kingdom with some totally banning oil exports in a move to discourage support to Israel, the resultant energy crisis of the 1970s spurred studies on energy in the western world. Later scholars began to model energy-economy interactions in developing economies (Blitzer, 1986; Shin, 1986; Rahman, 1982; Griffin and Schulman, 2005). The OPEC-inspired oil crisis marked the end of low cost energy era (Dunkerley, 1983). The impact of costly fuel energy in the development of energy-importing developing countries is a rich research field. Blitzer (1986) estimates that developing economies consume only about one-sixth of the world oil. Despite the insignificant share of developing countries in the world total oil consumption these economies are badly affected by price movements in the world markets because of their dependence on imported oil and low investments in alternative sources of energy. Energy has taken a significant place alongside labor, capital and land as key factors of production. Therefore, energy policy in development strategies is essential

Globally energy demand and carbon dioxide emissions are on the rise. The energy market dynamics are greatly affected by emerging economies. It is estimated that the share of non-OECD energy demand will rise from 55% in 2010 to 65% in 2035. China will lead in this demand, followed by India whose demand is expected to double. The transport sector in China, India and Middle East is expected to significantly account for the growing demand in oil consumption. .

However, fossil fuels continue to dominate in energy provision to the world's poor. Oil, gas and coal are estimated to grow in absolute terms by 2035, though their combined share of world energy will fall from 81% to 75% by that period (World Energy Outlook, 2012)

For the third world countries speculations are that fossil fuels and hydroelectric power will remain the potential sources of energy for commercial development, though biomass energy will account for a greater percentage in energy provision to the world poorest. However, such energy sources face challenges as noted by Dunkerley(1983) who argues that its expansion is dependent on the global forestry management from the world's environmentalists.

Income is one of the fundamental determinants for increased energy consumption in the world driven by increased demand by emerging economies whereas the supply side is stagnant. Most studies have pointed out that the main determinant of oil demand is income thus growth in income levels of large and fast growing economies led to a significant increase in global demand Cantore et al(2012,p.6). Growing economies like China and India are linked with currently increase demand for oil due to growth in income levels. Over a decade Tanzania's real GDP has been growing overtime which means more economic activities that generate income. In this case there is more demand for energy to facilitate these economic activities, however its demand changes might be insignificant at global level but at national level, *a priori* , more income would mean more demand for energy.

Consumption refers to manifestation of satisfied demand that can be measured therefore consumption occurs when a decision to purchase and consume is made. In an economy aggregate energy consumption is usually a sum of all commercial energy consumed per annum. Commercial energy refers to energy sources that can be traded in the market system this study therefore, focuses on the aggregation of three commercial energy sources namely oil, electricity and coal.

1.2 ENERGY BACKGROUND IN TANZANIA

The first energy policy in Tanzania was formulated in 1992, and the reviewed National Energy Policy (2003,p.5) objective is to "*provide an input in the development process by establishing an efficient energy production, procurements, transportation, distribution and end-user systems in an environmentally sound manner and with due regard to gender issues."* Ever since, the energy sub-sector and the entire economy have gone through structural changes, changed roles of the government, markets liberalization and the increasing role of private sector in energy issues has been encouraged. Following these adjustments the policy was revised in 2003 to take into consideration structural changes and political transformation at both the national and international levels[1].

In Tanzania, the main sources of commercial energy are petroleum, hydro-power and coal, with biomass dominating primary energy use. Biomass comprises fuel-wood and charcoal from both natural forests and plantations. It accounts for about 90% of total primary energy consumption in Tanzania. This is mainly because of the high electricity tariffs; and thus it is used largely by households majorly for cooking in both rural and urban areas, and this is regardless of their level of access to electricity. For commercial energy, petroleum accounts for about 8% of total energy consumption while electricity accounts for about 1.2%. Other sources of energy like coal, solar and wind contributes to less than 1%of the total energy.

1 Nationa Energy Policy (2003)

Domestic energy demand has grown rapidly due to increased population growth and increased economic activities and in 2003, it was estimated that the total energy consumption of the economy was more than 22 million tonnes of oil equivalent (TOE) or a 0.7 (TOE) per capita (National Energy Policy 2003).

The economy also has abundant energy sources ranging from hydro-power, coal, natural gas, uranium, solar, wind and geothermal energy though they are not fully utilized. If all these are tapped, the country could meet its growing demand and this is because hydro-power potential is estimated at 4.7 GW, coal reserves at 1200 million tonnes and natural gas estimates of about 45 billion cubic meters of proven reserves[2]. Recently Tanzania has been into natural gas for electricity production and possibilities of coal use for electricity generation are also being explored.

1.2.1 Petroleum

Petroleum in Tanzania is imported since oil exploration has not been a success. The main sectors that consume imported petroleum products include the transport sector, which is the major consumer at 40%, manufacturing sector at 25% and households at 10% while agriculture and commerce share the balance. The demand for petroleum is currently met by only 70%.

[2] National Energy Policy

Figure 1: Energy from petroleum in Tanzania

Where it comes from (%)	Total Oil Supply (%)	Where it goes by sector (%)
Imported refined products (29%)	TOTAL OIL SUPPLY (100%)	Transportation (47%)
		Industry (18.6%)
		Construction (2.8%)
Imported Crude Oil (71%)		Power generation (3.7%)
		Agriculture (4.3%)
		Household and Commercial (11.2%)
		Other (Bunker, Export Stock etc (12.9%)

Source: Mwandosya (1985)

1.2.2 Natural gas

This is the most likely substitute for oil, having been discovered at Songo Songo and Mnazi bay, with an estimated reserve of about 30 billion cubic metres and 15 billion cubic metres respectively. It is of importance to note that even before discoveries; natural gas has been used in Tanzania for electricity generation and geothermal industrial application. An efficient use of this the resource should thus be of national priority and since the markets and infrastructure for natural gas are underdeveloped, there is an agent need to set regulated mechanisms in order to protect other stakeholders who are less advantaged by such discoveries.

1.2.3 Electricity

Tanzania's electric supply consists of both interconnected and isolated systems. The interconnected transmission grids have an installed capacity of 863 MW from both thermal and hydro generation facilities. Hydro accounts for 559MW while thermal contribute 304MW.

According to EWURA, the main hydro power plants are Kidatu (204MW), Kihansi (180MW), Mtera (80MW), New Pangani Falls (68MW), Hale (21MW) and Nyumba ya Mungu (8MW). From isolated thermal generation the capacity is 29MW making a total of 892MW. Tanzania Electric supply Company is the sole supplier of electric power on main land and substantial electricity to Zanzibar. There are also three independent power producers (IPPs) that supply power to the national utility, 100MW diesel plant by Independent Power Tanzania Limited (IPTL), Kiwira Coal Mining and Tanganyika Wattle Company both supply about 4MW. However, much dependence on hydro-power has been handicapped lately by a series of long droughts this made the country to resort to emergency power procedures. With this the government is making efforts to increase power generations through locally available resources such as natural gas, coal and renewable energy.

1.2.4 Coal

Coal is one of the major energy sources in Tanzania regardless of its current minimal exploitation. The national electricity generation capacity from coal currently stands at 6MW, with expectation to increase this generation capacity. Mostly, coal has been used in industrial thermal application and less if not none in household energy supply. Therefore, there is a need to address more exploitation of this resource, developing its market in integrated basis to include supply to the household sector.

1.3 STATEMENT OF THE PROBLEM

The oil crisis of the 1970s adversely affected non-oil producing countries, particularly those in the developing economies. The crisis marked the end of cheap energy. It also ushered in a trend of oil price hikes now and then that hits hard on oil importing developing economies. Several studies have examined energy consumption and economic growth. The interest in these studies is whether energy consumption causes growth or the reverse. Literature shows no consistency on the findings. While some studies find a uni-directional causality running from energy to economic growth (Gately & Huntington, 2002; Kraft & Kraft, 1978; Dantama and Inuwa, 2012), others find a unidirectional causality running from economic growth to energy consumption (Aqeel and Butt, 2001; Mushtaq, 2008; Dunkerley, 1982). Others show bidirectional causality (Hye and Riaz, 2008; Huo, 2009) or no causality at all (Razzaqi and Sherbaz, 2007; Aqeel and Butt, 1987).

Since the nature of relationship between energy consumption and economic growth is not clear from literature, this study seeks to examine the nature of this relationship in the Tanzanian case. The findings of the study will further shed light on the divergent views found in the literature concerning the nature of this relationship.

1.4 RESEARCH QUESTIONS

i. What are the effects of energy price changes on aggregate output?
ii. What are effects of aggregate output on energy consumption?
iii. What is the direction of causality between energy consumption and economic growth, if at all it exists?

1.5 OBJECTIVES OF THE STUDY

The main objective of this study is to examine the macroeconomic effects generated by price movements in energy sector on aggregate output and trade balance in the Tanzanian economy. The study will specifically focus on;

i. Examine the effect of energy price changes on aggregate output in Tanzania.
ii. Examine the direction of causality between energy consumption and economic growth in Tanzania.

iii. Draw appropriate conclusions on the relationship between energy consumption and economic growth.

1.6 RESEARCH HYPOTHESIS

i. Energy consumption leads to economic growth

1.7 SIGNIFICANCE OF THE STUDY

This empirical study seeks to understand the relationship between energy consumption and economic growth. The results will give some directions regarding the divergence found in literature about the nature of relationship. Furthermore, the study tests the assertion that energy price affects an economy's aggregate output and trade balance; thus helping policy makers in developing an appropriate energy policy. Also, the study aims at contributing to existing literature on energy consumption and economic growth relationship.

CHAPTER TWO

2.0 LITERATURE REVIEW

In this section we review literature surrounding issues that are of concern in this paper, and with the large amount of literature on energy issues and its relationships to economic growth ever since the oil crisis of 1973-74. However, their relevance to this study has made the selection of a significant literature to be made that fits the scope of this study.

2.1 Theoretical literature

2.1.0 Energy consumption and economic growth hypothesis have been discussed by several scholars. The literature proposes four different hypotheses regarding the causality relationship as discussed in Belke et al (2010) and (Dantama and Inuwa, 2012)

The growth hypothesis

This hypothesis suggest that energy consumption is an important component in economic growth process either directly or as a complement to capital and labor as input factors of production. This hypothesis is supported if there exist a uni-directional causality from energy consumption to economic growth. Therefore, as Belke et al (2010) argues that under this hypothesis a decrease in energy consumption causes a decrease in real GDP in this case, the economy is energy dependant. So energy conservation policies will have a negative effect on economic growth.

The Conservation hypothesis

Under this hypothesis economic growth is the dynamic source that causes the increase in consumption of energy, such that policies that are directed towards reduction in energy consumption might have little or no adverse effects on economic growth. The hypothesis is valid if there exist uni-directional causality from economic growth to energy consumption (Belke et al, 2010) and (Apergis and Payne, 2009) .

The feedback hypothesis

The hypothesis states that energy consumption and economic growth affects each other simultaneously, that is the mutual relationship between the two. Bi-directional causality between energy consumption and economic growth validate this hypothesis, thus energy conservation policies may decrease economic growth and changes in economic performance are reflected back to energy consumption (Belke et al, 2010). It is also discussed in (Dantama and Inuwa, 2012) and the argument is that energy consumption and economic growth are complementary

The neutrality hypothesis

(Belke et al, 2010) argues that the hypothesis states that energy consumption does not affect economic growth, the hypothesis is supported if there is no evidence if causality between energy consumption and economic growth. Thus policy geared towards energy conservation would have no effect on real GDP or retard economic growth (George and Nickoloas, 2011).

Energy demand

In developing nations lack of modern energy services is one of the main causes of low levels of economic and social development. Access to modern energy sources such as electricity promotes social development and welfare by improving greater access to information, cleaner ways of storage and food preparation, and provision of heating and cooling services (Medlock III and Soligo, 2001)

Analysis of demand for energy is not different from micro economic analysis of any other good or commodity. Therefore, demand for energy arises from a number of reasons. Households tend to consume energy this as they do with other goods to satisfy their desires. They allocate their income across various competing needs to maximize their satisfaction from total expenditure. Also, in industries and other commercial consumers demand energy as their input in production process with the objective to minimize total cost of production (Bhattacharyya, 2011).

From microeconomic theory, demand for a good is a relationship between different units of the good consumed and the determinants of those amounts consumed. The determinants of demand are price of the good, prices of related goods, price of other goods, disposable income, preferences and tastes.

However, at both levels-household and industrial- energy is not used for the sake of consuming it to meet a desired level of utility rather through appliances or equipments (energy-using capital). In this case demand for energy is a derived demand since energy value is determined by its ability to provide a set of services. Its demand is manifested through demand for energy-using equipments that require energy to operate both in the household and industry. So the demand for energy-using capital equipment is for some purposes like production purposes, mobility, or even comfort (heating, cooling). Therefore, energy is a development contributor as it shifts the economy from manpower to mechanical power economy.

Demand for energy in the long and short run is influenced by factors like economic development that leads to changes in the structure of output. This in turn changes the manner at which demand grows relative to changes in income. Other factors include technological changes, effects of energy prices on composition, efficiency and utilization of energy-using capital and the policy variable.

Energy demand in the long run

Economic structure and technology are critical determinant of energy demand as they both influence energy intensity at macro level.

The economic structure of an economy changes as the economy grows and become more service oriented such that the unit of service output requires less energy than a unit manufacturing output. Also wealth of consumers is improved hence raising demand for energy-using equipment. Therefore, this structural change in production and consumption leads to change in structure of energy-using capital thus promoting changes in energy consumption and intensity (Evans and Hunt, 2009).

Technology influence demand for energy since as technology grows more energy-efficient capital is deployed, as a result the requirement for a given level of output declines allowing expansion of economic activities without a feedback effect of increase in energy demand. The relationship between technological change and energy demand and intensity arise from the *theory of dematerialization* that says technological progress effectively lowers the peak energy intensity of an economy (Evans and Hunt, 2009).

Energy demand decisions

Energy consumption at individual, household and firm level is a product of a set of simultaneous decisions that involve the choice of quantity and type of capital equipment to purchase. For consumers of energy to switch between commercial energy consumption and choice of capital equipment requires monetary exchange. This decision process can be considered as a three stage decision making process and all the three stages influence energy demand (Bhattacharyya, 2011). The first stage involves household decision whether to switch or not (switching decision), then appliance selection decision where consumers decides the type of capital equipment (appliances) to be used. The last stage is consumption decision made by deciding the usage pattern of each energy-using capital (appliance).

Therefore, energy demand decisions depend on the first decision of either to purchase an appliance or not. When a decision to purchase is made a demand for a particular energy arises, otherwise there is no demand for a particular energy (Hartman, 1979).

Energy-capital relationship arises from a derived demand of energy, such that the decision to consume certain type of energy is predetermined by the investment decision of purchasing an energy consuming appliance. Therefore, energy consumption depends on the energy efficiency and utilization rate of installed capital and the scale of operation (Evans and Hunt, 2009).

The elasticity of energy demand

Elasticity measures how much (in percentage) the demand would change if the determining variable changes by one percent. Generally in economic analysis the only variables considered for elasticities are output or economic activity (GDP), price and income (Bhattacharyya, 2011). The great interest of these elasticities arises from importance of the elasticities in making economic forecasting of energy demand.

Output or GDP elasticities of energy demand indicate the rate of change of energy demand for every one percent change in economic output. Often the GDP growth is positively related to energy demand but the value of elasticity varies depending on the stage of development of an economy (Bhattacharyya, 2011). It is believed that developed economies have an inelastic demand with respect to income whereas developing ones have an elastic demand.

Price elasticities indicate how much demand changes for every percent change in the energy price. Price elasticities are negative numbers, indicating that an increase in price results in a decrease in energy demand. Price elasticity aims at finding out the responsiveness of consumers to price changes, therefore the price to be used for this purpose have to be as close as to what consumers really pay (Evans and Hunt, 2009).

The own price elasticity is vital since it capture impacts of several energy policies that aimed at conservation for instance taxes and subsidies (Evans and Hunt, 2009). In the analysis of price elasticity usually there is a distinction between short-term and long-term price elasticites. The short-term price elasticity measures an instant reaction of the price change, where consumers have no possibility of changing their capital stock but can only change their consumption behavior. The long-term price elasticity measures the effects of adjustments overtime. In the lon-run consumers are able to adjust their capital stock as well as their consumption behavior (Bhattacharyya, 2011).

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2.3 EMPERICAL LITERATURE

Energy consumption and Economic Growth

In most studies energy consumption is associated with growth of an economy as energy plays a crucial role as a factor of production or an input in the input-output economic models of most countries. Studies have tried to link the energy sector to the aggregate economy due to its growing importance as an input in determining output as well as a final good consumption.

The unidirectional causal relationship from economic growth to energy consumption was found in Pakistan in a study by Aqeel and Butt (2001) on energy consumption, economic growth and employment such that economic growth caused total energy consumption. It is also argued that, “productivity is closely related with direct and indirect use of energy as an input”. Mushtaq et al (2008) referred the level of energy consumption as among the indicators of development in any economy since more use of energy, attention being paid on commercial energy, means there is growing industrialization which in turn is translated in more output and more use of modern energy by the household suggests reduction in energy poverty.

The study by Mushtaq (2008) found a unidirectional causality for GDP and oil consumption, electricity and GDP and a neutral impact for gas and GDP. Therefore, energy growth and GDP are highly correlated in a way that increase in GDP is invariably accompanied by increases in energy consumption, and some facts shows that energy consumption raises more rapidly in countries with most rapid economic growth, a study by Dunkerley (1982) evidently supports this.

Kraft and Kraft (1978) suggestive results shows a unidirectional causality in USA from energy consumption to GNP. Errol and Yu (1987) studied the trend in developed industrialized countries and found a unidirectional causality from energy to income in West Germany and a bi-directional causality in Italy and Japan with neutral results for United Kingdom and Canada as cited by Griffin and Gregory (1976).

Also energy consumption and economic growth are also linked by prices of energy, although in theory consumption is directly linked with level of income rather than prices. In support of the above Sterner (1989) studied on energy use in Mexican manufacturing concentrating on factor demand and their substitutability. It found that there is a strong increase in energy use due to falling price of this factor, the simulated results suggest that maintaining relative price between energy and other factors holding energy price below world price during 1970's would have reduced energy use by around 20% in 1981 which would have avoided energy intensity. This suggests that energy price is important factor in determining amount of energy consumed.

Other energy related issues

Energy consumption seems to differ with regions and level of economic activities and the composition of economic activities. The former SADCC region that included Tanzania back is said to consume a small amount of energy in world standards on per-capita basis, in 1985 the region per capita estimate was roughly 850 (kg) coal equivalent which is even lower that per capita consumption of a single economy like Sweden that was estimated to consume about 45000 kg of coal equivalents[3]. So if energy is a driver of economic activities then this region has to rethink on the trends and type of energy consumption that is efficient and productive since the region is largely predominated by traditional source of energy that takes a big share of the total primary energy.

[3] Beijer Institute (1985)

Energy use, industrialization and urbanization; the three have been so much related however energy consumption and level of industrialization is known to be associated in a significant way. The focus is on urbanization on how it changes energy demand patterns in an economy, in simple terms urbanization simply shifts economic activities that were conducted at home with insignificant or no energy use to other economic players or producers that use more significant share of energy in the process[4]. Therefore, in determining level of energy consumption one should consider urbanization as one of the factors since urbanization is associated with industrialization, use of transportation that is within the urban area and also food transportation from rural areas to consumers in urban, all these pushes on the demand for more energy use.

Also, (Jones, 1989) argues that urbanization is greatly associated with a shift from traditional source to modern energy sources mostly attributed by high densities in urban areas. The study on 59 developing countries had a promising result that elasticity of energy consumption to urbanization ranged between 0.35 and 0.48.

The results significantly suggest that, urbanization plays a role in influencing energy consumption trends. The argument put forward by Riaz and Stern (1980) from empirical result is that at an early stage of growth a country would rely much on non-commercial hence subsequent process of industrialization and urbanization are highly energy intensive thus will push demand for more modern energy. Supportively, countries like Kenya, Ivory Coast and Zimbabwe that are Low energy-High development countries have significantly continuing growing despite low energy resources, hence these economies continued importing more oil to meet energy demands over the year that is pushed up by high growth, urbanization, good transport and growing industrial sector[5].

[4] Jones (1989)
[5] Johnson and Wilson (1982)

2.4 OVERVIEW OF THE LITERATURE

Generally most of the literature focuses on the relationship between energy consumption and economic growth of which shows no consistency in their results on the nature of relationship. Some studies found uni-directional causality relationship either moving from energy consumption to growth or growth to energy consumption. While others found bi-directional and other with no causality, hence empirical evidence of this relationship is unclear.

Also some studies focused on the degree of substitutability between energy and other factor inputs and it is evidently substitution exist in the long run rather than in the short run. The empirical evidence suggest that the long run substitutability is due to movements in energy prices takes long to be felt in the economy in affecting levels of output as well as price elasticity of energy demand seem to be more in elastic in the short run than in the long run hence allowing for substitution in the long run.

All in all, most studies shows there is a link between energy consumption and economic growth even though it is not uniform.

CHAPTER THREE

3.0 THEORETICAL FRAMEWORK

This chapter discusses some of the models developed to link the relationships between energy consumption and aggregate output.

3.1 ENERGY DEMAND MODELS

A static model of representative firm

This is a short run model of energy demand for both a firm and household however, the discussion will be confined to a firm's problem. A firm problem is generally considered as profit maximization for a given level of output; since energy is treated as an input therefore the problem of the firm is cost minimization to maintain same level of output. The firm demand for energy is given as a function of its output, prices of all inputs with energy inclusive.

A firm seeks to minimize cost for a given level of output, such that output (Q) is a function of capital (K), labor (L), energy (E) and materials (M):

$$Q = f(K, L, E, M)$$

Whereas costs are sum of payments to the factors of production;

$$C = rK + wL + P_E\,E + P_M M$$

Where *r* is rent payment to capital, *w* is wage to labor, P_E is a price of energy and P_M is the price of materials inputs. So a firm problem is:

$$\underset{K,L,E,M}{\text{Min}}\ C$$

Subject to; $$\bar{Q} = f(K, L, E, M);$$

$$C = rK + wL + P_E\, E + P_M M$$

However, the total cost of capital incorporates energy utilization cost$P_E({}^{u}/_{\varepsilon})$ then, the equation for energy use above enters the constraint hence the firm problem can be restated as:

$$\min_{K,L,E,M} \left(r + P_E \frac{u}{\varepsilon}\right) K + wL + P_M M + \varphi\varepsilon + \gamma[\bar{Q} - f\left(K, L, \frac{u}{\varepsilon} K, M\right)]$$

Where φ is a cost of efficiency improvements, therefore the first order condition for the solution of minimization problem is that firm will choose input *K, L, E, M* and ε (efficiency of capital) and capital utilization rate *u.* In general form it is given as:

$$E^* = E(\bar{Q}, r, w, P_E, P_M)$$

However, in the short run firms can only adjust capital utilization rate of deployed capital when capital and technology are fixed. Thus an expression for a firms short run demand for energy is given as;

$$E^{*sr} = E(\bar{Q}, w, P_E, P_M, \bar{K}, \bar{\varepsilon})$$

The static model however ignores the intertemporal choices aspects of the choices that an energy consumer faces when choosing type of capital, utilization rate of capital and efficiency of capital. The model treats long and short run responses as equivalent such that it does not incorporate size and characteristics of energy-using capital stock.

Dynamic models of the household

These models considers the intertemporal choices that a consumer, or firm must make when choosing their optimal objective function. The model captures the three simultaneous decisions to consume energy, which is decision to purchase and maintain energy-using capital equipment; of which the latter is an investment problem.

A household problem is a utility maximization of the representative consumer, and energy is consumed in proportional to the services it renders hence utility of a consumer is affected by energy demand. Therefore, consumers seek to maximize discounted present value of lifetime utility.

$$\sum_{t=0}^{T} \beta^t U(C_t, E_t); t = time$$

Subjected to the constraint that purchases of energy *E*, other consumption goods C_t, investment good I_t, capital stock K_t and savings S_t in each period cannot exceed this period's income *Y* plus the returns on the last period savings $(1+r)S_{t-1}$. Depreciation rate of capital is δ, savings earn a rate of return *r*, and the discount rate is such that$0 < \beta < 1$. Therefore, the consumer's problem is therefore formulated as:

$$\max_{C,E,S} \sum_{t=0}^{T} \beta^t U(C_t, E_t)$$

Subject to:

$$P_c C_t + P_E E_t + P_K I_t + S_t \leq Y_t + (1+r)S_{t-1};$$

$$E_t = \frac{u_t}{\varepsilon_t} K_t;$$

$$I_t = K_t - (1-\delta)K_{t-1};$$

$$C_t, u_t, K_t \geq 0 \ t = 1, \ldots\ldots, T,$$

Note that the above equation is enters the consumer's problem through a second constraint that show how the relationship between energy and capital is accounted for.

Substituting the above constraint into the utility function, and the first-order condition for the maximum for the consumer's problem is;

$$U_K \frac{u^*}{\varepsilon_t} = U_Z \left[P_{E,t} \frac{u^*}{\varepsilon_t} + P_{K,t} - P_{K,t-1} \left(\frac{1-\delta}{1+r}\right)\right],$$

Asterisk denotes optimal values; the consumer will allocate income among purchases of energy, capital, savings and all other goods such that the marginal value of the energy services accrued from capital stock is equal to the marginal value of consumption of all other goods. However, the consumer is interested in energy services then the decision is on the condition that there is energy cost of capital utilization. Therefore, the term in the brackets is the user cost capital defined as;

$$\mu_{K,t} = P_{E,t} \frac{u^*}{\varepsilon_t} + +P_{K,t} - P_{K,t-1} \left(\frac{1-\delta}{1+r}\right),$$

So $\mu_{K,}$ is the user cost of capital stock and the first term $P_{E,t} (\frac{u^*}{\varepsilon_t})$ indicates consumer choice of the user cost such that capital utilization is a choice variable. Thus the whole set of first-order condition for this consumer's problem has a system of simultaneous equations that can be solved for each choice variable. Then, after we obtain the solution for K_t^* and u_t^* for a given$\varepsilon_{t,}$ then solution for energy consumption can be obtained using the energy use expression and the optimal level of energy demand is derived from optimal capital utilization rate, optimal size of the capital stock and efficiency. Energy demand is a function of user cost of capital, capital stocks and capacity utilization. Generally, user cost of capital is a function of energy price, energy efficiency, and the rental price of capital. Whereas, capital stocks are a function of the rental price of capital and income and capacity utilization is a function of energy price and income. Then, the general function of energy demand can be expressed as;

$$E_t^* = E(Y_t, P_{Z,t}, P_{E,t}, P_{R,t}, \varepsilon)$$

Formulations of energy demand have also been incorporated in models designed to provide representations of the interaction between energy and the economy and for policy analysis. There two ways of presenting the production-side modeling one is “bottom-up” approach which is outside the scope of this study and will not be discussed. The other one is the "top-down" approach that will be discussed shortly treats energy as a factor of production within a representation of output production. This approach was treats energy (*E*) as an input that is combined with capital (*K*), labour (*L*) and materials (*M*) to produce a level of output of a sector in an economy. A study by Hudson and Jorgenson (1974) used the same approach. The standard approach represented this relationship as:

$$y = g(K, L, E, M)$$

Where y is a measure of real output and *g(.)* is a functional form of production, however this kind of specification-single equation-modeling like Cobb-Douglas and CES forms impose restrictions on the elasticities of substitution between inputs. These restrictions were relaxed by the development of new models that allowed flexible functional form like generalized Leontief (Diewert, 1971) and translog (Christensen et al, 1973) production functions. Scholars that followed this approach of including energy as input are for example; (Griffin & Gregory, 1976), (Blitzer, 1986), (Rahman, 1982) and (Lindenberger & Kummel, 2002). However, in production-side modeling there is another direction that restricts substitution possibilities across factors of production. Especially between energy and capital, such that energy and capital are grouped as a bundle within production function as:

$$y = f[(K, E), L, M]$$

Therefore, capital and energy are substitutes within bundle and complements within the whole representation.

However, today many macroeconometric models the world over incorporate a KLEM-type of approach to modeling aggregate or sectoral production (Evans and Hunt, 2009).

There some studies that modeled the interaction of the energy sector and the macro economy for developing countries, therefore such literature are reviewed to provide an insight on how such model can be useful for this study since their specifications fits the developing economies peculiarities. A model by (Rahman, 1982) was developed to test energy-economy interaction in oil importing developing countries and tested using data from India. The model treats output (*Q*) as a function of capacity utilization (*J*), lagged capital stock (K_{t-1}) and energy consumption (*E*)

$$Q = h(J.K, E)$$

Capacity utilization was suggested by Solow (1957) that it is a utilized capital that enters the production function; it is a function of public investment expenditure (GI), energy imports(ME), non-energy intermediate goods imports (MENI), rainfall index (R) and price level (P)

$$J = j(GI, ME, MNEI, P, R)$$

Energy consumption is modeled as a function of dynamic response to price and income changes, and since long run price elasticity is different for its short run value because price adjustments takes longer to be felt then past prices also affect current consumption of energy.

Since in most developing countries, the public sector plays an important role in allocating available supplies to end uses of energy, therefore instead of relying on translog cost function a simple model of energy consumption behavior is used (Rahman, 1982).

$$E_t = b_1(P_t^{\alpha 0})^{1-\gamma}. Q^{\beta 0}. E_{t-1}^{\gamma}.$$

Hence, energy consumption is a function of adjusted price, income and past energy consumption trends.

Another model by Shin (1986) developed a model for Korean economy to study energy-economy structural links on the Effects of Oil prices on Korean economy that captured the effect of oil prices to the trade balance thus included a part of the current account.

Output is modeled as a function of lagged capital (*K*), labor (*L*) and energy (*E*);

$$Q = \alpha_0. K_{t-1}^{\alpha 2}. L^{\alpha 3}. E^{\alpha 4}$$

Energy consumption was also modeled taking into consideration the developing economies feature of public sector playing part in allocating supplies of end use energy. Hence, the model used a traditional way of modeling energy consumption as a function of lagged energy consumption, energy price and income.

$$E = \lambda_o . E_{t-1}^{\lambda 1} . [\frac{EP}{P} * 100]^{\lambda 2} . Q^{\lambda 3}$$

The price variable is a weighted-index of energy price over domestic price.

The current account section was represented with the trade balance so that the model would determine the effects of oil prices on the balance of trade of the economy, the export and import functions where specified. Export earnings (*X*) is a function of income measured as real GDP and export price index (*XP*), where as import is a function of income (Real GDP) and oil import price (*OMP*). The export function given as;

$$X = \gamma_0 . Q^{\gamma 1} . [XP]^{\gamma 2}$$

And the import function given as;

$$M = \gamma_0 . Q^{\gamma 1} . [OMP]^{\gamma 2}$$

The model was developed to capture the effects of energy price on the Korean economy focusing on the aggregate output, price level and the balance of trade. Oil price affects trade balance in a way that oil prices increases the value of imports over exports hence adding to a trade balance deficit.

3.2 The Production function

The output function adopted is a Neo-classical growth model developed by Solow (1957) without technical progress assumption. The aggregate production function is given as;

$Q_t = q(K_t, L_t)$……………………………………………………………………………..1

Where, Q is output, K_t is Capital stock, L_t is Labour force

The traditional production function also included materials as an input, in addition to labour and capital but this study ignores raw materials and follows the Solow's specification to adopt the above function.

The Neo-classical assumptions on the production function are;

a. Positive and diminishing marginal returns of factor inputs :

Such that;

$MPK_t = \frac{\partial Q_t}{\partial K_t} > 0$, $\frac{\partial MPK_t}{\partial K_t} = \frac{\partial^2 Q_t}{\partial K_t^2} < 0$ and;

$$MPL_t = \frac{\partial Q_t}{\partial L_t} > 0, \quad \frac{\partial MPL_t}{\partial L_t} = \frac{\partial^2 Q_t}{\partial L_t^2} < 0$$

b. Constant returns to scale with respect to capital and labour;

$q(\alpha K_t, \alpha L_t) = \alpha q(K_t, L_t)$, where; $\alpha > 0$.

Ever since, this growth model was used to explain growth dynamics in several economies though with other modifications from different scholars. However, following oil crisis of 1973-74 and that of 1978-79 several scholars started paying attention to energy as an input to the economy and modeled the growth with energy included as factor input. For instance, (Griffin & Gregory, 1976), (Blitzer, 1986), (Rahman, 1982) and (Lindenberger & Kummel, 2002). Their modeling follows the neo-classical modeling as;

$Q = q(K, E, L)$……………………………………………………………………………..2

Where; *Q, K and L as defined earlier E is energy*.

Therefore, such a modeling follows the argument that energy is a substitute to other factors of production rather than a complement, a specification that this study also adopts. The functional form adopted is a Cobb-Douglas function type since its simplicity in computation and the assumption of constant returns to scale in production is evidently favored in many developing countries[6], as the elasticity of substitution is a unity. However, there is an argument that Cobb-Douglas production function is a C-D in two inputs but it is no longer a C-D in three inputs since capital-labor substitution is less than one[7].

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[6] Rahman(1982)
[7] Griffin and Gregory (1976)

3.3 Energy Demand

From micro economic theory demand of a normal good is a function of price and other factors like income:

$E = e(P, Y)$……………………………………………………………………………………3

A study by (Griffin & Schulman, 2005) argues that from micro economic theory per-capita energy consumption depends on real income per capita and a distributed lag on past real prices of energy and a technical index of energy efficiency.

$\frac{Q}{N} = f[\frac{I}{N}, \mu(L)P_t, Z_t]$ ……………………………………………………………………………4

Where;

Q/N =per capita energy consumption

I/N =real income per capita

$\mu(L)P_t$ =distributed lags on past real prices of energy

Z_t =Technical index of energy efficiency

Energy consumption is modeled as a function of dynamic response to price and income changes, and long run price elasticity is different from its short run value since price adjustments takes longer to be felt then past prices also affect current consumption of energy unlike the income effect[8].

Therefore, following such arguments the following energy model is suggested.

$E_t = b_1(P_t^{\alpha 0})^{1-\gamma} . Q^{\beta 0} . E_{t-1}^{\gamma} . e$…………………………………………………………………..5

Where;

E_t=Current consumption of energy

$(P_{t-1}^{\alpha 0})^{1-\gamma}$ *=lagged past prices*

E_{t-1}^{γ} *=Past consumption of energy*

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[8] Baumol and Makower(1950)

Therefore, it is generally clear that energy as any other goods is a function of its own price and income level.

3.4 Empirical model

The model is an aggregate production function, where capital (K), labor (L) and energy (E) are the inputs. Capital is lagged because it is the stock of capital that enters production function and energy is measured as primary energy consumption. Primary energy depends on gross domestic product and responds to prices. Also, rate of urbanization affects energy consumption since urbanization is associated with industrialization, more use of modern energy-using appliances, transportation of goods and services. Therefore, urbanization is associated with more use of energy in its growth.

The variables used in the model can be defined as;

1. *Q= Real GDP*
2. *E= Aggregate energy consumption(Primary energy)*
3. *K= Capital (End period capital stock)*
4. *L= Labor (Total labor force)*
5. *EPI= Energy price Index (World Oil Price Index)*
6. *URB= Urbanization*
7. E_{t-1}*=lagged energy consumption*

The study will use a model which was developed and tested by Rahman (1982) on Indian data and some modifications derived from Shin Jeong-Shik (1986) model of Korean economy, the choice of model is based on data availability and modifications of some assumptions made that would make the model suits a low-income developing country like Tanzania.

The Model

$Q = q(K, L, E)$………………………………………………………………………………………6

where Q=Output (real GDP)

K=Capital

L=Labour

E=Energy

The macro-economy equation used is an aggregate production function that comprises of Q, K, L and E that output, capital, labour and energy respectively. The model assumes a groupwise separability and (1.) can be expressed as;

$f(g(K,E),L)$...6.a

Such that *f* and g general production function, K and E are assumed to be substitute in g, while g and L are substitute in *f.* If *f* is assumed to be of Leontief-Cassell fixed coefficient type , it may be expressed as:

$Q = min(g/\theta\,, L/\gamma)$...6.b

In a labour surplus economy, $\theta < \gamma$ and therefore the above can be expressed as

$Q = h(K,E)$...6.c

Rahman specification assumed growth of aggregate output is constrained by K and E, rather than L an assumption usually made in case of labour surplus economies where there is acute capital scarcity. Inclusion of labour as one of the inputs as opposed to Rahman (1982) model is a modification made regarding a model used by Shin (1986) that used labour as an input. This is so since such an assumption cannot be validated in Tanzanian economy. The model by Rahman (1982) also took into consideration adjustments in capital stock with capacity utilization as suggested by Solow (1957) that it is utilized capital stock, rather than capital itself, which belongs in the production function. However, in this equation we ignore capacity utilization due to insufficient data to compute such an increment. Therefore, the equation of estimation parameters can be specified as;

$Q = \beta_0 * {K_{t-1}}^{\beta 1} * L^{\beta 2} * E^{\beta 3} * e^{U1}$..6.d

Energy consumption equation

$E = e(Q, E_{t-1}, URB, EPI)$……………………………………………………………………………7

The consumption equation uses a simpler model that considers dynamic responses to prices and income changes. The use of a simple model is attributed by the fact that in most developing economies, the public sector plays a dominant role in allocating supplies to end uses of energy, instead of using translog cost functions or multinomial logit models for fuel choices[9]. Also such models require more information on cost function of the economy. A specified equation is;

$E = \beta_0 * Q^{\beta 1} * E_{t-1}^{\beta_2} * URB^{\beta 3} * EPI^{\beta 4} * e^{U2}$……………………………………………………7.a

The functional form of the model

All the estimation equations are multiplicative in form, adopting the Cobb-Douglas functional form of elasticity. Therefore assuming that the model takes a linear form in log, this form of function is adopted in order to get the rate of change among variables as it captures direct response among variables in elasticity form. Therefore, allows overtime dynamic changes among variables.

The eventual econometric estimation model can be written as:

$$lnGDP = \beta_0 + \beta_1 lnK_{t-1} + \beta_2 lnLAB + \beta_3 lnE + U_1 \qquad .10$$

$$lnE = \beta_0 + \beta_1 lnGDP + \beta_2 lnE_{t-1} + \beta_3 lnURB + \beta_4 lnEPI + U_2 \qquad .11$$

3.6 DATA, ESTIMATION METHOD AND TESTS

The study under consideration uses the time series secondary data for twenty five years from 1985 to 2010. The data is sourced from various institutional databases that include, U.S Energy Information Administration, World Bank Database, East African Community STATISTICS PORTAL.

This study used the two sets of equations that are simultaneous and this type of equation requires a convenient way of estimation apart from ordinary least squares. For a simultaneous system of equation there several ways to estimate of parameters, the methods are Instrumental Variable Method, Indirect

9 Rahman (1982)

Least Squares (ILS), Two-Stage Least Squares (2SLS) or single-equation method or limited information methods, Three Stage Least Squares-3SLS (system method of estimation or full-information methods. Therefore, to take care of the problem of endogeneity the study uses the Two-Stage Least Squares that uses the predicted values of the endogenous explanatory variable to obtain consistent estimates. The predicted valued are obtained by running a regression and get the predicted values of the dependent variables. Then the predicted values are used as independent variables in respective equations and then regression is run again when independent variables are replaced by predicted values.   This method is widely applied for system of equation with more than two equations since it does not require information of other equations. This method estimates each single equation independently only using information about the coefficients restriction of the particular equation.[10]

3.6.2 STATIONARITY TEST

A unit root test will be conducted so as to establish stationarity between two series so as to avoid a problem of spurious regression. This problem exists when regressing two uncorrelated series and their relationship in a regression seem to be statistically significant while the two series are not related. The study uses a standard Augmented Dickey-Fuller test for stationary. A test is given as;

$$y_t = \gamma + \delta y_{t-1} + \sum_{j=1}^{k} \theta_j \, \Delta y_{t-1} + e_t$$

3.6.3 GRANGER CAUSALITY TEST

Causality test will be conducted to check for a causal relationship between energy consumption and economic growth, using the Granger causality test.

Granger Causality: Refers to a limited notion of causality where past values of one series *(x_t)* are useful for predicting future values of another series *(y_t)* after past values of y_t have been controlled for.

[10] Maddala, G.S (1992)

The Granger causality test assumes that the information relevant to the prediction of the respective time series variables is contained in the time series data of the variables in question. The test proceeds as follows; consider two time series y_t *and* x_t. The series x_t *Granger cause* y_t if in a regression of y_t on lagged *y's* and lagged *x's* the coefficients of the latter are non-zero.

$$y_t = \sum_{i=1}^{k} \propto y_{t-1} + \sum_{i=1}^{k} \beta_1 x_{t-1} + u_t$$

Then, if $\beta \neq 0$ $(i = 1,2 \ldots \ldots \ldots, k)$, then x_t causes y_t . So the test is based on the following equations;

$$lnGDP_t = \mu_0 + \sum_{i=1}^{k} \propto_i lnGDP_{t-1} + \sum_{j=1}^{k} \beta_j lnE_{t-1} + U_t$$

$$lnE_t = \varphi_0 + \sum_{i=1}^{k} \gamma_i lnE_{t-1} + \sum_{j=1}^{k} \theta_j lnGDP_{t-1} + U_t$$

Where: k is a number of lags, $\mu, \propto, \beta, \varphi, \gamma$ *and* θ are parameters to be estimated.

Unit root test results for a production function equation (10)

Table 1: Stationary test-Augmented Dickey Fuller Test Statistic (ADF) of Production function (GDP, Capital, Labor and Energy)

VARIABLES	Augmented Dickey-Fuller Test (ADF)			**ORDER OF INTEGRATION**
	At levels	At first difference	At second difference	
lnGDP	4.758**	-1.839	-5.314**	I(2)
lnK	-1.085	-4.646**	-7.582**	I(2)
lnLAB	-0.689	-8.577**	-11.377**	I(2)
lnE	-0.700	-6.236**	-10.151**	I(2)

Source: Own computation using STATA

Asterik (*) = Significance at 10% or 0.1

(**) = Significance at 5% or 0.05

(***) = Significance at 1% or 0.01

The Augmented-Dickey fuller test was utilized to test for stationarity of the variables Real GDP, Capital (K), and labor force (LAB) and Energy consumption all in natural log. The ADF-test results are summarized in table 1 above. At levels we fail to reject the null hypothesis that the series contains unit root for all other variables except Real GDP which is stationary as its t-statistics is greater than the critical values at 1%, 5% and 10% of ADF test. Hence we can reject the null hypothesis and the series Real GDP is stationary at levels. The t-statistics for all the variables are less than the critical values of ADF hence they contain unit root. However, at first difference we can reject the null for all other variables but fail to reject null hypothesis for Real GDP that is non-stationary at first difference. Then, the second difference reveal significance results as all the variables are stationary at second difference thus all the series are integrated of order 2 that is; I(2)

Table 2: Stationary test-Augmented Dickey Fuller Test Statistic (ADF) of the energy consumption function (Energy, GDP, Urbanization and Energy price index)

VARIABLES	Augmented Dickey-Fuller Test (ADF)			**ORDER OF INTEGRATION**
	At levels	At first difference	At second difference	
lnE	-0.700	-6.236**	-10.151**	I(2)
lnGDP	4.758**	-1.839	-5.314**	I(2)
lnURB	-4.470**	-10.074**	-11.226**	I(2)
lnEPI	-1.061	-7.247**	-10.197**	I(2)

Source: Own computation using STATA

Asterik (*) = Significance at 10% or 0.1; (**) = Significance at 5%; (***) = Significance at 1% or 0.01

The ADF-test for the second equation is summarized above, results shows we can reject the null hypothesis of unit root for variables Real GDP and urbanization at levels as the two series are stationary. However, at first difference real GDP is non-stationary while we can still reject the existence of unit root in urbanization variable as well as energy price index and energy consumption. Then, at second difference all the variables exhibit stationary series and hence we reject the null hypothesis that series contains unit root. Thus all series are integrated of order 2.

3.7 REGRESSION RESULTS

Table 3: First stage regression results of the production function and energy demand equation

Variable |	Equation1	Equation2
Capital stock |	0.0870319 (0.225)	
Labor |	-0.4283181 (0.311)	
Lagged energy$_{t-1}$ |	-1.057743 (0.000)	0.0154286 (0.000)
Lagged energy$_{t-2}$|	-0.5519913 (0.004)	
Urbanization|		0.1959511 (0.333)
Energy price index|		0.0003533 (0.929)
Real GDP$_{t-1}$|		0.2174168 (0.440)
Real GDP$_{t-2}$|		-0.2300929 (0.224)
Constant |	0.0030038 (0.846)	0.0025299 (0.548)
N |	27	27
r2 |	0.5912	0.0987
r2_a |	0.5169	-0.1159
rmse |	0.0774	0.0167

p-values in parenthesis ( )

Source: Own computation using STATA

In the first stage regression the two periods lagged values of energy and real GDP were used as endogenous regressors of the independent variables energy consumption and real GDP consecutively. This is because in time series data past values have high correlation with the current value of a variable in question. The lagged energy consumption of the two periods is both significant at 5% in the production function. They also have a negative sign implying that past energy consumption has an opposite effect on the current energy consumption. The value of R^2 is 0.59 which is a good since the effect on dependent variable is explained the model with a good percentage.

The first stage regression shows the determinants of GDP and demand for energy. The first equation represents determinants of real GDP, such that the coefficient for capital stock is 0.0870319 suggesting a positive relationship between growths in stock and level of GDP growth. Labor and lagged energy consumption both had a negative sign of -0.428318 and -1.05774 respectively, implying that they influence real GDP negatively.

The second equation that captures the energy consumption results shows that previous period energy consumption is significant at 10% and increases the current consumption of energy by 1.5%. However, at 5% the p-value could not be used to conclude that it is significant but the t-statistic was slightly close to t-statistic of 1.19 hence suggesting the estimate was significant at default level of significance.

The second equation captures the demand for energy and the results suggested that past energy consumption influences positively the current energy demand as the coefficient for lagged energy is 0.0154286. Other factors that influence demand for energy are urbanization and past period income (lagged GDP) with positive effects on demand for energy, the coefficient for urbanization is 0.19591 while the coefficient for real GDP is 0.21741.

Table 4: Second stage regression results of the production and energy demand equations

Variable |	Equation1	Equation2
Capital stock |	0.03046683	
	(0.002)	
Labor |	-0.16719354	
	(0.167)	
Energy |	0.04527315	
	(0.013)	
Real GDP |		5.294566
		(0.172)
Lagged energy |		0.44626337
		(0.000)
Urbanization |		-0.35893632
		(0.678)
Energy price index |		-0.01228513
		(0.529)
Constant |	0.00240445	-0.01179966
	(0.306)	(0.548)
N |	27	27
r2 |	0.40515678	0.48193244
r2_a |	0.32756853	0.38773833
rmse |	0.01195732	0.07860413

p-values in parenthesis ( )

Source: Own computation using STATA

From the regression table above, the coefficient energy and capital are statistically significant at both 5% and 10% level of significance respectively. Labor coefficient is not statistically significant and has a negative value that implies labor force leads to a drop in aggregate output which is contrary to theory; however the overall significance test shows that all the coefficients are significant with F-statistic probability of less than 0.05. The production function has a R^2 of 40% and adjusted R^2 of 32.7%. The energy consumption equation estimates shows that lagged energy consumption is statistically significant at 1%. However, the coefficient of urbanization and real GDP are not significant as well as the sign of urbanization coefficient is negative which is contrary to expected sign. The coefficient of Real GDP is high such that a 1% increase in income leas to increase in energy consumption by 5.2%

The coefficient of energy input shows the expected sign as it contributes to economic growth as several literatures have empirically proved, a 1% increase in energy consumption leads to an increase in economic growth or output (real GDP) by about 0.0452 per cent. However, the sign of capital is positive in line with the theory as it contributes to growth of output in an economy. In the process to establish the effect of energy price changes into real GDP the study use the estimated equation for economic growth and energy consumption. By taking the differential of (10) with respect to energy (E);

$\frac{\partial lnGDP}{\partial E}$, and of equation (11) $\frac{\partial E}{\partial EPI}$. Using the chain rule to get changes of real GDP with respect to changes in energy prices, we have:

$$\frac{\partial lnGDP}{\partial EPI} = \frac{\partial lnGDP}{\partial E} * \frac{\partial E}{\partial EPI}$$

The differential coefficients are 0.04527 and -0.01228513 , from computation the obtained value is -5.56146477*10^{-04}, and that is 0.05% decrease in real GDP due to an increase of 1% in energy price worldwide.

Table 5: ENERGY CONSUMPTION-ECONOMIC GROWTH GRANGER-CAUSALITY TEST RESULTS

Dependent Variable: Real GDP				
Excluded	**Chi-sq**	**Df**	**Probability(Prob>Chi2)**	
Energy Consumption	**0.84482**	**2**	**0.655**	

Dependent Variable: **Energy Consumption**				
Excluded	**Chi-sq**	**Df**	**Probability(Prob>Chi2)**	
Real GDP	**7.427**	**2**	**0.024**	

Source: Own computation using STATA

Granger-causality test parameters

$$\ln GDP_t = -0.1669183 + \sum_{i=1}^{1} 1.7063 \ \ln GDP_{t-1} - \sum_{i=1}^{1} 0.00955 \ \ln E_{t-1} + U_t$$

$$\ln E_t = -1.01688 + \sum_{i=1}^{1} 0.59821 \ln E_{t-1} + \sum_{i=1}^{1} 0.75286 \ \ln GDP_{t-1} + U_t$$

The parameters in granger-causality test equations are all non-zero, which implies that from the simple rule there is a bidirectional causality running from energy consumption to real GDP. There is as well as a feedback effect of real GDP granger causing energy consumption. However, the granger causality test statistic is the Chi-square probability; such that the null hypothesis is energy consumption does not granger cause real GDP. Hence, in the first granger equation with p-value 0.655 which is not less than 5% or 0.05 we fail to reject the null and conclude that energy consumption does not granger cause real GDP. However, in testing the hypothesis real GDP has a feedback effect on energy consumption, the p-values allows to reject the null that real GDP does not granger cause energy consumption. Thus, we conclude that there is causation running from real GDP to energy consumption. Therefore, the results support the conservation hypothesis of energy-economic growth relationship.

CHAPTER FOUR

CONCLUSION AND POLICY RECOMMENDATIONS

The results of this model just gives a simple picture of how energy consumption is related to economic growth and further extension of the effects of price on output and direction of causality between energy consumption and economic growth.

The model achieved to explain the objectives of the study that linked energy consumption and economic growth, as the study results supports the conservation hypothesis of energy use since increase in income leads to more consumption of energy. The results suggest that there is unidirectional causality running from income to energy consumption. This energy-income relationship has been discussed in many economic literatures, and its relationship has been observed to be that an increase in GDP will lead to a increase in energy demand. However, a decrease in GDP may not necessarily have the same and opposite effects on energy demand (Evans and Hunt, 2009).

The model results also suggest that an increase in energy price has a negative impact on the aggregate output by reducing a fraction of output since increase in price is additional cost to producers or firms.

The study supports a conservation hypothesis of energy-economic growth theory which advocates that policies that focus on reduction in energy consumption might have little or no adverse effects on economic growth. Therefore, policy makers may develop policies that aim at conserving energy for future generation without affecting current economic growth and output. However, this suggest that as the economy grow in the future there will be more use of energy, hence energy conservation policies would be the best in an economy since in the future expectations of high energy use are too high. This is the result of growth of an economy in the long run that increases energy intensity.

The study succeeded in developing a rough picture of the relationship between energy consumption and economic growth; however there are limitations faced in the whole process of the study. One of the limitation is the literature relevant to the country in study are not adequate since very few studies were done with regard to this study case. The other limitation is the data aggregation since the study focus on macro variables of the whole economy then there is much of data aggregation. This hinders the possibility of capturing relevant effects of individual or separate energy use of individual energy source.

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APPENDICIES

Data for the energy demand function

Year	Energy Consumption (TOE)	Real GDP (Millions)	Urbanization growth (annual %)	Energy Price Index
1980	0.052725836	4494.91	7.921409981	43.68
1981	0.057337359	4549.41	6.130858147	51.64
1982	0.054853689	4551.92	6.051467901	49.55
1983	0.049436535	4511.68	5.965081471	53.54
1984	0.051187654	4532.64	5.86813217	50.54
1985	0.050575808	4712.91	5.768206404	50.27
1986	0.056249242	4977.86	5.544813585	28.95
1987	0.050441494	5288.08	5.45004293	31.44
1988	0.051901306	5599.98	5.402922034	27.43
1989	0.051940869	5811.17	5.413518763	36.23
1990	0.055369272	6220.38	5.452046225	49.86
1991	0.049176476	6349.36	5.033045422	32.95
1992	0.049882568	6386.33	5.069104265	33.57
1993	0.049476351	6463.37	5.012299488	25.02
1994	0.044130008	6564.65	4.843162012	30.26
1995	0.042369817	6799.04	4.609539702	33.62
1996	0.04363408	7108.02	4.469467821	44.05
1997	0.039781316	7358.6	4.271187863	32.33
1998	0.044311949	7631.49	4.13755513	19.54
1999	0.045566888	7900.88	4.087766047	46.91
2000	0.044185951	8290.69	4.097242261	47.27
2001	0.050570768	8787.95	4.22338072	34.74
2002	0.053833106	9417.48	4.23437797	52.27
2003	0.052927181	10065.99	4.252206328	56.14
2004	0.055062089	10853.99	4.272401708	73.02
2005	0.059190033	11653.91	4.294538544	105.83
2006	0.059512587	12474.62	4.485482219	114.52
2007	0.067696907	13341.54	4.50846479	168.05
2008	0.070338579	14315.13	4.53292546	77.71
2009	0.072402172	15274.82	4.557846972	140.86
2010	0.068373515	16274.93	4.580937148	169.33

Source:U.S Energy Information Administration, E.A.C Statistical Portal

Data for the economic growth function

Year	Real GDP (Millions)	Capital Stock	Labor force	Energy Consumption (TOE)
1980	4494.91	8630000000	8901621	0.052725836
1981	4549.41	10624000000	9187903	0.057337359
1982	4551.92	14622000000	9489011	0.054853689
1983	4511.68	11903000000	9203738	0.049436535
1984	4532.64	15060000000	10126590	0.051187654
1985	4712.91	18966000000	10452910	0.050575808
1986	4977.86	35345000000	10783400	0.056249242
1987	5288.08	71059000000	11120940	0.050441494
1988	5599.98	81452000000	11473550	0.051901306
1989	5811.17	112207000000	11853500	0.051940869
1990	6220.38	286073000000	12245222.18	0.055369272
1991	6349.36	373042000000	12684902.16	0.049176476
1992	6386.33	433547000000	13152609.76	0.049882568
1993	6463.37	566660000000	13620328.12	0.049476351
1994	6564.65	597751000000	14100490.64	0.044130008
1995	6799.04	626845000000	14565936.69	0.042369817
1996	7108.02	700803000000	15012344.76	0.04363408
1997	7358.6	1248860000000	15426872.78	0.039781316
1998	7631.49	1266790000000	15851108.03	0.044311949
1999	7900.88	1370940000000	16279569.78	0.045566888
2000	8290.69	1587740000000	16702198.1	0.044185951
2001	8787.95	1795410000000	17158556.41	0.050570768
2002	9417.48	2320540000000	17688689.96	0.053833106
2003	10065.99	3153370000000	18216813.56	0.052927181
2004	10853.99	4001090000000	18741502.92	0.055062089
2005	11653.91	4957780000000	19283189.39	0.059190033
2006	12474.62	6209740000000	19843549.09	0.059512587
2007	13341.54	7381260000000	20379271.32	0.067696907
2008	14315.13	8173220000000	20935012.52	0.070338579
2009	15274.82	10342500000000	21536457.19	0.072402172
2010	16274.93	13762100000000	22137648.46	0.068373515

Source: World Bank Database (Development Indicators)