ADDIS ABABA UNIVERSITY
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ENERGY AND ECONOMIC GROWTH IN ETHIOPIA: GRANGER CAUSALITY APPROACH

By:

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Approved by **Signature**

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Acronym

EEA	Economic Association
ECA	Economic Commission for Africa
ECM	Error Correction Model
VECM	Vector Error Correction Model
CONESA	Common Market for Eastern and Southern Africa
ADO	Automotive Diesel Oil
LFO	Light Fuel oil
HFO	Heavy fuel Oil
Ktoe	Kilo tone of oil equivalent
GW	Gigga watt hour
OECD	Organization for Economic Cooperation and Development
IEA	International Energy Agency
GTP	Growth and Transformation Plan
GDP	Gross Domestic Product
MoWE	Ministry of Water and Energy
VAR	Vector Autoregressive
PIM	Perpetual Inventory Method
UNDP	United Nations Development Program

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Abstract

The aim of this paper is to re-examine the causal relationship between energy consumption and economic growth in Ethiopia using annual data from 1981 to 2006, in a multivariate framework by including labor and capital as additional variables. We apply the Granger causality tei, variance decomposition analysis and Generalised impulse reionse analysis in linear multivariate models to evaluate how important is the causal impact of energy consumption on economic growth relative to labor and capital. The results give the evidence of causality running from economic growth to energy consumption. The variance decomposition analysis reveals that energy was no more than a minor contributing factor to output growth and certainly not the most imporiant one when compared to capital and labori Capital and labor are the most important factors in output growth in Ethiopia.

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Chapter One

1. Introduction

1.1. Background of the study

Arguably, energy plays a vital role in economic and social development. The role of energy in economic growth has long been a controversial topic in economics literature. As a result, the ongoing debate among energy economists about the relationship between energy use and output growth led to the emergence of two opposite views. One point of view suggests that energy is the prime source of value because other factors of production such as labour and capital cannot do without energy. According to this argument, energy use is expected to be a limiting factor to economic growth. The other point of view suggests that energy is neutral to growth. This is what became to be known in the literature as the 'neutrality hypotheses'. The main reason for the neutral impact of energy on growth is that the cost of energy is very small as a proportion of GDP and, thus, it is not likely to have a significant impact on output growth. It has also been argued that the possible impact of energy use on growth will depend on the structure of the economy and the stage of economic growth of the country concerned (Ghali and El-Sakka, 2009).

Theoretical disagreement on the role of energy is matched by mixed empirical evidence. That is, whether economic growth leads to energy consumption or that energy consumption is the engine of economic growth. The direction of causality has significant policy implications. Empirically it has been tried to find the direction of causality between energy consumption and economic activities for the developing as well as for the developed countries employing the Granger or Sims techniques.

Like other developing countries Ethiopia is energy using growing economy, with energy production of 14.1 and 20.9 total million metric tons of oil equivalent in 1990 and 2007 respectively. In terms of energy use it had 14.9 and 22.8 total million metric tons of oil equivalent for the same years under consideration and with the annual average growth of 2.6%. The biomass energy use is predominant which accounts 93.9% and 90.2% for the year 1990 and 2007 respectively and the balance goes to the modern energy. This shows that there is a gradual shift from traditional to modern energy sources (WDI, 2010). Moreover, it is believed that the modern energy penetration rate has increased as of 2010 because of the commissioning of the three hydro power plants in the country. Ethiopia is non-oil producing countries and its fossil oil energy needs are met by large quantities of imports.

The preceding facts show the power sector in Ethiopia is underdeveloped and hence energy consumption is very low. As a result Ethiopia is far from having satisfied the current energy demand of its people. Cognizant of this problem and in line with the millennium development goals, Ethiopia is trying to provide energy to its citizens by investing in major modern energy infrastructures in the country. This show that Ethiopia has recognized that accessibility to affordable energy services is a prerequisite to poverty alleviation, and necessary condition for sustainable economic growth. This policy goal implies that increased energy consumption can help achieve social development and enhance economic growth.

Thus to meet its growing needs of energy, Ethiopia faces both energy constraints from the supply side and demand management policies (EEA, 2009). The current concerns about global warming also poses a question about how can economic growths in

Ethiopia, will be reconciled with stabilization in the use of both traditional and fossil fuels. However, for any such policy making it is essential to determine the causal relationship between energy consumption and general economic activities.

It is important, therefore, to ascertain empirically whether there is a causal link between energy consumption and economic growth in Ethiopia. This is particularly true given the current debate about global warming and the need to reduce Greenhouse Gas Emissions by conserving energy consumption, since any constraints put on energy consumption to help reduce emissions will have an effect on growth and development if causality from energy to GDP exists.

1.2. Statement of the problem

Ethiopia has huge potential of modern energy resources; however availability of modern energy per se is not enough for the economic and social problems facing the country. Thus, the supply of modern energy is believed to be a necessary requirement for economic and social development.

The power investment that is currently taking place in Ethiopia is part of the process of the recognition that the quality and quantity of modern power supply can play a pivotal role in the country's social and economic development. This investment process is implicitly based on the assumption that investment in modern energy and the drive towards making the modern energy sector more efficient can promote economic growth.

Although energy use is a reflection of climatic, geographic and economic factors (such as the relative prices of energy), in developing economies growth in energy use is closely related to growth in the modern sectors (industry, motorized transport and urban areas). “There is a strong connection between the energy sector and a national economy. On the one hand, energy demand, supply and pricing have significant impact on socio-economic development and the overall quality of life of the population. On the other hand, the nature of economic structure and the change in that structure, the prevailing macro-economic conditions are key factors of energy demand and supply” (EEA, 2009).

The data compiled by Energy Information Administration for the periods 1980 to 2006 shows that GDP per capita have strong correlation coefficient of 0.6 with energy consumption (EEA, 2009). Although the existence of correlation between the two implies the existence of causality, on the other hand it is source of doubt, on the part of many growth theorists. The fact that economic growth tends to be very closely correlated with energy consumption, does not a priori mean that energy consumption is the cause of the growth. Indeed, most economic models assume the opposite: that economic growth is responsible for increasing energy consumption. It is also conceivable that both consumption and growth are simultaneously caused by some third factor.

With this background, (that is bourgeoning of different school of thought with regard to resource consumption in general and energy consumption in particular) there are numerous researches which have tried to figure out the casual relationship between energy use growth and economic growth.

As it is highlighted in the empirical literature review section of this paper, the results are very mixed with no clear consensus emerging, however. Different results for different countries are not necessarily surprising given the “many institutional, structural, and policy differences” (Masih and Masih, 1997). However, the lack of consensus for particular countries (and countries with similar characteristics and stage of development) is somewhat surprising, which according to Masih and Masih (1997) is primarily due to methodological differences in terms of definition and specifications of variables, the econometric techniques employed, and lag structures chosen.

To avoid such discrepancy, Chontanawat, Hunt, and Pierse (June, 2006) have tried to test whether there is evidence of causality between energy and GDP for 30 OECD countries and 78 non-OECD countries including Ethiopia using same methodology and data set. And in particular the paper tested the hypothesis that the link is strongest for the non-OECD developing countries. For the case of Ethiopia the study shows, Granger causality running from economic growth to energy consumption.

Some of them are also undertaken in Africa and, among them is a study conducted by Yemane Wolde-Rufael. The study tested the causal relationship between energy demand and economic growth in 19 African countries for the period 1971–2001 using a newly developed co-integration test proposed by [Pesaran, M. H., Shin,Y,&Smith, R. (2001). Bounds testing approach to the analysis of level relationships. The empirical evidence shows that there was a long run relationship between the two series for only eight countries and causality for only ten countries.

And for the causal relationship between electricity consumption per capita and real gross domestic product (GDP) per capita for 17 African countries for the period 1971–

2001. The empirical evidence shows that there was a long-run relationship between electricity consumption per capita and real GDP per capita for only 9 countries and Granger causality for only 12 countries. For 6 countries there was a positive uni-directional causality running from real GDP per capita to electricity consumption per capita; an opposite causality for 3 countries and bi-directional causality for the remaining 3 countries.

The results of the early studies that tested for Granger causality using a bivariate model were generally inconclusive and they mostly indicated that causality runs from output to energy. Most economists believe that capital, labor, and technical change play a significant role in determining output. “When there is more than one input both capital and natural resources there are many alternative paths that economic growth can take, determined by both the nature of technology and institutional arrangements. When relevant variables are omitted from the model, there will be no co-integration and a spurious regression will result” (David I. Stern. 2011). To this effect, Stern tested for Granger causality in a multivariate setting using a VAR model of GDP, capital and labor inputs for U.S.A .When the multivariate approach were employed, energy was found to Granger cause GDP.

While there are several studies that have investigated the causal relationship between energy consumption and economic growth using a production function framework for developed and some developing countries. The research about African countries is almost exclusively based on the bivariate causality model with energy consumption used as the sole factor input.

Accordingly, Wolde-Rufael re-examine the causal relationship between energy consumption and economic growth for seventeen African countries in a multivariate framework by including labor and capital as additional variables.

And the most striking result he found from the empirical evidence is that the introduction of both gross capital formation and labor has altered the direction of causality.

The multivariate methodology is important because changes in energy use are frequently countered by the substitution of other factors of production resulting in an insignificant overall impact on output (David I. Stern, 2003). It is against this backdrop that this paper attempts to fill the gap by investigating the inter-temporal causal relationship between energy consumption and economic growth in a production function framework by including labor and capital as intermitting variables. And the reason for inclusion of capital and labour in the production function framework employed in this paper are unlike previous country specific time series studies for African countries where most of these studies were concentrated in a two-variable case, we include capital and labor as additional variables to the energy-growth nexus as energy alone might not be strong enough to spur economic growth. The potential gains to economic growth may depend on the degree to which capital, energy and labor act as complements. Further, we include these two additional variables because exclusion of a relevant variable(s) makes not only the estimates biased as well as inconsistent but also no-causality in a bivariate system can result from neglected variables (Lütkepohl, 1982, as quoted by Wolde Rufael, 2008).

Thus the previous bivariate causality tests between energy consumption and economic growth may be invalid due to the omission of important variables affecting both energy consumption and economic growth. It is possible that the introduction of capital and labor in the causality framework may not only alter the direction of causality but also the magnitude of the estimates (Loizides and Vamvoukas, 2005; Odhiambo, 2008 as cited by Wolde Rufael, 2008). Further, since a four VAR case incorporates more information than the bivariate case, the causal inference drawn can be more reliable (ibid).

The study conducted by Chontanawat et al. (2006) although it includes Ethiopia, the model is based on the bivariate causality model with energy consumption used as the sole factor input. And the study conducted by Wolde-Rufael (2008) did not include Ethiopia albeit his model is multivariate including capital and labour.

Similarly Yohannes (2010) examined cointegration and causality relationship between economic growth and energy consumption in Ethiopia, using the Autoregressive Distributive Lag model and Johansen test for cointegration. The study has shown a uni-directional causality running from energy consumption to economic growth.

The answers to questions pose in the hypothesis, which are recognised in many previous studies, have important implications for policy makers.

As noted by Wolde-Rufael (2005), amongst others, if causality runs from energy consumption to GDP then it implies that an economy is energy dependent and hence energy is a stimulus to growth implying that a shortage of energy may negatively affect economic growth or may cause poor economic performance, leading to a fall in income and employment. In other words, energy is a limiting factor in economic growth (Stern 2000). Whereas if causality only runs from GDP to energy consumption this implies that an economy is not energy dependent hence, as noted by Masih and Masih (1997) amongst others, energy conservation policies may be implemented with no adverse effect on growth and employment. If, on the other hand, there is no causality in either direction (referred to as the 'neutrality hypotheses), it implies that energy consumption is not correlated with GDP, so that energy conservation policies may be pursued without adversely affecting the economy.

The non-existence of such research work in the country, at least to the knowledge of the research worker, shows there is a gap to be filled, so that energy policy lesson can be drawn.

And the inconclusive empirical results which make it difficult to draw a conclusion about Ethiopia and the important role energy plays in economic development in country, the purposes of this paper is therefore to fill this gap by attempting to undertake the energy economic growth nexus employing multivariate model consisting of GDP, capita, labour and energy consumption growth.

1.3. Hypothesis of the Study

Toman and Jenelkova (2003) argue that most of the literature on energy and economic development discusses how development affects energy use rather than vice versa. The literatures which advocate such argument considers economic growth as the main driver for energy demand and only advanced economies with a high degree of innovation capacity can decrease energy consumption without reducing economic growth.

Stern and Cleveland (2004), on the other hand, often ascribe to energy the central role in economic growth. "If energy supply is considered a homogenous input for the production function, this means that if policy constraints affect energy supply, economic development is harmed. When energy services are differentiated, emphasizing the existence of higher and lower-quality forms of energy, society should make a choice in terms of an optimal energy mix, considering that higher- quality energy services could produce increasing returns to scale. This means that energy regulation policies supporting the shift from lower-quality (typically less efficient and more polluting) to higher-quality energy services could provide impulse to economic growth rather than be detrimental to the development process" (Costantini and Martini, 2010).

In view of the above two conflicting argument the paper tries to address the question, is energy an important driver of economic growth, vice versa or not? And accordingly the paper will empirically test the following four hypothesises.

"Growth Hypothesis" which suggests that energy consumption cause economic growth as complement to other inputs in the production functions.

"Conservation hypothesis" which testifies that policy on energy consumption have no effect on the economic growth. It may be due to little share of energy in the production function. That is economic growth Granger cause energy consumption growth.

“Feedback hypothesis” asserts that energy consumption and economic growth are interdependent. Bidirectional causality between energy consumption and economic growth show such behaviour.

“Neutrality hypothesis” proposes that energy consumption and economic growth are independent.

1.4. Objective of the Study

The objective of this paper is to investigate empirically the existence and direction of causal relationship between energy consumption and economic growth in Ethiopia.

Specific objectives

- Test whether economic growth Grander causes energy consumption;
- Test whether energy consumption Grander causes energy consumption;
- To test whether energy growth and economic growth have bidirectional relationship;
- To test whether energy growth and economic growth have no relationship at all; and
- To obtain policy implication from the result

1.5. Limitation of the Study

In line with many researchers, in the absence of capital stock for all African countries, gross capital formation has been used as proxy for the stock of physical capital. Using gross capital formation as a proxy for capital stock has several limitations. Gross capital formation as a flow variable, does not measure the stock of capital accumulated over the years and it does not take into account any adjustments for the depreciation of assets. Aggregate investment is merely a change in aggregate capital stock, less depreciation. Gross capital formation also includes stocks. Sari and Soytas (2007) point out that since in the perpetual inventory method (PIM) of estimating the capital stock assumes a constant depreciation rate, any variance in capital is mostly related to a change in investment. Thus, it is possible to obtain a fairly reliable measure of the trend in capital stock from new fixed investment data (Sari and Soytas, 2007; Lee et al., 2008).

1.6. Significance of the Study

According to the draft Growth and Transformation Plan of Ethiopia the plan target for the real GDP growth rated in next five years is 11.2% at a base case scenario; while for the energy sector the five year target are increasing the number of customers access to electricity from 2,000,000 to 4,000,000 by expanding electricity access for new areas; and increasing the existing 41% electricity power coverage of the country to 75%.

Therefore, the paper is relevant for Ethiopia, because, having a better view on link between energy consumption and GDP can help untangle the question to which extent economic growth can be sustained under various energy availability scenarios.

Moreover recently, the question of causality of economic growth and energy consumption has faced a renewed interest given the increasing debate about the world climate changes as a consequence of greenhouse gases emissions. As it was pointed out by, Amirat et.al (undated), "The direction of causality, in fact, can assist the policy makers to take the most suitable decisions in climatic matters: for instance, evidence of unidirectional causality running from income to energy consumption could suppose the full compatibility between energy conservation policies and economic growth policies since the firsts can be pursued without limiting the seconds. On the opposite the finding of unidirectional causality running from energy consumption to income may assume a particular significance with regard to the current debate about whether developing countries should be allowed to pollute more than the industrialized world, arguing that energy consumption could represent a stimulus for economic growth (Guttormsen, 2004)". Therefore, in light of this background the study is relevant for Ethiopia as well.

1.7. The Energy Sector in Ethiopia

Ethiopia's Energy consumption is predominantly based on biomass energy sources. An overwhelming proportion (92.2%) of the country's energy demand is met by traditional energy sources such as fuel wood, charcoal, branches, dung cakes and agricultural residues. The balance is met by commercial energy sources such as electricity and petroleum. The most important issue in the energy sector is the supply of household fuels, which is associated with massive deforestation and the resultant land degradation. The increasing scarcity of fuel wood is compounded by Ethiopia's high population growth rate. Unless stated the source of the data is MoWE.

Table 1 the National Energy Balance for 2001 (2008/09 G.C)

Item Unit: ktoe	**Light petroleum products**	**Heavy petroleum products**	**Electricity**	**Primary Biomass energy**	**Derived biomass energy**	**Total energy**
Product of primary Energy			283	29297		29577
Imports	719	1337				2056
Total energy requirements	719	1337	283	29297		31636
Energy converted	-122	0	36			-86
Other conversion industries				-2484	862	-1622
Consumption by energy sector						
Losses in transport and distribution			-51			-51
Statistical differences	145	-3	0	-1	4	145
Final consumption	741	1334	269	26813	867	30024
By industry & Construction (0.99%)	82	116	102			300
By transport (5.32%)	378	2118		5		1601
Road	157	1218				1375
Air	221					221
By households(92.79)	281		102	26623	845	27851
By service (0.91%)			65	185	22	272
	2.47%	4.44%	0.90 %	89.31%	2.89%	100%

Source: MoWE

The National Energy Balance for 2001 is shown in Table 6. Main indicators of the national energy balance of the year are as follows:[1]

[1] Source MoWE

- The total energy requirement is 31,636Ktoe, of which 29,297Ktoe biomass, 283Ktoe electricity and 2,056Ktoe petroleum products.

- The total primary energy produced was 29,580Ktoe of which 283 Ktoe electricity from hydro and 29,297Ktoe from primary biomass.

- The total final energy consumption by all sectors of the economy was about 30,024Ktoe of which 741Ktoe light petroleum products (MGR, LFO, Jet fuel and kerosene), 1,334Ktoe light petroleum products (ADO and HFO), 269Ktoe electricity and 27,680Ktoe biomass.

- Biomass energy sources (primary and derived) are the predominant, representing 92.2 percent of total energy sources.

- Modern fuels contributed 7.8 percent of total energy consumed, of which 6.9 percent petroleum products (light products 2.5 percent and heavy products 4.4 percent) and 1.0 percent electricity.

- Petroleum product consumption by industry and construction was 9.6 percent, household 13.**5** percent and transport 76.9 percent.

- Electricity use by industry and construction sector was 37.9 percent, 37.9 percent household and 24.2 percent Service.

- Sectoral energy consumption was dominated by the household sector which accounted for 92.8 percent, then 5.3 percent by the transport sector, 1.0 percent industry and construction and 0.9 percent service sector.

- Household energy use was almost entirely from biomass (98.6 percent), electricity and petroleum products together accounted for 1.4 percent of household consumption.

- Transportation sector energy use accounted for 5.3 percent of final consumption and 76.9 percent of petroleum fuels.

- Industry and construction sector use accounted 1.0 percent of the final consumption, of which 66.0 percent petroleum products and 34.0 percent electricity.

- Service sector use accounted 0.9 percent of the final consumption, of which 23.9 percent electricity and 76.1 percent biomass.

- Electricity generated amounted to 3,728 GWh, of which 84.1 percent was from hydro and 15.9 percent from thermal generation.

Table 2 Summary of the % Share of Energy consumption for 2004/05 – 2008/09

	Year (Ethiopian calendar)					
Energy Type	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Biomass	**94.5**	**94.2**	**93.6**	**93.2**	**92.4**	**92.2**
Electricity	**0.6**	**0.66**	**0.74**	**0.8**	**1.0**	**1.0**
Petroleum	**4.9**	**5.1**	**5.6**	**5.9**	**6.7**	**6.9**
			By Sector			
Household	**95.4**	**95.1**	**94.2**	**93.9**	**92.9**	**92.8**
Industry and construction	**0.7**	**0.8**	**0.9**	**0.8**	**0.9**	**1.0**
Transport	**3.6**	**3.8**	**4.2**	**4.5**	**5.3**	**5.3**
Service	**0.3**	**0.3**	**0.8**	**0.9**	**1.0**	**0.9**

Source: MoWE

Table 2 shows that there is a gradual shift from traditional to modern energy fuel. The % share of traditional biomass has decreased from 94.5 % to 92.2% and electricity has increased from 0.6% to 1% in the last six years. The petroleum fuel also increased from 4.9% in 1996 to 6.8% in 2001. The modern energy penetration rate will be very high starting 2003 because of the commissioning of the 3 hydro power plants in the country.

Indicators Comparisons between 2004/05 and 2008/09 Energy Balances

The comparison of indicators between the national energy balances of 2004/05 and 2008/09 is given below

Total Energy Requirement

In 1997 energy required from all energy sources (Biomass, petroleum and electricity) are 25,144Ktoe, 1,436Ktoe and 218Ktoe respectively. Whereas, in 2001 the energy required from the aforementioned sources are 29,297Ktoe, 2,056Ktoe and 283Ktoe respectively.

The total energy requirement of the country is accounted 26,798ktoe in 2004/05 and 31,636Ktoe in 2008/09.

The total energy requirement of the country increased by 18 %, from 26,798ktoe in 2004/05 to 31,636ktoe in 2008/09. Of this, imported fuels (petroleum products) accounted for 12.8 % (620ktoe) while locally available sources supplied accounted for 87.2 % (4,215ktoe).

In 2004/05, imported petroleum products which amounted to 1,436ktoe comprised mainly, light petroleum products (kerosene, light fuel oil, Jet fuel and motor gasoline) 37.9 % and heavy petroleum products (automotives diesel oil and heavy fuel oil) 62.1%. The indigenous production (25,362 ktoe) was mainly derived from biomass (99.1%) and hydro electricity (0.9%)

In 2008/09, imported petroleum products which amounted to 2,056ktoe comprised mainly, light petroleum products (kerosene, light fuel oil, Jet fuel and motor gasoline) 35.0% and heavy petroleum products (automotives diesel oil and heavy fuel oil) 65.0%. The indigenous production (29,580ktoe) was mainly derived from biomass (99.0%) and hydro electricity (1.0%)

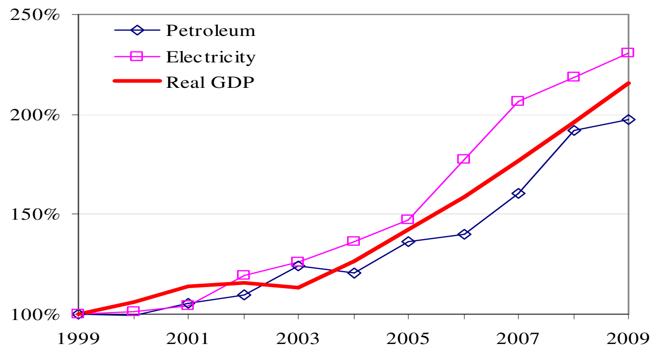


Figure1 Rate of GDP growth vs. commercial energy demand growth (normalized to 1999 values) Source: National Energy Network

As it is shown in the Figure 1 that electricity consumption has been growing faster than real GDP and petroleum at about the same rate as GDP

In the current Strategic Plan for the Ministry of Water and Energy, the elasticity of GDP with respect to electricity demand was estimated at 2.15, meaning that a 1% rise in GDP will increase electricity demand by 2.15%. This implies that annual GDP growth of 11% (GTP base scenario) will result in annual demand for electricity growing by 24%. Similarly, the GDP elasticity with respect to petroleum consumption is estimated at 0.8 to 1.0, implying petroleum demand will grow at around the annual rate of growth for real GDP.

Chapter Two

2. Review of Related Literature

.1. 2Theoretical Literature2

2.1.1. The ecological economics approach

Introduction

Ecological economists derive their view of the role of energy in economic growth from the biophysical foundations of the economy. They also argue that substitution between capital and resources and technological progress can only play limited roles in mitigating the scarcity of resources. Some ecological economists also downplay the role of technological change, arguing that either increased energy use accounts for most apparent productivity growth, or that technological change is real but innovations mainly increase productivity by allowing the use of more energy. Therefore, increased energy use is the main or only cause of economic growth.

A prominent tradition in ecological economics is represented by biophysical models that consider energy to be a primary factor of production and the only such primary factor. In this view, all value is derived from the action of energy that is directed by capital and labour.

[2] Unless otherwise specified, this section of the paper draws on (Stern, 2011)

2.1.2. Energy as a Factor of Production

The laws of thermodynamics and the conservation of matter describe the immutable constraints within which the economic system must operate. The mass-balance principle means that, in order to obtain a given material output, greater or equal quantities of matter must be used as inputs with the residual a pollutant or waste product. Therefore, there are minimal material input requirements for any production process producing material outputs. The second law of thermodynamics (the efficiency law) implies that a minimum quantity of energy is required to carry out the transformation or movement of matter or, more generally, perform physical work. Carrying out transformations in finite time requires more energy than these minima. All production involves work. Therefore, all economic activities must require energy, and there must be limits to the substitution of other factors of production for energy so that energy is always an essential factor of production.

Primary factors of production are defined as inputs that exist at the beginning of the period under consideration and are not directly used up in production (though they can be degraded or accumulated from period to period), while intermediate inputs are those created during the production period under consideration and are used up entirely in production. Mainstream economists usually think of capital, labour, and land as the primary factors of production, and goods (such as fuels and materials) as intermediate inputs. The prices paid for the various intermediate inputs are seen as eventually being payments to the owners of the primary inputs for the services provided directly or embodied in the produced intermediate inputs. This approach has led to a focus in mainstream growth theory on the primary inputs, and in particular, capital and labour. The classical factor of land, including all natural resource inputs, gradually diminished in importance in economic theory as its value share of GDP fell steadily and is usually subsumed as a subcategory of capital.

2.1.3. The Mainstream Theory of Growth

The core mainstream growth models, including the Solow growth model and later developments, do not include resources or energy. In the Solow model, the long-run rate of economic growth is given by the rate of technological progress while diminishing returns to capital mean that growth derived from capital accumulation is a transitional phase as the economy moves toward this long-run dynamic steady state. If the savings rate is increased, growth will occur for a while until a new equilibrium is reached. Improvement in the state of technological knowledge raises the rate of return to capital, thereby offsetting the diminishing returns to capital that would otherwise apply a brake to growth. Without technological change, economic growth eventually halts but the economy can remain in a steady state indefinitely.

Early growth models did not explain how improvements in technology come about, so that these models are said to have exogenous technological change. More recent models attempt to indigenize technological change—explaining technological progress as the outcome of decisions taken by firms and individuals. More recent endogenous growth models are represented by the so-called AK models where the relationship between capital and output can be written in the form $Y = AK$, where A is a constant and K is a composite of manufactured capital and disembodied technological knowledge is thought of as a form of capital. Technological knowledge is a non-rival good and thus is not depleted with use, and it generates positive externalities in production that benefit the economy as a whole. The economy can sustain a constant growth rate in which the diminishing returns to manufactured capital are exactly offset by the external effect of knowledge creation. In AK models, saving is directed to either manufactured capital accumulation or the increase of knowledge. The growth rate is permanently influenced by the savings rate; a higher savings rate increases the economy's growth rate, not merely its equilibrium level of income.

2.1.4. Growth Models with Resources and no Technical Change

Adding non-renewable natural resources that are essential in production to the basic mainstream growth models means that capital also needs to be accumulated to compensate for resource depletion. When there is more than one input - both capital and natural resources - there are many alternative paths that economic growth can take, determined by both the nature of technology and institutional arrangements.

Solow showed that sustainability is achievable in a model with a non-renewable natural resource with no extraction costs and non-depreciating capital when the elasticity of substitution between the two inputs is unity, and when certain other technical conditions are met. Sustainability, and even indefinite growth in consumption, can occur when the utility of individuals is given equal weight without regard to when they happen to live. However, under competition the same model economy results in exhaustion of the resource and consumption and social welfare eventually fall to zero. With any constant discount rate the efficient growth path also leads to eventual depletion of the natural resource and the collapse of the economy. The Hartwick rule shows that if sustainability is technically feasible, a constant level of consumption can be achieved by reinvesting the resource rents in other forms of capital, which in turn can substitute for resources.

A common interpretation of this body of work is that substitution and technical change can effectively decouple economic growth from the use of energy and other resources. Depleted resources can be replaced by more abundant substitutes, or by "equivalent" forms of human-made capital (people, machines, factories, etc.).

2.1.5. Growth Models with Resources and Technical Change

In addition to substitution of capital for resources, technological change might permit growth or at least constant consumption in the face of a finite resource base. When the elasticity of substitution between capital and resources is unity, exogenous technical progress will allow consumption to grow over time if the rate of technological change divided by the discount rate is greater than the output elasticity of resources. Technological change might enable sustainability even with an elasticity of substitution of less than one. Once again, technical feasibility does not guarantee sustainability. Depending on preferences for current versus future consumption, technological change might instead result in faster depletion of the resource.

Therefore, mainstream economic growth theory assumes that resource consumption is a consequence, not a cause, of growth.

2.1.6. Synthesis: Unified Models of Energy and Growth

The mainstream growth models ignore energy in the economic growth, by contrast, the ecological economics literature posits a central role for energy in driving growth but argues that limits to substitutability and/or technological change might limit or reverse growth in the future. But none of the models and theories reviewed so far really provides a satisfactory explanation of the long-run history of the economy. Until the industrial revolution, output per capita was generally low and economic growth was not sustained. Ecological economists point to the invention of methods to use fossil fuels as the cause of the industrial revolution. But the mainstream growth models that ignore energy resources can at least partly explain economic growth over the last half a century.

There are currently two principal mainstream theories that explain the growth regimes of both the preindustrial and modern economies and the cause of the industrial revolution, which formed the transition between them. These are endogenous technical change approach, and the second approach is represented by two sectors- Malthusian Sector and Solow Sector.

The approximations inherent in the use of a single-sector equilibrium model based on the Cobb–Douglas (C–D) production function result in a potentially misleading mathematical implication: namely that the output elasticities of the factors should correspond to payments in the National Accounts. However, the national accounts reflect payments only to capital (as interest, dividends, rents and royalties) and to labor (as wages and salaries). The accounts do not reflect payments to 'nature'. This fact, in combination with other standard economic assumptions and mathematical characteristics of the C–D function implies that resource (energy) flows do not contribute much to aggregate productivity and thence cannot be a significant contributor to growth. (Ayres, 2001)

To integrate the different approaches, Stern (2011) proposed to modify Solow's growth model. In the model Stern added an energy input that has low substitutability with capital and labor, while allowing the elasticity of substitution between capital and labor to remain at unity. In this model, depending on the availability of energy and the nature of technological change, energy can be either a constraint on growth or an enabler of growth. Omitting time indexes for simplicity, the model consists of two equations:

$$Y = \left[(1-\gamma)\left(A_L^{\beta} B^{\beta} K^{1-\beta} + \gamma(A_E E)^{\Phi}\right)\right]^{\frac{1}{\Phi}} \quad \text{-----------------------} \ (1)$$

$$\Delta K = s(Y - P_E E) - \delta K \quad \text{---------------------------------} \ (2)$$

Equation (1) embeds a Cobb–Douglas production function of capital (K) and labor (L) in a constant elasticity of substitution (CES) function of value added and energy (E) that produces gross output Y.

$\phi = \frac{\delta - 1}{\delta}$; Where δ is the elasticity of substitution between energy and the value-added aggregate; PE the price of energy; and γ is a parameter reflecting the relative importance of energy and value added.AL and AE are the augmentation indexes of labor and energy, which can be interpreted as reflecting both changes in technology that augment the effective supply of the factor in question and changes in the quality of the respective factors.

Equation (2) is the equation of motion for capital that assumes like Solow that the proportion of gross output that is saved is fixed at s and that capital depreciates at a constant rate δ.

As $\delta \rightarrow 1$and $\gamma \rightarrow 0$ we have the Solow model as a special case, where in the steady state, K and Y grows at the rate of labor augmentation. Additionally, depending on the scarcity of energy, the model displays either Solow-style or energy constrained behavior.

2.1.7. Factors Affecting the Linkage between Energy and Economic Growth

So far, we have established that energy is an essential input, that in theory in the long-run energy availability could constrain economic growth, and that the current relative abundance of energy sources has alleviated these constraints. It is commonly asserted that there has been a decoupling of economic output and resources and it is often implied that there has been a permanent change in the relationship between energy and growth. And there are factors that affect the linkage between energy and economic growth.

We can use a production function approach to examine the factors that could weaken or strengthen the linkage between energy use and economic activity over time and summarize the empirical evidence on each of these mechanisms. A general production frontier, assuming for simplicity that there is separability between inputs and outputs, can be represented as

$$(Q1, \ldots, Qm) = f(A, X1, \ldots, Xn, E1, \ldots, Ep)$$

where the Qi are various outputs, such as manufactured goods and services, the Xi are various non-energy inputs, such as capital and labor, the Ei are different energy inputs, such as coal and oil, and A is the state of technology as defined by the TFP indicator.

The relationship between energy and an aggregate of output, such as GDP, can then be affected by

- substitution between energy and other inputs;
- technological change—a change in A;
- shifts in the composition of the energy input; and
- shifts in the composition of output.

2.2. Empirical Literature Review

Over the past few years the relationship between energy consumption and economic growth has been extensively researched. Yet, there seems to be no consensus regarding the direction of causality between energy consumption and economic growth.

Rognvaldur Hannesson (2009) examined the relationship between the growth in energy use and the growth of gross national product (GDP) for 171 countries 1950-2004. The paper uses linear regression of the growth rate in energy use on the growth rate in GDP for 171 countries. GDP per capita, and the price of oil, run for all 171 countries and for subsets of rich, medium rich and poor countries, market economies versus centrally planned economies, and oil exporting versus oil importing countries. And according to the study, there is a significant positive relationship between growth in energy use and growth in GDP for all countries taken together and for all subsets of countries, although not necessarily proportional. There is some indication that growth in energy use declines with GDP per capita, for any given growth in GDP. There is a significantly negative relationship between the price of oil and the growth in energy use for all countries taken together and for all subsets of countries, except for planned economies and for oil exporting countries.

In a study of over more than hundred countries, Chontanawat et al. (2008) find that the causal relationship between energy consumption and economic growth is more pronounced in developed than in developing countries. Causality running from energy consumption to economic growth was found in only 35% of the poorest nations and in 42% of the middle-income nations while it was found in 69% the high-income countries. Ethiopia was included in the study and the result shows there is Granger causality running from economic growth to energy consumption.

Stern (1993) examined the causal relationship between energy use and GDP in the USA. He employed a multivariate vector autoregressive (VAR) analysis and used a weighting index of energy quality, where content of energy use shifts from lower quality energy such as coal to high quality energy such as electricity, rather than using a measure of total energy use. He also employed a different test of causality. He found that total energy use does not Granger cause GDP. However, using a weighting measure of energy is found to be Granger causing GDP. Stern (2000) extends his analysis on the US economy by introducing cointegration analysis of the relationship between energy and GDP. He found again that using total energy use does not seem to be Granger causing GDP. However, using quality weighting index of energy is found to be Granger causing GDP. His cointegration results show that energy cannot be excluded from the cointegration space.

Masih and Masih (1996) used cointegration analysis to study this relationship in a group of six Asian countries and found cointegration between energy use and GDP in India, Pakistan, and Indonesia. No cointegration is found in the case of Malaysia, Singapore and the Philippines. The flow of causality is found to be running from energy to GDP in India and from GDP to energy in Pakistan and Indonesia.

Sari and Soytas (2007) re-examined the inter-temporal link between energy consumption and income in six developing countries (Indonesia, Iran, Malaysia, Pakistan, Singapore, and Tunisia) with diverse economic backgrounds and energy statistics, in a production function framework.

They specifically employ generalized forecast error variance decompositions and generalized impulse response approach to assess the relative strength of gross capital formation, labor and energy in income equations and the transmission mechanism between the variables under investigation. The findings reveal that in these countries energy is an important factor in determination of income. In two countries, the impact of energy on income is greater than other inputs, and only in one country energy is the least important input.

In Iran and Pakistan, growth of energy accounts for the greatest portion of forecast error variance of income growth. In Indonesia, Malaysia, Singapore, and Tunisia, the impact of energy growth is either greater than the impact of growth of labor or growth of gross capital formation. In Singapore, energy seems to be less important than the other inputs in short run.

The results of impulse responses are-A shock to energy consumption initially has positive impact on income in all countries. In Tunisia income responds to a shock in energy consumption negatively in the second year while in all other countries the responses are positive and remains so until the shock dies out. In Singapore, impulse responses, while more volatile than those for other countries, do eventually die out. These findings suggest that the effects are not permanent in all countries.

Nondo and Mulugeta (2009) applied panel data techniques to investigate the long-run relationship between energy consumption and GDP for a panel of 19 African countries (COMESA) based on annual data for the period 1980-2005. They have estimated the long-run relationship and test for causality using panel-based error correction models. The results indicate that long-run and short-run causality is unidirectional, running from energy consumption to GDP. The paper did not elaborated county specific result, it simply indicated the result in its aggregate form, and the study did not include Ethiopia.

Using a bivariate analysis Ebohon, O. J. (1996), examines the causal directions between energy consumption and economic growth (proxied by GDP and GNP) for Nigeria and Tanzania. The results show a simultaneous causal relationship between energy and economic growth for both countries.

In a bivariate relationship between energy consumption and economic growth in African countries, Wolde-Rufael (2005) also found conflicting evidence with the neutrality hypothesis supported in a substantial number of countries, with little support for the hypothesis that energy consumption causes economic growth.

For five countries (Algeria, Democratic Republic of Congo, Egypt, Ghana and Ivory Coast) there was a uni-directional causality running from economic growth to energy use implying that economic development seems to take precedence over energy consumption and that economic growth caused greater demand for energy.

For three countries (Cameroon, Morocco and Nigeria) there was an opposite causality running from energy use to economic growth. For the Cameroon there was a positive causality running from energy consumption to economic growth indicating that energy consumption acted as a stimulus to economic growth, which implies that energy conservation measures may not be undertaken without jeopardising the economic growth of Cameroon.

For Morocco and Nigeria, there was a negative causality running from energy consumption to economic growth signifying that energy use negatively impacts on economic growth.

Bi-directional causality was detected for two countries, Gabon and Zambia. In Gabon the bi-directional causality was positive both ways while in Zambia it was negative both ways. For Gabon, energy use promotes economic growth while for Zambia energy had a negative impact on GDP.

For the remaining nine countries (Benin, Kenya, Togo, Zambia, Congo Republic, Senegal, the Sudan, South Africa and Zimbabwe) where there was no causality in any direction between Economic growth and energy consumption, energy consumption seems neither to promote nor to retard economic growth. Theoretically, for these countries energy conservation policies may be pursued without adversely affecting economic growth.

The lack of significant relationship between energy use and economic development can be attributed to omitted variables. The omission of other factors such as energy price and other factors of production that can complement energy, such as physical and human capital, may contribute to lack of relationship between energy and economic development in these countries (Wolde-Rufael, 2005). To this end, Wolde-Rufael re-examine the causal relationship between energy consumption and economic growth for seventeen African countries in a multivariate framework by including labor and capital as additional variables. He also applied the variance decomposition analysis due to Generalised impulse response in linear multivariate models, to evaluate how important is the causal impact of energy consumption on economic growth relative to labor and capital. The results of the multivariate modified Granger causality analysis tend to reject the neutrality hypothesis for the energy–income relationship in fifteen out of the seventeen countries. In contrast, results of the variance decomposition analyses show that in eleven out of the seventeen countries, energy is no more than a contributing factor to output growth and not an important one when compared to capital and labor. Labor and capital are the most important factors in output growth in fifteen out of the seventeen countries.

The most striking result of the empirical evidence is that the introduction of both gross capital formation and labor has altered the direction of causality in thirteen countries that were previously investigated by Wolde-Rufael (2005). In seven of the countries where Wolde-Rufael (2005) found no evidence of causality in any direction between energy consumption and economic growth, he now found evidence of Granger causality for seven of these countries: Benin, Senegal, South Africa, Sudan, Togo, Tunisia and Zimbabwe. In Benin and South Africa causality runs now from energy consumption to economic growth; in Senegal, Sudan and Tunisia causality runs now from economic growth to energy consumption, and in Togo and Zimbabwe we find now that energy and economic growth were mutually causal.

Causality was also reversed in another six counties: Algeria, Cameroon, Gambia, Ghana, Morocco and Nigeria. In Algeria causality was reversed from economic growth to energy consumption, to the opposite causality running from energy consumption to economic growth contrary to the no causality found by Chontanawat et al. (2008). In contrast, in Morocco and Nigeria causality was reversed from energy consumption to economic growth, to the opposite causality running from economic growth to energy consumption. In Ghana causality was also reversed to feedback, from economic growth to energy consumption, in line with that found by Chontanawat et al. (2008). In Kenya, as in the bivariate case and also in line with result that found by Chontanawat et al. (2008), he found no evidence of causality in any direction between energy consumption and economic growth. In the Ivory Coast and Egypt, as in the bivariate case, causality running from economic growth to energy consumption was confirmed while in Gabon the feedback hypothesis was confirmed in contrast to the no causality found by Chontanawat et al. (2008). In contrast, in Zambia the bi-directional casualty found by Wolde-Rufael (2005) was reversed into unidirectional causality running from economic growth to energy consumption. Cameroon was the only country where causality from energy consumption to economic growth was reversed to no causality in his present study. This is in line with Chontanawat et al. (2008) who found no evidence of causality in any direction between energy consumption and economic growth in the case of Cameroon.

To provide any indication how important is the causal relationship between economic growth and energy consumption and assess how each variable responds to innovations in other variables, Wolde-Rufael have applied the generalised forecast error variance decomposition analysis. The result shows in eleven countries, energy was not even the second most important factor when compared to capital and labor. However, even though energy's contribution relative to output was not so high as that of capital or labor, its contribution to output growth was still relatively high in Algeria (29%), in Cameroon (41%), South Africa (23%) and Tunisia (44%). All these countries are natural-rich countries. The least contribution energy made to economic growth was in the Ivory Coast, Gabon, Senegal, Sudan and Zimbabwe, with energy contributing to a negligible percentage to the forecast error variance of economic growth. In the case of Cameroon, even though there was no evidence of Granger causality running in any direction between energy and economic growth, the GDP forecast error variance due to energy was one of the highest (41%). In eight countries, capital formation contributed more to output growth relative to energy and labour. Similarly in seven countries, labor contributed more to output growth relative to energy and capital.

Amirat et.al (undated) undertook analyses of the causal relationship between the per capita energy consumption and the per capita GDP in Algeria by using annual data from 1980 to 2007. They include capital and labor as additional variables to the energy-growth nexus. They used Granger causality test and the variance decomposition analysis. The results give the evidence of causality running from energy consumption to economic growth. The variance decomposition analysis reveals that energy was no more than a minor contributing factor to output growth and certainly not the most important one when compared to capital and labor. 73.8% of future changes in output growth are due to changes in capital, 1.4 % due to labor and 9.2% due to energy in Algeria after five years horizon. Capital is the most important factors in output growth in Algeria. After 5-year horizon, the shocks to GDP due to shocks of energy were very negligible.

Similarly, using a multivariate causality test, Akinlo (2008) found also conflicting results for eleven African countries. The eleven (11) countries covered in the study are namely Cameroon, Cote D'Ivoire, Congo, Gambia, Ghana, Kenya, Nigeria, Senegal, Sudan, Togo and Zimbabwe. Although Akinlo used multivariate causality test, capital and labor are not part of the equation, instead he use price (P) and government expenditure (G). Government expenditure is used as a measure of government activity as public expenditure is an important instrument for a government to control the economy. Prices are incorporated in the specification because of two main reasons. One, they play significant role in energy consumption particularly in economy that is highly energy dependent. Two, they serve as proxy for the degree of the efficient functioning of the economy.

The result shows that energy consumption is cointegrated with economic growth in seven of the countries included Cameroon, Cote D'Ivoire, Gambia, Ghana, Senegal, Sudan and Zimbabwe. In addition, in few of the countries, the result suggests that energy consumption has a significant long run impact on economic growth, e.g. Ghana, Senegal and Sudan. Granger Causality test within the VECM framework shows bidirectional relationship between energy consumption and economic growth for Gambia, Ghana and Senegal. However, the Granger causality test shows that economic growth Granger cause energy consumption in the case of Sudan and Zimbabwe. In the case of Cameroon and Cote D'Ivoire, the Granger causality test shows no causality between energy consumption and economic growth.

The Granger causality test within the VAR framework for countries where cointegration was not found shows unidirectional causality running from economic growth to energy consumption for Congo. However no causality in either direction was found in Nigeria, Kenya and Togo.

Olatunji Adeniran (undated) tested for causal relationship between energy consumption and GDP in Nigeria using systematic econometric techniques. The study found that there is a unidirectional causality that runs from GDP to electricity consumption. The study also found that GDP Granger causes gas consumption. However, the analyses reveal no causality between oil consumption and GDP. In aggregate, the study reveals that energy consumption Granger causes economic growth in Nigeria.

Jumbe (2004) examined cointegration and causality between electricity consumption (kWh) and, respectively, overall GDP (GDP), agricultural GDP (AGDP) and non-agricultural GDP (NGDP) using Malawi data for 1970–1999 periods. The results show that kWh is, respectively, cointegrated with GDP and NGDP, but not with AGDP. Both the standard Granger-causality (GC) and error correction model (ECM) techniques were used to examine causality between kWh and, respectively, GDP and NGDP. The GC results show a bi-directional causality between kWh and GDP, but a unidirectional causality running from NGDP to kWh. However, ECM results detect one-way causality running from GDP to kWh and from NGDP to kWh.

Yohannes (2010) has conducted causal relationship between economic growth and energy consumption in Ethiopia and he found energy consumption Granger cause economic growth.

Chapter Three

3. Methodology and Source of Data

3.1. The general theoretical model

3.1.1. Neo-classical production technology

To investigate the relationship between energy use and output growth, we propose a framework based on the conventional neo-classical one-sector aggregate production technology where we treat capital, labor, and energy as separate inputs. That is:

$$LnY_t = f\left(LnK_t, LnL_t, LnE_t\right) \quad \text{- - - - - - - - - - - - - - - - - - (3)}$$

Where Y is aggregate output or GDP, K is Gross Capital formation, L is the total work force, E is energy use, and the subscript t denotes the time period. Taking the differential of Eq. (3) we obtain:

$$dY_t = Y_k dK_t + Y_L dL_t + Y_E EdE_t \quad \text{- (4)}$$

Where dYi is the partial derivative of Y with respect to its ith argument. On dividing Eq. (4) through by Yt and rearranging the resulting expression, we obtain the following growth equation.

$$\dot{Y} = a\,\dot{k}_t + b\,\dot{L}_t + c\,\dot{E}_t \quad \text{- (5)}$$

Where a dot on the top of a variable means that the variable is now in a growth rate form. The constant parameters a, b and c are the elasticities of output with respect to capital, labor and energy, respectively.

The relationship between output and capital, labor, and energy inputs described by the production function in Eq. (3) suggests that their long-run movements may be related. Furthermore, if we allow for short-run dynamics in factor-input behavior, the analysis above would also suggest that past changes in capital, labor, and energy could contain useful information for predicting the future changes of output, Ceteris paribus. These implications can be easily examined using tests for multivariate cointegration and Granger-causality.

3.2. Methodology

3.2.1. General

When two or more totally unrelated variables are trending over time, they will appear to be correlated simply because of the shared directionality. Correlation does not necessarily imply causation in any meaningful sense of that word. The econometric graveyard is full of magnificent correlations, which are simply spurious or meaningless. (Eviews user's guide I, 2011) Therefore, traditional linear regression or correlation methods cannot be used to establish casual relations among a group of variables. Two methods for testing for causality among time-series variables are Granger causality tests (Granger, C.W.J. 1969).and cointegration analysis (Engle, R.E. & C.W.J. Granger. 1987). Hendry and Juselius discuss the application of these methods to energy economics where they have been applied extensively to test for causality and cointegration between energy, GDP, and other variables from the late 1970s on. (As cited in Stern, 2010). To this effect, the study will use the Granger causality test and cointegration analysis to empirically explore the causal interactions between energy use and output growth in the case of Ethiopia.

The Granger (1969) approach to the question of whether x causes y is to see how much of the current y can be explained by past values of y and then to see whether adding lagged values of x can improve the explanation. Y is said to be Granger-caused by x if x helps in the prediction of y, or equivalently if the coefficients on the lagged x's are statistically significant. Note that two-way causation is frequently the case; x Granger causes y and y Granger causes x.

Following Granger (1969), the concept of "causality" assumes a different meaning with respect to the more common use of the term. The statement " yt Granger causes xt" (or vice versa), in fact, does not imply that yt (xt) is the effect or the result of xt (yt), but represents how much of the current yt (xt) can be explained by the past values of yt (xt) and whether adding lagged values of xt (yt) can improve the explanation (Amirat and Bouri, undated). For this reason, the causality relationship can be evaluated estimating the following two regressions:

$$Y_t = \beta_1 + \sum_{s=1}^{M} \gamma_{1,s} Y_{t-s} + \sum_{s=1}^{M} \gamma_{2,s} E_{t-s} + \sum_{s=1}^{M} \gamma_{3,s} K_{t-s} + \sum_{s=1}^{M} \gamma_{4,s} L_{t-s} + U_{1t} \quad \text{-(6)}$$

$$E_t = \beta_2 + \sum_{s=1}^{N} \delta_{1,s} E_{t-s} + \sum_{s=1}^{N} \delta_{2,s} Y_{t-s} + \sum_{s-1}^{N} \delta_{3,s} K_{t-s} + \sum_{s-1}^{N} \delta_{4,s} L_{t-s} + U_{2t} \quad \text{- - - - - - - - - - - (7)}$$

$$K_t = \beta_3 + \sum_{s=1}^{P} \phi_{1,s} E_{t-s} + \sum_{s=1}^{P} \phi_{2,s} Y_{t-s} + \sum_{s}^{P} \phi_{3,s} K_{t-s} + \sum_{s}^{P} \phi_{4,s} L_{t-s} + U_{3t} \quad \text{- - (8)}$$

$$L_t = \beta_3 + \sum_{s=1}^{P} \theta_{1,s} E_{t-s} + \sum_{s=1}^{P} \theta_{2,s} Y_{t-s} + \sum_{s}^{P} \theta_{3,s} K_{t-s} + \sum_{s}^{P} \theta_{4,s} L_{t-s} + U_{4t} \quad \text{- - (9)}$$

The four variables will be measured by their natural logarithm so that their first difference approximates their growth rates.

3.2.2. Unit Root Test

Since Granger causality tests are sensitive to the stationarity of the series we first study the stationarity properties of the variables. There are a variety of unit root tests that sometimes yield conflicting results. Therefore, in order to proceed with cointegration and VEC analyses one needs to be confident as to the order of integration of the series used. If the series are integrated of the same order one can proceed with the cointegration tests.

This initial formulation by Granger used levels of variables as shown in equations (6), (7), (8) and (9). However, following the development of unit root testing and cointegration, for non-stationary variables, integrated of order one or I(1), equations (6) to (9) are replaced by:

$$\Delta Y_t = \beta_1 + \sum_{s=1}^{M} \gamma_{1,s} \Delta Y_{t-s} + \sum_{s=1}^{M} \gamma_{2,s} E_{t-s} + \sum_{s=1}^{M} \gamma_{3,s} \Delta K_{t-s} + \sum_{s=1}^{M} \gamma_{4,s} \Delta L_{t-s} + U_{1t} \quad \text{- - - -(10)}$$

$$\Delta E_t = \beta_2 + \sum_{s=1}^{N}\delta_{1,s}\Delta E_{t-s} + \sum_{s=1}^{N}\delta_{2,s}\Delta Y_{t-s} + \sum_{s=1}^{N}\delta_{3,s}\Delta K_{t-s} + \sum_{s=1}^{N}\delta_{4,s}\Delta L_{t-s} + U_{2t} \quad \text{------(11)}$$

$$\Delta K_t = \beta_3 + \sum_{s=1}^{P}\phi_{1,s}\Delta E_{t-s} + \sum_{s=1}^{P}\phi_{2,s}\Delta Y_{t-s} + \sum_{s}^{P}\phi_{3,s}\Delta K_{t-s} + \sum_{s}^{P}\phi_{4,s}\Delta L_{t-s} + U_{3t} \quad \text{----- (12)}$$

$$\Delta L_t = \beta_3 + \sum_{s=1}^{q}\theta_{1,s}\Delta E_{t-s} + \sum_{s=1}^{q}\theta_{2,s}\Delta Y_{t-s} + \sum_{s}^{q}\theta_{3,s}\Delta K_{t-s} + \sum_{s}^{q}\theta_{4,s}\Delta L_{t-s} + U_{4t} \quad (13)$$

Where Δ is the first difference operator, so that the terms are introduced in differences to ensure that they are stationary or I(0). Here the concept of causality is formulated in terms of changes to the variables and the presence of Granger-causality depends on the significance of the ΔYt-s terms and ΔEt-s terms in equations (10) to (13) respectively.

3.2.3. Co- integration test

Generally speaking, two or more variables are said to be co-integrated if they share a common trend. In other words, the series are linked by some long-run equilibrium relationship from which they can deviate in the short run but they must return to in the long-run, i.e. they exhibit the same stochastic trend .Cointegration can be considered as an exception to the general rule which establishes that, if two series are both I(1), then any linear combination of them will yield a series which is also I(1). The exception is when a linear combination of two or more series is integrated of a lower order: in this case, in fact, the common stochastic trend is cancelled out, leading to something that is not spurious but that has some significance in economic terms (Amirat and Bouri, undated).

Given the above fact, the variable will be subjected to Johansen cointegration test and if it is found that the variables are co-integrate. Then, using the Granger representation theorem, we may posit the following testing relationships that constitute a vector error correction (VEC) model for output growth.

3.2.4. Vector Error Correction

The existence of cointegration implies Granger causality; however, does not point out the direction of causality. In order to assess the direction, we employ a vector error correction (VEC) modelling. If the variables in concern are cointegrated, a vector error correction model should be estimated rather than a VAR as in a standard Granger causality test (Granger, 1988). Hence, following Granger (1988), and Engle and Granger (1987), we estimated a VEC model for the Granger causality test. The VEC representation is as follows:

$$\Delta Y_t = \beta_1 + \sum_{k}^{r} \alpha_{1,k} v_{k,t-p} \sum_{s=1}^{M} \gamma_{1,s} \Delta Y_{t-s} + \sum_{s=1}^{M} \gamma_{2,s} E_{t-s} + \sum_{s=1}^{M} \gamma_{3,s} \Delta K_{t-s} + \sum_{s=1}^{M} \gamma_{4,s} \Delta L_{t-s} + U_{1t} \quad (14)$$

$$\Delta E_t = \beta_2 + \sum_{k}^{r} \alpha_{2,k} v_{k,t-p} + \sum_{s=1}^{N} \delta_{1,s} \Delta E_{t-s} + \sum_{s=1}^{N} \delta_{2,s} \Delta Y_{t-s} + \sum_{s-1}^{N} \delta_{3,s} \Delta K_{t-s} + \sum_{s-1}^{N} \delta_{4,s} \Delta L_{t-s} + U_{2t} \quad (15)$$

$$\Delta K_t = \beta_3 + \sum_{k}^{r} \alpha_{3,k} v_{k,t-p} \sum_{s=1}^{P} \phi_{1,s} \Delta E_{t-s} + \sum_{s=1}^{P} \phi_{2,s} \Delta Y_{t-s} + \sum_{s}^{P} \phi_{3,s} \Delta K_{t-s} + \sum_{s}^{P} \phi_{4,s} \Delta L_{t-s} + U_{3t} \quad (16)$$

$$\Delta L_t = \beta_3 + \sum_{k}^{r} \alpha_{4,k} v_{k,t-p} \sum_{s=1}^{q} \theta_{1,s} \Delta E_{t-s} + \sum_{s=1}^{q} \theta_{2,s} \Delta Y_{t-s} + \sum_{s}^{q} \theta_{3,s} \Delta K_{t-s} + \sum_{s}^{q} \theta_{4,s} \Delta L_{t-s} + U_{4t} \quad (17)$$

Where, vi (i= 1,2,3) refer to error correction terms whose coefficients measure speeds of adjustment, μ1, …, μ2 are intercepts, and M, N, p, and q are lag lengths. The vi (i= 1,2,3) are derived from long-run cointegrating relationships i.e Y= K+ E+L

In addition to being consistent with the specifications in Eqs (6) and (7), the model in Eqs. (14)– (17) describes the intertemporal interaction between output and the factor inputs included in the production function. Once the equilibrium conditions represented by the cointegrating relations are imposed, the VEC model describes how, in each time period, output growth is adjusting towards its long-run equilibrium state. Since the variables are supposed to be co-integrated, then in the short term, deviation of output from its long-run equilibrium path will feed back on its future changes in order to force its movement towards the long-run equilibrium state. The cointegrating vectors from which the error-correction terms are derived are each indicating an independent direction where a stable, meaningful long-run equilibrium state exists. The coefficients of the error-correction terms, however, represent the proportion by which the long-run disequilibrium in the dependent variables is corrected in each short-term period (Ghali and El-Sakka, 2004).

Since our interest is on causality between economic growth and energy use, thus on the basis of regression Equations 14 and 15, unidirectional causality from Et-s to Yt is implied if not only the estimated coefficients on the lagged Et-s variables in Equation 14 are statistically different from zero as a group (based on standard F-statistic) but also the coefficient on the error-correction term in Equation 14 is significant, and if the set of estimated coefficients on the lagged Yt variables in Equation 15 are not statistically different from zero. On the other hand, Yt-s causes Et if the estimated coefficients on the lagged Yt-s variable in Equation 15 are statistically different from zero as a group, the coefficient on the error-correction term in Equation 15 is significant, and if the set of estimated coefficients on the lagged Et variables in Equation 14 are not statistically different from zero. Bidirectional causality or feedback between Yt and Et would exist if the set of estimated coefficients on the lagged Et-s variables in Equation 14 were statistically significant as a group and the set of estimated coefficients on the lagged Yt-s variables in Equation 15 were also statistically significant as a group and also the coefficient of error-correction terms in both Equations are significant (Chang, Tsangyao, 2002).

3.2.5. Granger Causality Test

Based on the theoretical facts discussed under the model section in this paper, the reported F-statistics of the Wald statistics for the joint hypothesis for each equation will be undertaken. The null hypothesis is that Y does not Granger-cause E in the first regression and that E does not Granger-cause Y in the second regression.

3.2.6. Test of Volatility

There are two approaches, impulse response function and variance (forecast error) decomposition, for characterising the dynamic behaviour of the VAR model. The impulse response functions and variance decomposition technique suggested by Sims (1980) are useful devices in the VAR framework for testing the sources of variability. The impulse response function can trace the response of the endogenous variables to a shock in another variable. The variance decomposition breaks down the variance of the forecast error for each variable into components that can be attributed to each of the endogenous variables.

Following Sims' (1980) seminal paper, dynamic analysis of VAR model is routinely carried out using the "orthogonalized" impulse responses, where the underlying shocks to the VAR model are orthogonalized using the Cholesky decomposition method. This method assumes the system is recursive and the estimations of impulse response function and variance decomposition are orthogonalized so that the covariance matrix of the resulting innovations is lower triangular (Chen and Patel, 1998). Therefore, the Choleski decomposition method is criticised as an arbitrary method in attributing a common effect and changing the order of the equation may dramatically change the impulses. Recently, Pesaran and Shin (1998) proposed an alternative approach, the generalised impulse response analysis, which is invariant to the ordering of the variables in the VAR. In contrast to the Choleski decomposition method, the generalised impulse response functions are unique (Ibid).

Chapter Four

4. Results and Discussion

4.1. Data Description

Data used in the analysis are annual time series on real GDP, capital, labor and energy use, for Ethiopia during the period 1981–2006. The choice of the starting period was constrained by the availability of data on gross fixed capital formation. All data are extracted from the World Bank, World Development Indicators 2011. In line with many researchers, in the absence of capital stock for all African countries, gross capital formation has been used as proxy for the stock of physical capital. Some descriptive statistics for the variables under consideration are presented in Table 1.The variables' notations and definitions are as follows.

E: "Energy use kt of oil equivalent"

Y: "GDP at market prices at constant 2000 US$"

K: "Gross fixed capital formation"

L: "Labor force 15+ years total"

All variables are transformed into their natural logarithm so that their first differences approximate their growth rates.

Table3 some basic statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
LnGDP	26	22.64858	.2539189	22.3029	23.23989
Lnenergy	26	9.674509	.2056774	9.325809	10.01319
Lncapital	26	20.8997	.4853161	20.13395	21.82198
lnlabor	26	16.94469	.2833088	16.49102	17.39812

Source*: Author's calculation from WDI 2010*

4.2. Unit Root Test Results

Since, the VEC specification in Equations (9)–(13) requires that some or all the variables are integrated of order one, we herein investigate the stationarity status of the variables. In order to have robust results, we conducted five different unit root tests (using Eviews), namely augmented Dickey–Fuller (ADF), Elliot–Rothenberg–Stock Dickey–Fuller GLS detrended (DF–GLS), Phillips–Perron (PP), Kwiatkowski–Phillips–Schmidt–Shin (KPSS), and Ng–Perron MZα (NP). We do not discuss the details of the unit root tests here to conserve space (see Eviews 7.0 guide II, for excellent treatment of ADF, PP, KPSS, and DF–GLS; and Ng and NP).

Although ADF and PP tests are criticized due to their low power properties, we included them in our analysis since most of the studies in the literature still use them (Soytas and Sari, 2006). All unit root tests (except the KPSS) employed in our study have a null hypothesis stating that the series in question has a unit root against the alternative that it does not. The null of KPSS, on the other hand, states that the variable is stationary. In the literature, KPSS is sometimes used to verify the results of commonly used ADF and PP tests although it also suffers from the same low power problems (Soytas and Sari, 2006).

In all cases, a constant and a linear trend were included since this represents the most general specification. The max number of lags was set equal to 4. The choice of the number of lags actually employed was assigned to the Akaike Information Criterion (AIC). Table 2 reports the results obtained.

Table 4 Unit root testes result

Level	ADF	DF–GLS	PP	KPSS	NP (MZα)	
					MZa	MZt
LnGDP	-4.374307	-1.568377	-4.374307	0.216000	-23.8000	-3.42000
LnENERGY	-4.394309	-3.770000	-4.374307	0.216000	-23.8000	-3.42000
LnCapital	-2.872000	-3.770000	-4.374307	0.119000	-17.3000	-2.91000
LnLabor	-4.374307	-3.190000	-4.374307	0.119000	-14.2000	-2.91000
1st difference						
LnGDP	-3.612199 (5%)	-3.770000	-4.394309	0.216000	-14.2000	-2.62000
LnENERGY	-3.243079 (10%)	-3.190000	-3.243079 (10%	0.216000	-14.2000	-2.62000
LnCapital	-4.394309	-3.770000	-4.394309	0.216000	-14.2000	-2.62000
LnLabor	-4.416345	-3.770000	-4.416345	0.216000	-14.2000	-2.62000

Table 4 reports the results of testing for unit roots in the level variables as well as in their first difference. The absolute values of the calculated test statistics for all the variables are less than its critical value at the 5 per cent level. Therefore, in the first half of the Table the null hypothesis that each variable has a unit root cannot be rejected by both tests. In other words, we fail to reject the null hypothesis. However, after applying the first difference, both tests reject the null hypothesis. Since the data appear to be stationary in first differences, no further tests are performed. We, therefore, maintain the null hypothesis that each variable is integrated of order one.

4.3. Co-Integration Test Results

Given the results of unit roots, i.e. since all the variables are I(1), we now use the Johansen cointegration method to test cointegration between the variables. However, before applying this test it is necessary to determine an appropriate lag length in the VAR equation 1, because Granger causality test is very sensitive to the selection of lag length. If the chosen lag length is less than the true lag length, the omission of relevant lags can cause bias. If the chosen lag length is more, the irrelevant lags in the equation cause the estimates to be inefficient (Wolde-Rufael, 2009). The lag length was selected according Final prediction error (FPE), Akaike information criterion (AIC), Schwarz information criterion (SC) and Hannan-Quinn information (HQ). When we start with a lag length of 4 (maximum allowed by the data), the final prediction error, the Akaike information criterion, Schwarz information criterion (SC) and Hannan-Quinn information (HQ)yield 4 to be the optimum lag length. The report of the result is shown in Table5.

Table 5 VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	98.19671	NA	2.24e-09	-8.563338	-8.364966	-8.516607
1	229.3945	202.7602*	6.56e-14	-19.03587	-18.04401	-18.80221
2	243.7972	17.02141	9.00e-14	-18.89066	-17.10532	-18.47009
3	264.9118	17.27558	9.34e-14	-19.35562	-16.77679	-18.74813
4	312.6009	21.67684	1.98e-14*	-22.23644*	-18.86413*	-21.44203*

* indicates lag order selected by the criterion

The results of testing for the number of cointegrating vectors are reported in Table 6 and 7, which presents the maximum eigenvalue (λ max) and the trace statistics, the 5% critical values as well as the corresponding λ values.

Table 6 Unrestricted Co-integration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.997303	229.6159	63.87610	0.0000
At most 1 *	0.950694	99.47469	42.91525	0.0000
At most 2 *	0.618578	33.26116	25.87211	0.0050
At most 3	0.421907	12.05647	12.51798	0.0596

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table 7, Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.997303	130.1412	32.11832	0.0000
At most 1 *	0.950694	66.21353	25.82321	0.0000
At most 2 *	0.618578	21.20470	19.38704	0.0270
At most 3	0.421907	12.05647	12.51798	0.0596

Max-eigenvalue test indicates 3 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

From Table 6 and 7 we can see that both tests suggest the existence of three cointegrating vectors driving the series with common stochastic trends in the data and in the cointegrating equation. Cointegration indicates a long-run relationship between the variables. In effect, this finding suggests that energy consumption may contain important information regarding economic growth.

4.4. Vector Error Correction

The existence of cointegration implies Granger causality; however, it does not point out the direction of causality. Moreover, it shows that the standard Granger causality is inappropriate. In order to assess the direction, we employ a vector error correction

(VEC) modelling. We use VEC because, if the variables in concern are cointegrated, a vector error correction model should be estimated rather than a VAR as in a standard Granger causality test (Granger, 1988).

The error correction terms in VEC provide an additional channel for Granger causality to emerge that is completely ignored by the standard Granger causality tests. That is, in addition to the direction of Granger causality amongst variables, the VECM approach provided the opportunity to examine the causal relationship by preserving the short run dynamics without the loss of long run information (Soytas and Sari, 2006). On top of the extra way for causality to emerge, the VEC offers another advantage that the lost information due to differencing is brought back into the system through the error correction term (ibid). Hence, following Granger (1988), and Engle and Granger (1987), we estimated a VEC model for the Granger causality test using the equations (14) to (17). Sources of causation between the variables in one equations (14) – (17) can be identified through three channels:

(a) the lagged error correction terms γ values

(b) The coefficients of each explanatory variable in one equation (weak or short-run Granger causality);

(c) The terms just described in (a) and (b) jointly (strong or long-run Granger causality).

Hence, following Granger (1988), and Engle and Granger (1987), we estimated a VEC model for the Granger causality test. The VEC representation is as follows:

$$\Delta Y_t = \beta_1 + \alpha_{1,1} v_{1,t-1} + \alpha_{1,2} v_{2,t-1} + \alpha_{1,3} v_{3,t-1} + \sum_{s=1}^{M} \gamma_{1,s} \Delta Y_{t-s}$$

$$+ \sum_{s=1}^{M} \gamma_{2,s} E_{t-s} + \sum_{s=1}^{M} \gamma_{3,s} \Delta K_{t-s} + \sum_{s=1}^{M} \gamma_{4,s} \Delta L_{t-s} + U_{1t} \quad \text{- - - - - - - - - (18)}$$

$$\Delta E_t = \beta_2 + \alpha_{2,1} v_{1,t-1} + \alpha_{2,2} v_{2,t-1} + \alpha_{2,3} v_{3,t-1} + \sum_{s=1}^{M} \gamma_{1,s} \Delta Y_{t-s}$$

$$+ \sum_{s=1}^{M} \gamma_{2,s} E_{t-s} + \sum_{s=1}^{M} \gamma_{3,s} \Delta K_{t-s} + \sum_{s=1}^{M} \gamma_{4,s} \Delta L_{t-s} + U_{1t} \quad \text{- - - - - - - - - - - - - - (19)}$$

$$\Delta K_t = \beta_3 + \alpha_{3,1} v_{1,t-1} + \alpha_{3,2} v_{2,t-1} + \alpha_{3,3} v_{3,t-1} + \sum_{s=1}^{M} \gamma_{1,s} \Delta Y_{t-s}$$

$$+ \sum_{s=1}^{M} \gamma_{2,s} E_{t-s} + \sum_{s=1}^{M} \gamma_{3,s} \Delta K_{t-s} + \sum_{s=1}^{M} \gamma_{4,s} \Delta L_{t-s} + U_{1t} \quad \text{- - - - - - - - - - - - - (20)}$$

$$\Delta L_t = \beta_4 + \alpha_{4,1} v_{1,t-1} + \alpha_{4,2} v_{2,t-1} + \alpha_{4,3} v_{3,t-1} + \sum_{s=1}^{M} \gamma_{1,s} \Delta Y_{t-s}$$

$$+ \sum_{s=1}^{M} \gamma_{2,s} E_{t-s} + \sum_{s=1}^{M} \gamma_{3,s} \Delta K_{t-s} + \sum_{s=1}^{M} \gamma_{4,s} \Delta L_{t-s} + U_{1t} \quad \text{- - - - - - - - - - - - (21)}$$

4.5. Granger Causality Test Results

This section is concerned with tests of Granger causality between GDP and energy. The estimated F-statistics of the causality test are reported in the Tables below. From the result of the Table we fail to accept the null hypothesis that LNGDP does not Granger cause LNENERGY, but we fail to reject the null hypothesis that LNENERGY does not Granger cause LNGDP. Therefore it appears that Granger causality runs one-way from GDP to ENERGY and not the other way.

Table 8 Pair-wise Granger Causality Tests
Lags: 4

Null Hypothesis:	Obs	F-Statistic	Prob.
LNGDP does not Granger Cause LNENERGY	22	4.53434	0.0164
LNENERGY does not Granger Cause LNGDP		0.84939	0.5189
LNCAPITAL does not Granger Cause LNENERGY	22	3.95144	0.0259
LNENERGY does not Granger Cause LNCAPITAL		0.94987	0.4666
LNLABOR does not Granger Cause LNENERGY	22	1.30916	0.3176
LNENERGY does not Granger Cause LNLABOR		0.65143	0.6360
LNCAPITAL does not Granger Cause LNGDP	22	4.12096	0.0226
LNGDP does not Granger Cause LNCAPITAL		2.83008	0.0687
LNLABOR does not Granger Cause LNGDP	22	1.31314	0.3162
LNGDP does not Granger Cause LNLABOR		0.39215	0.8106
LNLABOR does not Granger Cause LNCAPITAL	22	2.95714	0.0611
LNCAPITAL does not Granger Cause LNLABOR		0.14055	0.9641

Vector Error Correction Granger Causality Wald Test

After undertaking pair wise granger causality test, Error Correction Model is also used in the Equations (10) – (13) form and the result are shown in Table 9.

Table 9 VEC Granger causality Wald test result

Dependent variable: D(LNGDP)

Excluded	Chi-sq	df	Prob.
D(LNENERGY)	0.892079	2	0.6402
D(LNCAPITAL)	2.236450	2	0.3269
D(LNLABOR)	3.337130	2	0.1885
All	6.836007	6	0.3363

Dependent variable: D(LNENERGY)

Excluded	Chi-sq	df	Prob.
D(LNGDP)	8.475589	2	0.0144
D(LNCAPITAL)	9.199848	2	0.0101
D(LNLABOR)	8.006716	2	0.0183
All	17.04785	6	0.0091

In the Table 9 where GDP is dependent variable the null hypothesis energy consumption does not Granger cause economic growth and the alterative hypothesis is energy consumption Granger cause economic growth does Granger cause. From the Table it shown that the P values is 0.6402 and based on the "P-value" we tend to accept HO. That is, energy does not granger cause economic growth.

In the Table 9 where energy is dependent variable and with hypothesis GDP does not Granger cause energy consumption and the alternative hypothesis that GDP does Granger cause energy consumption. The "P-value" is 0.0144 and accordingly we tend to reject the null hypothesis and hence we tend to accept the alterative hypothesis. Therefore, the evidence of multi-variate analysis is in line with the growth-led energy consumption hypothesis where causality running from economic growth to energy consumption.

The above two results that is the pair wise Granger causality (which is bi-variate analysis) and the vector error correction model Granger causality test (which is multi-variate analysis including capital and labor) are consistent with each other. Both evidences are in line with the growth-led energy consumption hypothesis where causality running from economic growth to energy consumption, implying that economic development seems to take precedence over energy consumption and that economic growth caused greater demand for energy. The economy of Ethiopia is heavily dominated by the agricultural sector. However the energy use of the sector is insignificant. And the results show that shortage of energy may not adversely affect GDP growth or cause a fall in the GDP in the short run. This is because the agricultural sector does not depend on energy.

The above result of Granger causality running from economic growth to energy consumption in Ethiopia goes in line with the finding of Chontanawat et al. (2008) who found economic growth Granger cause energy consumption using bivariate analysis for Ethiopia. Chontanawat et al. (2008) explicitly discussed that "the degree of causality from energy to

GDP is generally less in the developing world than the developed world (or alternatively causality from energy to GDP generally increases at higher stages of development). Hence the results support the view that energy is generally neutral with respect to its effect on economic growth in the developing world, implying that the effect of energy conservation policies to help combat global warning would have a greater detrimental effect on the overall growth of OECD/developed countries than that of the non-OECD/developing countries".

And it also support the finding of Wolde-Rufael (2005) for five countries (Algeria, Democratic Republic of Congo, Egypt, Ghana and Ivory Coast) who found economic growth Granger cause energy consumption using bivariate analysis. And similarly it goes in line with what found by Wolde-Rufael (2009) for Sudan and Zimbabwe which Granger causality test shows that economic growth Granger cause energy consumption using multi-variate analysis consisting GDP, capital, energy and labor. However it contradicts results for Cameroon, Gambia, Ghana, Morocco and Nigeria. And the result go in line with the result of Akinlo (2008) who found for Sudan and Zimbabwe Granger causality running from economic growth to energy consumption. The result is consistent with Masih and Masih (1996) for Pakistan and Indonesia, Olatunji Adeniran (undated) for Nigeria, Jumbe (2004) for Malawi.

The result also contradicts the result of Yohannes (2010) in Ethiopia of and the result of Amirat et.al (undated) who undertook analyses of the causal relationship between the per capita energy consumption and the per capita GDP in Algeria adding capital and labor to the economic growth and energy consumption nexus and found Granger causality running from energy consumption to economic growth which reverse the result of Chontanawat et al. (2008) for Algeria. It is also inconsistent with Nondo et.al (2009) for 19 CEMESA member countries.

The implication of the uni-directional causality running from economic development to energy consumption result is that, the result may statistically suggest that energy conservation measures may be taken without jeopardising economic development. In practice however, to suggest measures that can lead to the reduction of energy consumption to the end-user in order to halt any conservation problem arising out energy consumption may not be a viable option for Ethiopia particularly given the magnitude of the energy problems and the fact that the current energy infrastructure of the country is still inadequate to support the quest for rapid economic growth that is required to eradicate poverty and to raise the living standards of the people. Reducing energy consumption while the overwhelmingly majority of the population is still denied access to the use of modern form of energy may not be a viable option. Ethiopia has not yet reached the energy ladder that may warrant such a suggestion but it can still substantially improve the detrimental consequences of energy consumption (example the loss of natural resource for energy and the subsequent loss of soil fertility and erosion) without reducing its use. By making its energy sector more efficient and by making it available to a larger part of the population (especially electricity) energy used per unit of output can be raised.

4.6. Test of Volatility

The Granger-causality tests conducted above indicate only the existence of causality. They do not, however, provide any indication on how important is the causal impact that energy has on output growth. For example, when there is a shock to energy supply, it would also be interesting to know by how much this shock will affect the growth rates of output. In addition, it is very important to know how much time the effect of such a shock will last. In order to provide answers to these questions, we next decompose the variance of the forecast-error of output growth into proportions attributable to innovations in each variable in the system including its own.

4.6.1. Variance Decompositions

Consider again the VEC model in Eqs. (18) – (21). A change in anyone of the random innovations Ui,t, is1, 2, 3, 4 will immediately change the value of the dependent variable and, hence, will also change the future values of the remaining variables in the system through the dynamic structure of the model. Since changes in the random innovations produce changes in the future values of the variables, it is possible to decompose the total variance of the forecast-error in anyone of them and determine how much of this variance each variable explains.

Table10 Results of variance decomposition

Variance Decomposition of LNGDP: Period	S.E.	LNGDP	LNENERGY	LNCAPITAL	LNLABOR
1	0.069693	100.0000	0.000000	0.000000	0.000000
2	0.102653	95.26059	1.340314	0.020477	3.378624
3	0.124090	76.46997	4.682919	9.668670	9.178445
4	0.138588	64.75990	4.160713	20.34437	10.73502
5	0.145461	63.86346	3.789056	21.99754	10.34995
6	0.152539	66.59593	3.620604	20.00349	9.779975
7	0.159734	68.66586	3.768251	18.33019	9.235700
8	0.165557	69.72928	3.618262	17.38388	9.268578
9	0.171321	70.10078	3.466246	16.66630	9.766676
10	0.177709	69.57709	3.545265	16.24169	10.63596
11	0.184304	68.48345	3.589158	16.83770	11.08969
12	0.190099	68.09865	3.481717	17.19294	11.22669
13	0.195458	68.51985	3.397668	16.89648	11.18601
14	0.200734	69.06966	3.389332	16.40376	11.13725
15	0.205762	69.44905	3.363517	16.06932	11.11812

Since our interest focuses on the response of output growth to shocks in the factor inputs, in particular energy, we only decompose the forecast-error variance of the output growth variable in response to a one standard deviation innovation in capital, labor and energy. These responses are estimated using random generation of the parameters of the model Eqs. (18)–(21) in a Monte Carlo study with 100 iterations. Since the innovations are not necessarily totally uncorrelated, the residual terms are orthogonalized using a Choleski decomposition in order to obtain a diagonal covariance matrix of the resulting innovations and, therefore, isolate the effects of each variable on the other.

Figure 2 Variance decomposition of LN GDP

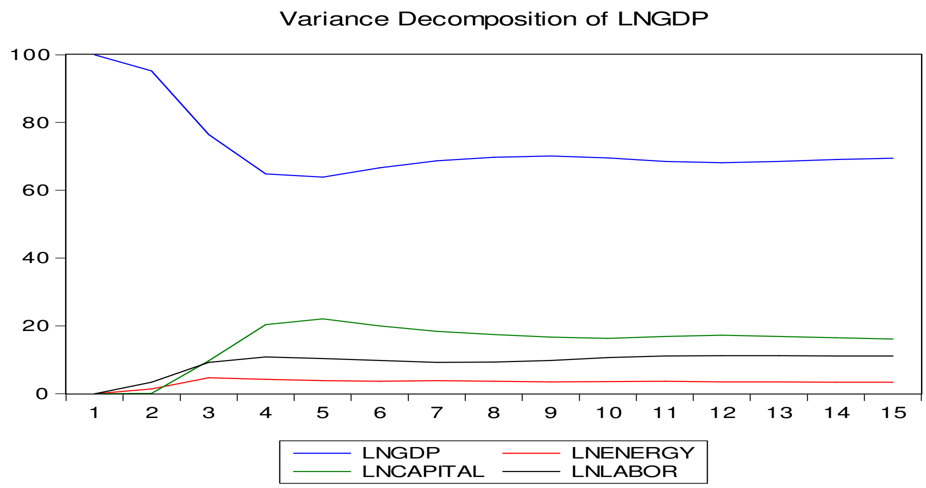


Figure2 the response of output growth in Ethiopia to a one standard deviation innovation in inputs

Table 10 and Figure 2 report the results of the variance decomposition of output growth in Ethiopia within a 15-period horizon. As can be seen in the Table, the three factor inputs together explain approximately 30.56% of the future changes in output growth in Ethiopia. The remaining 66.44% are due to changes in output growth itself. Looking at the separate effects of factor inputs, capital has the highest effect on output growth followed by labor then energy. Approximately 16% of future changes in output growth are due to changes in capital, 11% due to labor and 3.4% due to energy. The result shows capital is the most important input in Ethiopia followed by labor and energy respectively.

The results in Table 10 clearly indicate that capital has an important impact on future growth rate of output in Ethiopia. Energy has less importance compared to capital and labor. As can be seen from the Table 10 the response of output growth to shocks coming from energy input is slow during the first periods and its full effect on output starts during third period and its permanent effect start at period five. Capital starts its full effect during the 4th period and its permanent effects starts at the ninth period. And labor starts its full and permanent effect on output at the 11th period.

The result is consistent with Amirat et.al (undated) who found the variance error decomposition of capital high compared to energy and it is also consistent with the result of Sari and Soytas (2007) who found in Singapore, energy to be less important than the other inputs in short run.

The relatively low level contribution of energy to output growth for Ethiopia may be an indication that the causal relationship between energy consumption and economic growth is relatively weak when compared to either capital or labor. The low level of economic development that characterizes this country reflects and reinforces the limited energy development and consumption. The current energy infrastructure is insufficient to promote sustainable economic development (ECA, 2004).

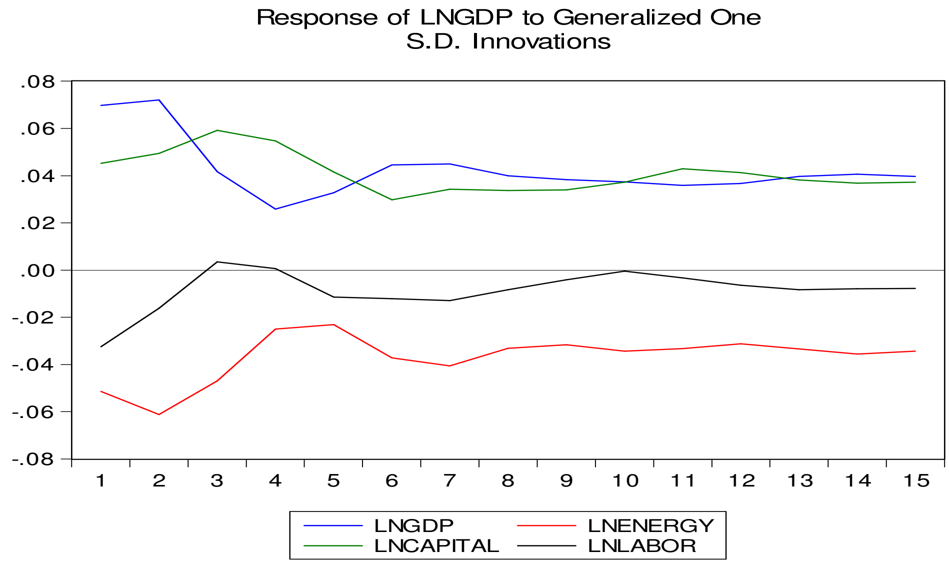
The empirical evidence indicates that capital may be relatively more important input than both labor and energy in Ethiopia. Although this may be due to the fact that in Ethiopia, labor tends to be abundant and relatively cheaper, our results suggest that in order to sustain high economic growth rates in the long run the country need to expand its saving capacity to generate capital.

4.6.2. Generalized Impulse Responses

Although variance decomposition by the estimate of the proportion of output (GDP) variance accounted its determinants, it cannot indicate whether the impact is positive or negative, or whether it is a temporary jump or long-run persistence. Thus, impulse response functions are computed to give an indication of the system's dynamic behaviour. Also, the impulse response functions can be used to predict the responses from output determinants to output (GDP). An impulse response function shows how a variable in the VECM system responds to a single 1 percent exogenous change in another variable of interest.

Table 11 Impulse repose function

Figure 3 Impulse response function



The Figure 3, which is a combined graph of all the endogenous variables illustrated the estimated impulse response functions for 15 years.

Table 11 and Figure 3 indicates the following results. In response to a one standard deviation disturbance output (GDP) itself future output increase by .07 in the first year and it declines in the third year but it never die out in the long run and reaches 0.04 at the fifteenth year. A one standard deviation disturbance originating from energy produces up to -.05 decline in output; and it increases to -.025 after the fourth year and it did not die out in the time horizon and reaches -.034 at the 15th year. The result from the Table 11 and graph shows the impact of energy is permanent.

A one standard deviation disturbance originating from capital results in an approximately 0.05 percent increase in output in first year and it further increase to .06 in the 3rd year and it did not die out in the time horizon and consequently it reaches .04

at the 15th year. A one standard deviation disturbance originating from labor results in an approximately -.03 percent decrease in output in first year and it dies out in the long run and consequently it reaches -.007 at the 15th year. The result shows the impact of capital is permanent while that of labor is not permanent

The striking result is the disturbance originating from energy is negative (albeit it is small in magnitude) signifying that energy use negatively impacts on economic growth. The negative relationship between energy consumption and economic growth indicates the low level of energy efficiency in the country. Energy efficiency measures the amount of GDP generated by one unit of energy use. Although the average African currently uses far less energy than the world average, producing a dollar's worth of GDP uses more energy in Africa on the average than the rest of the world (ECA, 2004).Ethiopia has low level of energy efficiency in Africa, with $2.6 of GDP for one unit of energy use in 2000 compared to the Sub-Saharan Africa average of $2.9 (ibid). Moreover, electricity transmission and distribution losses were a fifth (20%) of total output in Ethiopia compared to 2.9% for Zambia and the world average of between 10 and 12% (ibid). Like many African countries, Ethiopia has to reduce inefficacy in the supply and use of energy.

The power shortage due to insufficient hydropower generation during time of drought as hydroelectricity represents the primary source of electricity for Ethiopia could also be another factor for the negative relationship between energy and economic growth. These shortages and inefficiencies could constrain enterprise development and detrimental to the growth of employment in the country.

Chapter Five

5. Conclusions and Policy Implications

In this paper, we study the relationship between income and energy consumption in a multivariate framework by including capital and labor in the causality analysis. The evidence is in line with the growth-led energy consumption hypothesis where causality running from economic growth to energy consumption, implying that reducing energy consumption may be implemented with little or no adverse effect on economic growth. In practice however any conservation measures taken to reduce energy consumption may not be a viable option for Ethiopia particularly given the magnitude of its energy problems and the fact that the current energy infrastructure of the country is still inadequate to support its quest for rapid economic growth and for eradicating poverty.

The option therefore might be for Ethiopia to enhance the level of efficiency in the energy sector. Increasing energy efficiency can cut down growth of energy demand that can mitigate conservation and health problem. As noted by IEA (2002), finding ways of expanding the quality and quantity of energy services while simultaneously addressing the environmental impacts associated with energy use represents one of the critical challenges Africa is facing. This means that energy regulation policies supporting the shift from lower-quality (typically less efficient and more polluting) to higher-quality energy services could provide impulse to economic growth rather than be detrimental to the development process (Costantini and Martini, 2010).

The strength of this causal relationship, as measured by the variance decomposition analysis, reveals that, energy was no more than a minor contributing factor to output growth and certainly not the most important one when compared to capital and labor. Labor and capital were the most important factors in output growth in Ethiopia. The empirical evidence indicates that capital may be relatively more important input than both labor and energy in Ethiopia. Although this may be due to the fact that in Ethiopia, labor tends to be abundant and relatively cheaper, our results suggest that in order to sustain high economic growth rates in the long run the country need to expand its saving capacity to generate capital. But concomitantly the country needs to expand its energy generating capacities. Energy needs of Ethiopia will not only be affected by rising residential energy demand as a result of income growth, but also by the industrial demand for energy as the economies expand in the long run.

Since short run energy shortages may have significant impacts on the long run economic performances, the country need to attract new capital for its energy industries. However, expanding energy production is not the one and only solution to the growth problems of the country. Promoting energy efficiency and focusing on decreasing energy intensity may also have positive impacts on economic growth rates without putting considerable pressure on the environment. Developing energy sources that are renewable and that have low or no carbon content seem to be essential for this purpose.

Irrespective of the strength of the causal relationship between energy consumption and economic growth, the energy challenge facing Ethiopia is daunting. Since in Ethiopia the current energy infrastructure is simply insufficient to promote sustainable economic development, the country can stimulate economic growth by investing more on energy and by reducing energy inefficacy in the supply and use of energy. Unfortunately, in

Africa, it is not energy lack that is the basic problem but the lack of "…institutions, rules, financing mechanisms, and regulations needed to make markets work in support of energy for sustainable development" (UNDP, 2004). Until these elementary limitations that are restraining the development of an efficient and accessible energy sector are fully solved, energy supply will still persist to be a major obstacle for the economic and social development Ethiopia.

References

Akinlo, A.E., 2008. "Energy consumption and economic growth: evidence from 11 African countries." *Energy Economics 30, 2391–2400.*

Amirat and Bouri, undated. "Energy and Economic Growth: The Algerian Case"

Aqeel, A., Butt, M. S. 2001. The Relationship between Energy Consumption and Economic Growth in Pakistan. *Asia-Pacific Development Journal, 8, 2.*

Asafu-Adjaye, J. 2000. "The Relationship between energy consumption, energy prices and economic growth: Time series evidence from Asian developing countries". *Energy Economics*, *22*, 615–625.

Ayres, R.&I.Nair. 1984. "Thermodynamics and economics." *Phys. Today* 35, 62–71.

Chang, Tsangyao. 2002. "An econometric test of Wagner's law for six countries based on cointegration and error-correction modelling techniques." *Applied Economics, 34, 9, 1157 — 1169*

Chen and Patel, 1998. "House Price Dynamics and Granger Causality: An Analysis of Taipei New Dwelling Market". *Journal of the Asian Real Estate Society 1, 101 – 126*

Chontanawat, J., Hunt, L.C., Pierce, R., 2008. "Does energy consumption cause economic growth? Evidence from systematic study of over 100 countries." *Journal of Policy Modelling 30, 209–220*

Cleveland, C.J., R.K. Kaufmann & D.I. Stern. 2000. "Aggregation and the role of energy in the economy." *Ecological Ecoomics.*32, 301–318.

Costantini,V.and C.Martini. 2010. "The causality between energy consumption and economic growth: a multi-sectoral analysis using non-stationary cointegrated panel data". *Energy Economics.* 32, 591–603.

DavidG.Ockwell.2008. “Energy and economic growth: Grounding our understanding in physical reality.” *Energy Policy 36, 4600–4604*

Ebohon, O. J. 1996. “Energy, economic growth and causality in developing countries: A case study of Tanzania and Nigeria”. *Energy Policy*, *24*, 447–453.

ECA (Economic Commission for Africa), 2004. “Unlocking Africa's Trade Potential. Economic Report:”

ECA (Economic Commission for Africa), 2008. “Energy for Sustainable Development: Policy Options for Africa UN-ENERGY/Africa.”: A UN collaboration mechanism and UN sub-cluster on energy in support of NEPAD.

EEA. 2009. “Problems and Prospects of energy sector in Ethiopia” *Bulletin of the Ethiopian Economic Association. .3, 5*

Ghali, K.H. and M.I.T. El-Sakka, 2004. “Energy use and output growth in Canada: a multivariate cointegration analysis”. *Energy Economics 26, 225–238*

Granger, C.W.J. 1969. “Investigating causal relations by econometric models and cross-spectral methods.” *Econometrica* 37, 424–438

Granger, C.W.J., 1988. Causality, cointegration, and control. *Journal of Economic Dynamics and Control 12, 551–559.*

Gujarati, D. 1995. “Basic Econometrics analysis.” 3rd Edition, McGraw-Hill, New York.

IEA.2004. World Energy Outlook

IEA. 2010. World Energy Outlook

Jumbe, C.B.L. 2004. “Cointegration and Causality between Electricity Consumption and GDP: Empirical Evidence from Malawi.” *Journal of Energy Economics, 26,1, 26-68.*

Kraft, J. and A. Kraft. 1978. “On the relationship between energy and GNP” *Journal of Energy Development 3, 401-403.*

Masih, A.M.M., Masih, R., 1998. "A multivariate cointegrated modeling approach in testing temporal causality between energy consumption, real income and prices with an application to two Asian LDCs." *Applied Economics 30, 1287–1298.*

Ministry of Finance and Economic Development (MOFED).2010. "Growth and Transformation Plan (GTP), 2010/11-2014/15". September 2010, Addis Ababa

Ministry of Water and Energy, Strategic Plan, (2011-2015)

Ng, S., Perron, P. 2001. "Lag length selection and the construction of unit root tests with good size and power." *Econometrica 69, 1519–1554.*

Nondo and Mulugeta. 2009. "Energy Consumption and Economic Growth: Evidence from COMESA Countries."

Pesaran, M.H., Shin, Y. 1998. "Generalised impulse response analysis in linear multivariate models." *Economics Letters 58, 17–29.*

Rognvaldur Hannesson. 2009. "Energy and GDP growth." *International Journal of Energy Sector Management , 3, 2, 2009, 157-170*

Soytas, U. and R. Sari. 2003. "Energy consumption and GDP: causality relationship in G-7 countries and emerging markets" *Energy Economics, 25, 33-37.*

Sari, R., Soytas, U., 2004. "Disaggregate energy consumption, employment, and income in Turkey." *Energy Economics 26, 335–344.*

Soytas, U., Sari, R., 2006. "Energy consumption and income in G-7 countries." *Journal of Policy Modelling 28, 739–750.*

Soytas, U., Sari, R., 2007. "The relationship between energy and production: evidence from Turkish manufacturing industry." *Energy Economics 29, 1151–1165.*

Stern, D.I. 1993. "Energy use and economic growth in the USA, a multivariate approach." *Energy Economics.* 15, 137–150.

Stern, D.I. 1996. "Limits to substitution and irreersibility in production and consumption: A neoclassical interpretation of ecological economics." *Ecological Economics 21, 197-215*

Stern, D.I. 2000. "A multivariate cointegration analysis of the role of energy in the U.S. macro economy." *Energy Economics.*22, 267–283.

Stern, D.I., Cleveland, C.J., 2003. "Energy and economic growth." Rensselaer Working Papers in Economics 0410.

Stern, D.I. 2010. "Energy quality. *Ecological Economics* 69, 1471–1478.

David I. Stern. 2011. "The role of energy in economic growth". *Ecological Economics Reviews. Eds. Ann. N.Y. Acad. Sci. 1219, 26–51.*

Toman, M.A. & B. Jemelkova. 2003. "Energy and economic development: an assessment of the state of knowledge." *Energy J. 24, 93–112.*

Wooldridge, J.M. 2002. "Econometrics analysis of time series data." The MIT press, Cambridge, Massachesetts, London, Engalnd.

Wolde-Rufael, Y. 2004. "Disaggregated industrial energy consumption and GDP: the case of Shanghai, 1952– 1999" *Energy Economics 26, 69-75.*

Wolde-Rufael, Y. 2004. "Electricity consumption and economic growth: a time series experience for 17 African countries." *Energy Policy 34, 1106–1114*

Wolde-Rufael, Y. 2005. "Energy demand and economic growth: the African experience." *Journal of Policy Modelling 27, 891–903.*

Wolde-Rufael, Y. 2008. "Energy consumption and economic growth: The experience of African countries revisited." *Energy Economics 31, 217–224*

Wolde-Rufael, Y. 2009. "Energy consumption, pollutant emissions and economic growth in South Africa." *Energy Economics 32, 1374–1382*

World Bank. 2010. World Development Indicators.

Yohannes Hailu. 2010. “Energy, Growth, and Environmental Interaction in the Ethiopian Economy.”

Yuan, J., Kang, J., Zhao, C., Hu, Z. 2008. “Energy consumption and economic growth revisited: evidence from China both at the aggregate ad disaggregate level.” *Energy Economics 30, 3077–3094.*

Zachariadis, T., 2006. “An empirical time series analysis of energy consumption in Cyprus”

Zachariadis, T., 2007. “Exploring the relationship between energy use and economic growth with bivariate models: new evidence from G-7 countries.” *Energy Economics 29, 1233–1253*

Declaration

I do, the undersigned, hereby declare that this project is my original work, has not been presented for a degree in any other university and that all sources of material used for the project have been duly acknowledged.

Declared by:

Name: ____

Signature: ____

Date: ____

Confirmed by advisor:

Name:____

Signature; __________________________________

Date: ________________________________

Place and date of submission:

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