Energy Demand Management in Selected African Countries

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Abstract

This thesis contains five empirical papers that contribute to the energy demand management literature on Africa. It investigates the following policy issues – business cycle and energy conservation, government fuel subsidies and energy efficiency, economic growth and environmental quality, structural effects in parameters, the transition between energy efficiency and energy inefficiency, forecast of energy demand, shifts in demand behaviour, and the persistence profile of energy demand to shocks – using data from five countries: Algeria, Nigeria, South Africa, Cameroon and Ghana.

In terms of contribution, this thesis provides the first empirical attempt to investigate the transition between energy efficiency and energy inefficiency; provides a comprehensive analysis of road transport energy demand and the implications of structural breaks for model parameters; provides evidence to support the fact that economic growth and environmental quality are jointly achievable, and argues that there is an income state that drives investment in energy efficiency.

The main results of the thesis are as follows. First, low income state does not promote investment in energy efficiency. Second, reducing or withdrawing government fuel subsidies will enhance energy efficiency. Third, investment in technology in the industrial sector is a likely panacea to integrate the goals of economic growth and environmental quality. Fourth, the existence of structural breaks in the data significantly changes how price of crude oil, FDI, economic structure and trade openness promote energy efficiency. Fifth, the characteristics of industries and technology absorptive capacity of countries significantly facilitate energy savings in FDI. Sixth, the duration of an energy inefficient state is about twice as long as an energy efficient state, mainly due to fuel subsidies, low income, high corruption, regulatory inefficiencies, poorly developed infrastructure and undeveloped markets. Finally, diesel and gasoline fuels differ in many respects which suggest that a discriminatory tax policy would be an appropriate tax policy than a uniform tax policy.

Keywords: Energy demand management, structural effects, energy conservation policy, Business cycle, transition between energy-use states, Algeria, Cameroon, Nigeria and South Africa, Ghana

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Dedication

To my mother Mrs Elizebeth Adutuwumwaa Oheim, my sister Joyce Adom, my wife Mrs Edna Yaa Manu Adom and my daughters Elizebeth Adutwumwaa Adom and Kisiwaa Nhyira Adom.

But you, be strong and do not let your hands get weak, for God will reward the works of your hands... 2 chronicles 15:7.

Contents

List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Adom, P.K. (2015). Business Cycle and Economic-wide Energy Intensity: The implications for Energy Conservation Policy in Algeria. *Energy*, 88(8), 334-350.

II Adom, P.K. (2015). Asymmetric impacts of the determinants of energy intensity in Nigeria. *Energy Economics* 49(2), 570-580.

III Adom, P.K. (2015). Determinants of energy intensity in South Africa: Testing for Structural effects in parameters. *Energy*, 89(9), 334-346.

IV Adom, P.K. (2016). The transition between energy efficient and energy inefficient states in Cameroon. *Energy Economics*, 54(1), 248-262.

V Adom, P.*K.*, Bekoe W., Quartey G, Barnor C., Amakye K. (2016). Shift in demand elasticities, road energy forecast and the persistence profile of shocks in Ghana. Accepted in *Economic Modelling.*

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The contribution of Philip Kofi Adom to the papers included in this thesis was as follows:

V I proposed the idea. I was involved with the conceptualisation and the writing of introduction and literature. I did the data analysis and discussion of the results.

Abbreviations

ARDL Autoregressive Distributed Lag
Btu British thermal unit
EPA Environmental Protection Agency
EKC Environmental Kuznet Curve
EU European Union
FDI Foreign Direct Inflows
GDP Gross Domestic Product
GM Generalised Methods
GM-ARMA Generalised Methods-Autoregressive Moving Average
IEA International Energy Agency
IMF International Monetary Fund
OECD Organization for Economic Cooperation and Development
OLS Ordinary Least Squares
MENA Middle East and North Africa
MW Megawatt
SCVAR Structural Cointegration Vector Autoregressive

1 Introduction

This thesis contains five papers that touch on various aspects of energy demand management in five selected African countries – Algeria, Nigeria, South Africa, Cameroon and Ghana. Energy efficiency, as used in this thesis, implies producing more output or providing more services with less energy. It follows that energy inefficiency result when more energy is used to provide/produce less service/output. Using energy intensity as an indicator, energy efficiency/inefficiency implies a reduction/rise in energy intensity.

The first paper focuses on Algeria and investigates three important policy issues. First, it investigates the income state that is compatible with energy conservation behaviour. Second, it simulates the benefit of withdrawing government fossil fuel subsidies. Third, it tests the hypothesis that long-term sustainable economic growth and environmental quality are jointly feasible policy goals if industrial expansion should move parallel with technological change.

The second paper focuses on Nigeria and addresses two main policy issues. First, it investigates the country conditions that facilitate the energy saving potential of foreign direct inflows. Second, it tests for the existence of structural effects in the parameter estimates.

The third paper focuses on South Africa. First, the study examines how de-industrialisation and changes in trade structure in favour of more imports have contributed to energy efficiency improvement in South Africa. Second, it tests for the existence of structural effects in the parameters.

The fourth paper investigates the transition between energy efficient and energy inefficient states in Cameroon. It provides estimates of the transition probabilities for and the duration of energy efficient and energy inefficient states. In an intertemporal sense, energy efficient/inefficient states are states with negative/positive growth rate in energy intensity. Thus, in energy efficient state, more services/output is provided/produced with less energy.

The fifth paper analyses road transport energy demand in Ghana. It touches on four main policy issues. First, we investigate if a uniform tax policy for diesel and gasoline fuels is justified. Second, we predict diesel and gasoline consumption from 2012 to 2030. Third, we determine how the price and income elasticities have changed after the eighties. Finally, we examine the persistence profile of aggregate energy, diesel and gasoline energy consumption to shocks in the system, price, income and consumption.

The contribution of $C0_2$ emissions from energy sources to global atmospheric concentration of $C0_2$ continues to grow due to the surge in global energy use. Between 1980 and 2000, global total primary energy consumption increased from 283.1474 quadrillion btu to 398.276 quadrillion btu. This represents a growth rate of 41%. By the end of 2012, global total primary energy consumption had increased from 398276 quadrillion btu in 2000 to 524.0758 quadrillion btu, which represents a growth rate of 32% (Energy Information Administration Statistics). Thus, growth in global energy use has been astronomical in the recent decade compared to previous decades. Much of this recent increase can be blamed on the growth in size of most economies and the widespread inefficiencies in certain sectors in some economies. Consequently, global $C0_2$ emissions from energy sources have increased from 24,041,047 million metric tonnes in 2000 to 32,310.287 million metric tonnes in 2012 (Energy Information Administration Statistics), which represents a growth rate of 34.4%. Emphasizing global energy use management is now one of the important policy tools favoured by the international community to mitigate the adverse effects of climate change. This is because energy efficiency has been identified as the least cost way to curb the adverse effects of climate change. Since energy efficiency emphasises saving energy and resources, it could also be seen as a tool to address poverty in most less developed economies. This is because money saved from using less energy could be saved or diverted to other productive uses in the economy.

Growth in Africa has been impressive recording 3.5% in 2013, 3.9% in 2014 and 4.5% in 2015 (Africa Development Bank, 2015). It is estimated that growth will hit 5% in 2016 (Africa Development Bank, 2015). The major drivers have been vibrant service and industrial sectors. Figure 1 shows the plot of real gross domestic product for South Africa, Nigeria, Ghana, Cameroon and Algeria. Real GDP increased steadily between 1960 and 1981; levelled off between 1981 and 1994 but increased sharply between 1994 and 2013 in South Africa. The early period growth (i.e. 1960-1981) was driven more by a vibrant industrial sector. However, the coexistence of limitless trade restrictions and increased inefficiencies in the public sector moderated the speed of growth. The persistence of the limitless trade restrictions in the country combined with the fall in global commodity prices and international sanctions contributed to growth stagnation during 1981 and 1994. In 1994 and 2006, the government implemented the government liberalization program and the Accelerated and Shared Growth Initiative of South Africa, respectively. Among other things, these policy initiatives boosted business confidence and increased fixed investment both domestic and foreign. These programs, alongside institutional reforms, have contributed to the recent economic fate of South Africa.

In Nigeria, real GDP remained stable between 1960 and 1970; increased gently between 1970 and 1980 but fell again between 1980 and 1988. Real

GDP has since increased steadily picking up strongly after 2002. The period prior to 1970 characterises the pre-oil boom period. During this period, growth was largely driven by the agricultural sector with very high government protection in the sector. However, local industries did not successfully take advantage of the protection to improve their competitiveness making them vulnerable to international competition. The ill-adapted technology; predominance of subsistence agriculture; bias nature of public policy; weak institutions and the narrow production base which characterized the period before the oil boom may have contributed to the stagnant nature of the economy. The emergence of oil in 1970 helped create a more vibrant industrial sector causing growth between 1970 and 1980. Also, the implementation of the "operation feed the nation" program helped promote growth during the period. However, the collapse in oil price during 1980 and 1988 and the rise in government debt contributed to the recession in this period. One of the reasons for implementing the Structural Adjustment Program was to reduce the reliance on the petroleum sector and also to create a more sustainable low inflation economy. The impact of the policy on the economy was mild as growth only increased marginally during 1989 and 2002. Several factors contributed to the slow growth. These include but not limited to high corruption which slowed foreign investment; raw material constraints in the industrial and manufacturing companies; power blackouts and limited supply of petroleum. The government after 2002 introduced an anti-corruption bill. This, combined with the increase in the price of crude oil and other institutional reforms, contributed positively to growth after 2002. That notwithstanding, the poor state of public infrastructure especially in the energy sector and the prevalence of corruption continue to be major constraints to Nigeria's economic success.

Ghana's growth had been derailed prior to 1983 largely due to government quantitative restrictions which increased economic-wide inefficiencies and resulted in unfavourable macroeconomic aggregates. As shown in Figure 1, real GDP remained very low prior to the year 1983. In 1983, the government instituted an economic reform program which aimed, among other things, at creating a more liberalized economy and restoring macroeconomic aggregates. Coupled with other complementary programs such as the Structural Adjustment program in 1986 and the Financial Structural adjustment Program in 1988, growth in the economy picked up tremendously. As depicted in Figure 1, real GDP has increased sharply since 1983.

Cameroon experienced economic stagnation during 1960 and 1972. This period characterized the restricting stage after obtaining independence in 1960. Therefore, the natural barriers that confront every newly independent economy were at play. Political instability was still prevalent and macroeconomic aggregates were not favourable. However, beginning from 1972, growth picked up thanks to the oil boom which created a vibrant industrial sector and increased optimism in the country. As shown in Figure 1, real GDP increased but the trend reversed between 1987 and 1994. The major cause of the recession during this period included high public debt and restricted economy. The government in response to the crisis embarked on a liberalization and deregulation program. This, in addition to other pro-growth policies, contributed to the upsurge in growth. Figure 1 shows that, during this period, real GDP increased.

Algeria’s real GDP has increased consistently with noticeable periods of recession and stagnation. Much of this growth has been driven by the hydrocarbon sector. The hydrocarbon sector in Algeria constitutes 98% of export earnings and about 46% of gross domestic product. In 2011, for instance, the hydrocarbon sector constituted 98% of total export earnings; 78% of budget revenue and 36.7% of gross domestic product. However, the continuous state-dominated nature of the economy and restrictive trade and foreign investment policies are potential constraints to future economic prospects.

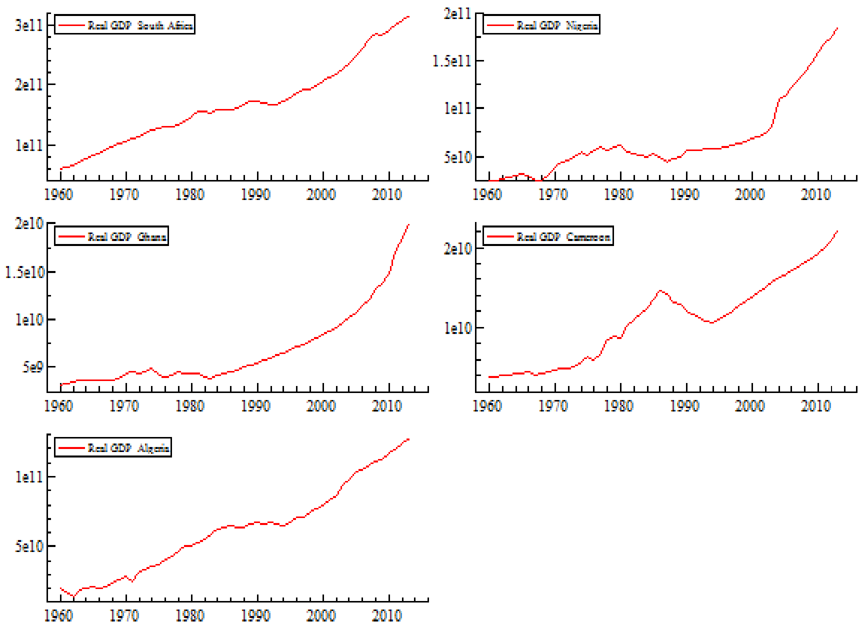

Figure 1: Time plot of real gross domestic product (constant 2005 US$) 1960-2013

Data source: World Bank Development Indicators database

Though gross domestic product in these economies has experienced leaps and bounds, on the average, gross domestic product has improved in these economies. This has caused aggregate demand in these economies to increase and result in growth in energy consumption. Figure 2 shows the time plot of total primary energy consumption in these countries. It is evident that total primary energy consumption in these countries continues to increase. As at 2012, total primary energy demand in Africa stood at 739 million tonnes of oil equivalent (Mtoe) with North Africa accounting for 23% (International Energy Agency, 2014). In sub-Saharan Africa, total energy demand stood at 570 Mtoe in 2012, and the largest energy centres in this region has been Nigeria (141 Mtoe) and South Africa (141 Mtoe) (International Energy Agency, 2014). Unfortunately, the region has not experienced similar expansion in economic infrastructure in all sectors to match the growth in energy demand. Consequently energy intensity, which is a measure of how efficient energy is used, remains high in the region. Figure 3 shows the plot of energy intensity in Africa compared to other continents. Africa and Middle East are the regions with the highest energy intensity. This suggests that energy is inefficiently used in these regions. Figures 4 to 7 show the sub-regional energy intensities. In North Africa, energy intensities in Egypt and Algeria are the highest (see Figure 4). In Southern Africa, energy intensity in South Africa is the highest (see figure 5). In Central Africa, energy intensities in Sao Tome, Congo and Cameroon are the highest (see figure 6) while, in West Africa, energy intensities in Mauritania, Ghana, Nigeria, Cape Verde and Guinea are the highest (see figure 7). This implies that, on the average, more energy is required to produce a unit of output in these economies. Thus, energy is inefficiently used in these economies. The current energy situation in Africa has caused energy access problems (International Energy Agency, 2014) and frequent power outages (Adom et al., 2015; Akpan and Nde, 2011; Verwijs, 2008; Isife, 2010; World Bank, 2015). For example, sub-Saharan Africa has the lowest electricity access rate in the world. More than 620 million people in the region are without electricity (International Energy Agency, 2014).

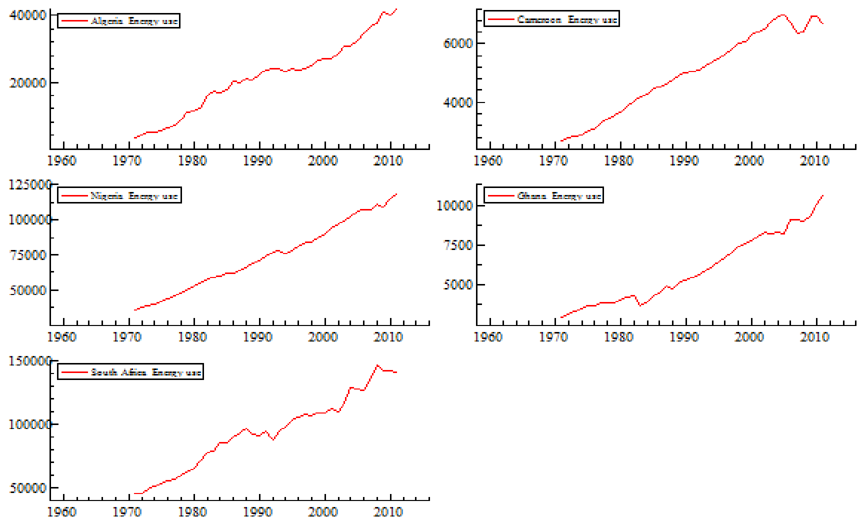

Figure 2: Time plot of total primary energy use (kt of oil equivalent) 1971-2011

Data source: International Energy Statistics – Energy Information Administration

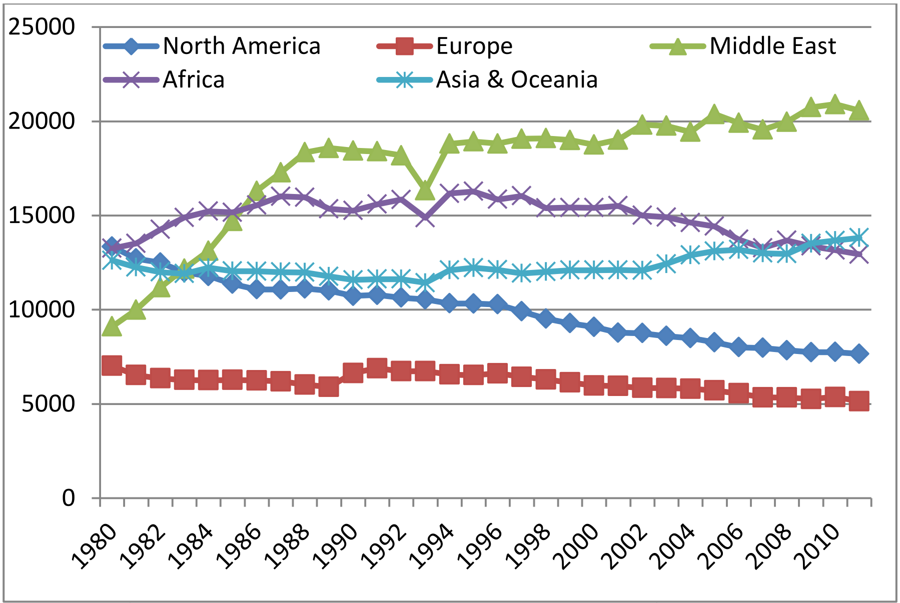

Figure 3: Plot of Energy intensity - Total Primary Energy Consumption per Dollar of GDP (Btu per Year 2005 U.S. Dollars (Market Exchange Rates))

Data source: International Energy Statistics – Energy Information Administration

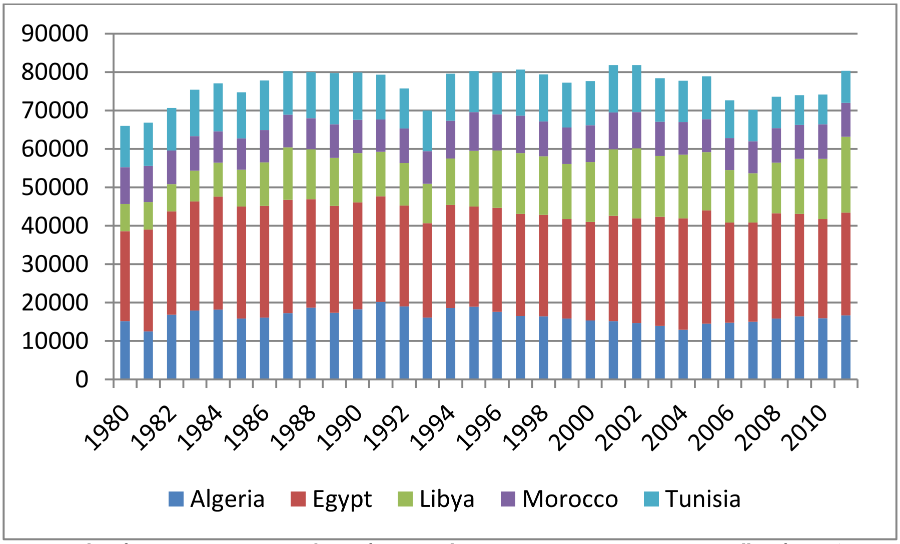

Figure 4: Plot of Energy intensity in Northern Africa - Total Primary Energy Consumption per Dollar of GDP (Btu per Year 2005 U.S. Dollars (Market Exchange Rates))

Data source: International Energy Statistics – Energy Information Administration

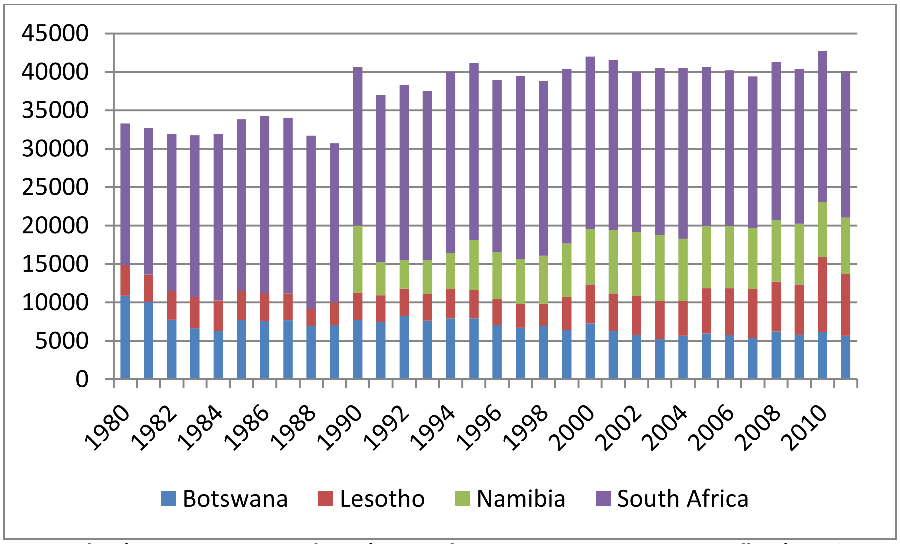

Figure 5: Plot of Energy intensity in Southern Africa - Total Primary Energy Consumption per Dollar of GDP (Btu per Year 2005 U.S. Dollars (Market Exchange Rates))

Data source: International Energy Statistics – Energy Information Administration

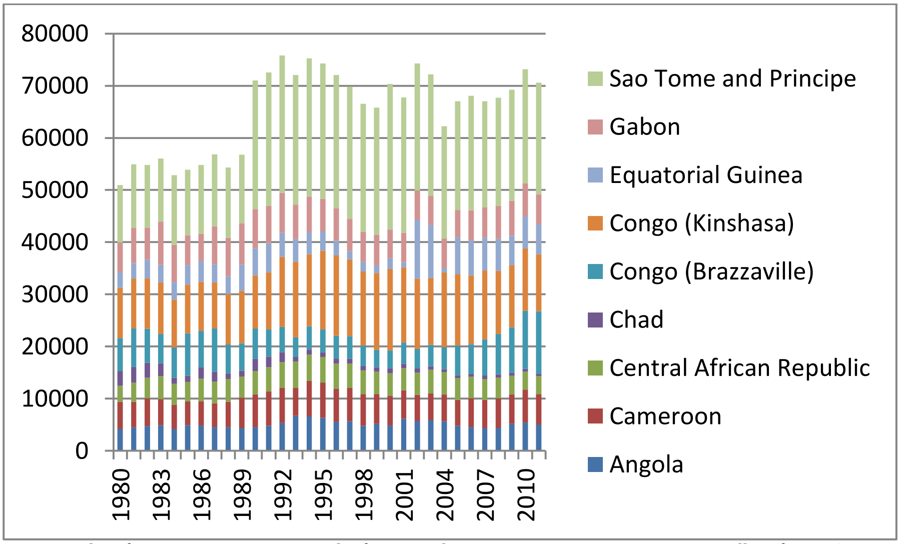

Figure 6: Plot of Energy intensity in Central Africa- Total Primary Energy Consumption per Dollar of GDP (Btu per Year 2005 U.S. Dollars (Market Exchange Rates))

Data source: International Energy Statistics – Energy Information Administration

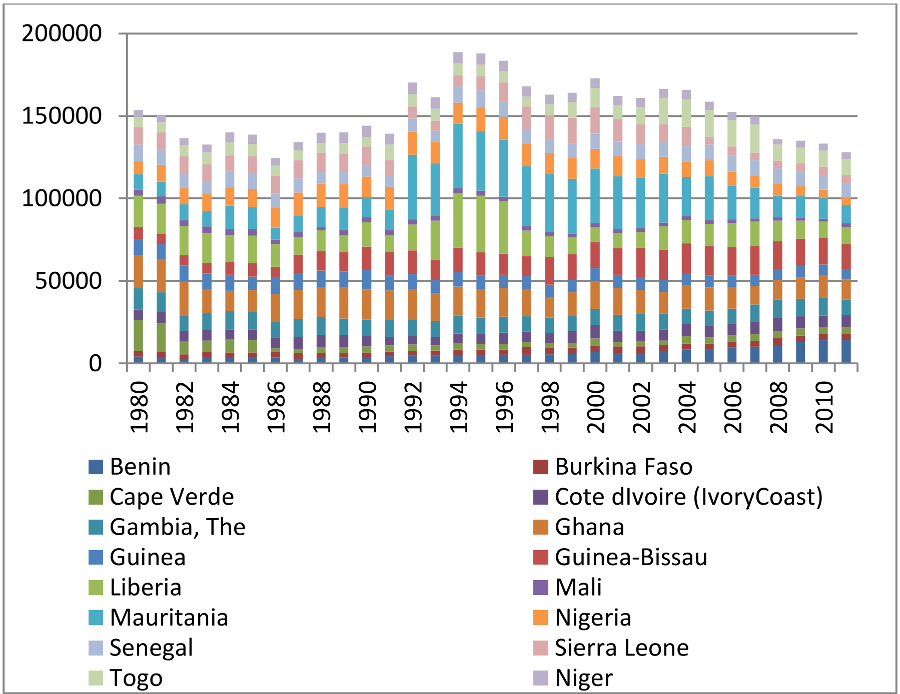

Figure 7: Plot of Energy intensity in West Africa - Total Primary Energy Consumption per Dollar of GDP (Btu per Year 2005 U.S. Dollars (Market Exchange Rates))

Data source: International Energy Statistics – Energy Information Administration

In terms of the effect on the environment, the high energy use has led to a corresponding increase in $C0_2$ emissions from energy sources. Figure 8 indicates that $C0_2$ emissions from petroleum, natural gas and coal continue to increase in Africa and the story is not very different in South Africa, Nigeria, Ghana, Cameroon, and Algeria. Given the close link between energy consumption and climate change (see Akhmat et al., 2014a; Akhmat et al., 2014b and Khan et al., 2014), emphasizing energy demand management in these economies is critical both to the security of their energy system and sustainability of their environment. Since these economies are major economies in their respective sub-regions, these countries provide model studies for other countries in their respective sub-regions. As a result, the policy recommendations from these studies will benefit other Africa countries.

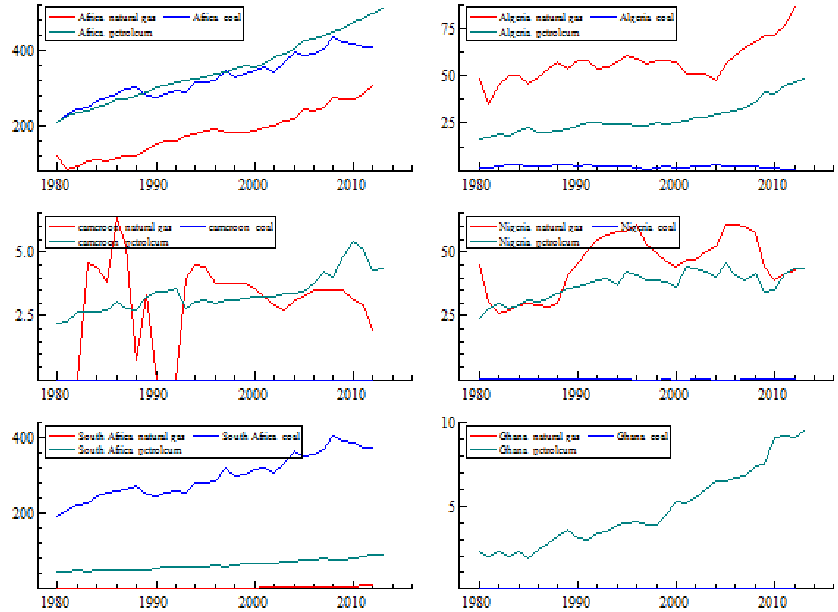

Figure 8: CO2 emissions from energy sources (in million metric tonnes)

Data source: International Energy Statistics – Energy Information Administration

The rest of the thesis is structured as follows. Section 1.1 discusses the implications of different economic states for energy conservation policies. Section 1.2 discusses the complementarity nature of sustainable economic growth and environmental quality. Section 1.3 discusses the country conditions that may enhance the energy-saving potentials of foreign direct inflows (FDI). Section 1.4 discusses the implications of structural breaks to the estimation decision rule. Section 1.5 discusses the transition between energy efficient and energy inefficient states. Section 1.6 discusses the literature on transport energy demand. Section 1.7 outlines the main contributions of this thesis. Finally, in Section 2, I provide a summary of all five papers contained in this thesis.

1.1 Business cycle and energy conservation

Every economy experiences business cycles, and this significantly affects how economic agents make decisions. For instance, in deciding on how much energy to use, individual economic agents consider their present economic situation. Polk (2009), in a survey, shows that, during the 2007/2008 economic crisis, more than two-thirds of the respondents indicated their intention to keep their car longer than they would have normally done in the absence of the crisis. In the same survey, about 70% of the respondents indicated their intention to buy second-hand cars in their next automobile purchase. In a report by OECD/IEA (2009), it was revealed that the sale of hybrid cars fell by 46% during the 2007/2008 economic crisis.

There are two contrasting arguments about how different economic states affect individual economic agents' decision to be energy efficient in the literature. One section of the literature argues that higher income will decrease energy productivity (see Jones, 1989; Jones, 1991 and Parikh and Shurkla, 1995). According to them, higher income will increase the purchase of energy-using appliances. In their explanation, the increase in output is expected to be less than the increase in energy. The policy consequences of this is that, taxing energy inputs in a low income state is not an ideal policy tool to promote energy efficiency. This explanation has the following implicit assumptions: first, it assumes that individual economic agents do not dispose of existing energy-using appliances. Thus, individual economic agents have strong cultural ties with these appliances that make it difficult for them to dispose them. Second, if disposability is possible, then the newly acquired energy-using appliance should be energy inefficient. Third, it rules out the possibility of substituting among energy inputs. In the event that one of these assumptions is violated, the explanation provided by this section of the literature may be inappropriate.

The other side of the literature offers an opposite explanation. According to them, a high income state will spur energy efficiency (see Cole, 2006; Su-yun and Zhen-yu, 2010; Kepplinger, 2013; Sadorsky, 2013). Bernardini and Galli (1993) have outlined three reasons why a higher income state will promote energy efficiency. First, it changes the structure of final demand as economies pass through the different phases of industrialization. Second, it leads to technological progress that improves energy efficiency. Third, the progress in technology leads to the usage of substitute materials that are less energy intensive. The policy consequence, according to this view, would be to tax energy inputs in a low income state. This explanation assumes possible disposability and substitution. Thus, it rules out the possibility that individual economic agents may be reluctant to dispose existing energy-using appliances and potential back-fire due to a rebound effect.

These two sides of the literature regarding income level and energy efficiency base their explanation on the direction of the sign of a single income coefficient. Thus, either side of the literature do not offer any threshold level to judge individual economic decisions. This is important because of the fact that income increases do not guarantee that economic agents will invest in energy-efficient appliances. Therefore, looking at how economic agents change their decision as we pass a certain income threshold or income state will provide a better insight into the relationship between income and energy efficiency and the implication for government energy conservation policy. For example, examining how economic agents change their energy conservation decision during periods of recession and boom is more interesting. However, empirical evidence relating to this is missing.

1.2 Sustainable economic growth and environmental quality

The pursuit of sustainable economic growth and environmental quality are desirable policy goals that every economy seeks to achieve. However, these policy goals have been perceived to be at odds with each other. The pursuit of sustainable economic growth requires strong drive for industrialization particularly heavy industrialization. The pursuit of higher industrialization is a more energy-intensive activity. El-Katiri and Fattouh (2015) found that the concentration of energy-intensive companies in Middle East (ME) and North Africa (NA) countries contributes to the rising energy intensity in the region. Consequently, energy related emissions increase substantially. On the other hand, the pursuit of environmental quality is achieved via promoting less energy-intensive industries such as the service sector. However, in the long-term, this may not promote sustainable economic growth, if there is a weak industrial base. The current literature on the subject provides policy conclusions that are consistent only with the environmental quality goal and not the long-term sustainable economic growth goal (see Inglesi-Lotz and Pouris, 2012; Herrerais et al., 2013; Su-yun and Zhen-yu, 2010; Hubler and Keller, 2010; Poumanyvang and Kaneko, 2010; Adom and Kwakwa, 2014; Li and Lin, 2014). This from a developing country perspective, where growth is required, does not sound very logical. Technically, these studies fail to show that sustainable economic growth and environmental quality goals are not mutually exclusive. The environmental Kuznet curve posits that at a lower stage of development, promoting economic development would be at the cost of environmental quality, but at a higher stage of development environmental quality and economic development would coexist (see Shafik, 1994; Holtz-Eakin and Selten, 1995; Neumayer, 2004; Narayan and Narayan, 2010). The mutually exclusive nature of environmental quality and economic growth goals during early stages of development is due to the lack of or nonexistence of technology advancement. This means that if countries can promote technological growth in the early stages of development, they can transcend to the falling side of the EKC faster. At that stage, the pursuit of economic development and environmental quality are jointly achievable.

1.3 Country conditions and the energy-saving potential of FDI

Developing countries continue to embark on policy reforms in order to attract foreign direct inflows to help grow the economy. However, whether the inflow of foreign direct investments promotes growth or leads to economic decline remains a continuous debate (see Romer, 1993; Boyd and Smith, 1992). In the energy efficiency literature, there are ongoing discussions about how foreign direct inflows can promote energy efficiency. But the empirical evidence remain mixed in the literature. While some studies confirm the energy-saving role of FDI (see Kretschmer and Hubler, 2013; Yuan-yuan and Li, 2010; Zhang and Chen, 2009; Mielnik and Goldemberg, 2002 *inter alia*), other studies could not find support for the energy-saving role of FDI (see Antweiler et al., 2001; Hubler and Keller, 2010; Adom and Kwakwa, 2014).

One possible cause for the mixed result is that the energy-saving role of FDI is context dependent. Thus, specific country characteristics such as industry structure and the technology absorptive capacity (i.e. ability to absorb and implement new technologies) of the host country may be important inducements for the energy-saving role of FDI. Countries with greater technology absorptive capacity have the ease to evaluate the performance of external technologies, select the most efficacious technology and operate and use the technology. Similarly, the structure of industry may influence the type of FDI a country receives. For instance, if the industry structure is dominated by the oil and gas sector, it will attract high-tech technologies that are more energy efficient. Despite the importance of these country characteristics to the energy-saving potential of FDI, empirical evidence to support this is limited. The only exceptional study in this regard is the study by Hubler and Keller (2010) that investigated how industry structure influences the energy-saving effect of FDI. Their study was based on a panel data. Given the fact that countries differ greatly in terms of their industrial structure, a country specific study about the influence of specific country conditions on the energy-saving effect of FDI will provide more insight into the subject than a group study. Second, their study did not consider the importance of technology absorptive capacity to the energy-saving role of FDI.

1.4 Structural effects in parameters

Estimated parameters are used significantly to inform government policy decisions. This follows that, if these parameters are not correctly identified, policy inference based on them will be incorrect. Correctly identifying and estimating a reliable estimate is therefore crucial to make proper policy inference. Parameter estimates are unlikely to be constant, since as policy regimes change, individuals change how they form their expectations, and this changes the estimated decision rule (Lucas, 1976 in Adom, 2013). Thus, according to Lucas (1976), model parameters are not policy-invariant (Also see Watson, 1985). This means that estimating a time-invariant model when there is a significant structural break in the dataset is tantamount to model misspecification. Cooley and Prescott (1973), Terasvirta and Anderson (1992), Stock and Watson (1996) and Phillips (2001) all posit that time-invariant models are inherently vulnerable to structural changes in the economy. Yet existing studies on the drivers of energy intensity have estimated a time-invariant model, which makes their parameter estimates vulnerable to structural breaks (see Hubler, 2011; Sbia et al., 2014; Wu, 2012; Fisher-

Vanden et al., 2004; Su-yun and Zhen-yu, 2010; Cole, 2006; Zheng et al., 2011; Keller, 1997; Keller, 2000; Shen, 2007; Voigt et al., 2014; Birol and Keppler, 2000; Cornillie and Fankhanser, 2004; Hang and Tu, 2007; Lin and Moubarak, 2014; Song and Zheng, 2012; Ting et al., 2011; Mielnik and Goldemberg, 2002; Eskeland and Harrison, 2003; Shi, 2002; Zhang and Chen, 2009; Yuan-yuan and Li, 2010; Kretschmer and Hubler, 2013; Antweiler et al., 2001 *inter alia*).

Estimating a time-variant model is appropriate if there is a significant structural break in the dataset. As argued by Fan and Zhang (2008), time-variant models are able to capture the dynamic pattern in the data effectively and also explain many physical and social phenomena that models with time-invariant parameters cannot. Though there have been recent attempts to accommodate the effect of structural breaks, they should be considered as offering a partial solution to the problem. Adom and Kwakwa (2014) investigated how the effects of manufacturing output and trade openness on energy intensity have changed after the economic reform in 1983 in Ghana. Li and Lin (2014) examined whether the effects of industry structure on energy intensity in China is nonlinear. The models of Adom and Kwakwa (2014) and Li and Lin (2014) should therefore be considered as quasi-flexible. A complete flexible model should give each parameter the opportunity to change. This offers more insight into the effect of structural breaks on parameter estimates.

1.5 The transition between energy efficiency and energy inefficiency

The current literature on the drivers of energy efficiency has strong underpinning assumptions (see Fisher-Vanden et al., 2004; Hang and Tu, 2007; Hubler and Keller, 2010; Hubler, 2011; Wu, 2012; Sadorsky, 2013; Mulder et al., 2014; Lin and Moubarak, 2014; Adom and Kwakwa, 2014; Keller, 1997; Keller, 2000; Shen, 2007; Voigt et al., 2014; Birol and Keppler, 2000; Cornillie and Fankhanser, 2004; Hang and Tu, 2007; Lin and Moubarak, 2014; Song and Zheng, 2012; Ting et al., 2011; Mielnik and Goldemberg, 2002; *inter alia*). First, the current literature assumes that the process that is responsible for the observations in year t is known with certainty. For instance, it is assumed that an energy inefficient state is responsible for observations in year t throughout the sample. In what state, an economy finds itself is a hidden and random process. I cannot infer beforehand what process might be responsible for observations in date t throughout the sample. Therefore, beginning with the assumption that an energy inefficient (efficient) state is responsible for the observations in date t throughout the sample may be a wrong assumption to begin with. The best approach is to form a probabilistic inference about these hidden states as to how likely they may have been responsible for the observations in date t in the sample.

Second, the current literature assumes a smooth and complete transition process, for instance, from an energy inefficient state to an energy efficient state. By implication, it is assumed in these studies that removing fuel subsidies; instituting flexible trade scheme and foreign investment policies and investing in technology will successfully move the economy to the desired energy efficient state. What these studies ignore are the other important mechanisms that may obstruct the smooth transition from an energy inefficient state to an energy efficient state. Especially from a developing country perspective, mechanisms such as high corruption, regulatory inefficiencies, and poor infrastructural development and institutions could impose great natural restrictions on the transition process, and this may slow the transition towards energy efficiency (i.e. increase the duration of an energy inefficient state). This makes the policy implications of the current literature overly optimistic.

Globally, the goal is to move towards energy efficiency to ensure a clean environment and energy security. But achieving energy efficiency is not enough since we are not guaranteed that it will persist forever. Therefore, investigating the potential conditions that would ensure the sustainability of energy efficiency is very critical. Despite the policy importance of the subject, empirical evidence relating to the subject is missing.

1.6 Transport energy demand

Theoretically, demand for any commodity is determined by price of the commodity, income of consumers and other social-economic and demographic factors. However, which factors are crucial to consider largely depends on the type of good and the context of study. In the transport sector, demand for energy is dependent on the price of energy, income, traffic situation, number of miles travelled, fuel efficiency and state of road infrastructure. Nevertheless, empirical studies have concentrated on the price of energy and income mainly due to data availability. These empirical specifications have also been justified on the grounds that income changes may reflect in the number of miles travelled, stock of vehicles, and fuel efficiency. As a result, the effects of income may reflect these behaviours albeit in a more compact form. Basically, the current literature on transport energy demand can be categorised into four: constant elasticity studies, varying elasticity studies, asymmetric price response studies, and energy forecast studies.

The constant elasticity studies assume that individual behaviour does not change (see: Sharma et al., 2002; Belhaj, 2002; Akinboade et al., 2008; Sene, 2012; Ackah and Adu, 2014; Alves and Bueno, 2003; Romero-Jordan et al., 2010; Broadstock and Hunt, 2010; Nicol, 2003; Polemis, 2006; Iwayemi et al., 2010). They are useful for simulating government pricing and taxing policies in the transport sector. However, the assumption of constant elasticities makes their parameter estimates vulnerable to structural breaks and that questions the reliability of the estimates and the corresponding policy inference. From a policy perspective, they lead to the design of rigid tax scheme due to the inability to reveal how consumer behaviour has changed.

This has motivated other studies that allow price and income elasticities to change. Time varying elasticity studies are more flexible and useful in designing a more flexible tax scheme. Dahl (2011) finds that price and income elasticities have not remained constant and they may change in a fairly systematic way as countries develop and consumers adjust to various price levels. Goodwin et al., (2004), in a survey, find that income elasticity has declined over the last forty years. Small and van Dinder (2007) find that price elasticity was lower between 2000 and 2004 than from 1960 to 2000 for the U.S transport demand. Hughes et al., (2008) examines whether gasoline demand exhibits structural shifts between run ups in the last half of the 1970s and the price run ups in the early part of this century. Their result shows that, price elasticity was around -0.30 between 1975 and 1980, but only -0.04 between 2001 and 2006. Al Dossary (2008) extends the stability analysis to 22 countries. The result shows a statistically less elastic price response for France and the U.S. since the mid to late 1980s, for both the short-run and long-run gasoline demand. But the author did not find any evidence of a significantly less elastic price response for diesel fuel for these same 22 countries. In a recent study, Fouquet (2012) analyses the trends in income and price elasticities of transport demand from 1850 to 2010. The result shows that price and income elasticities for the transport sector in U.K. were large (3.1 and -1.5) in the mid-nineteenth century but has declined since. In 2010, long-run income and price elasticity of aggregate land transport demand were 0.8 and -0.6. According to Fouquet (2012), these trends suggest that future elasticities for the transport sector may decline gradually in developed countries but faster in developing countries where the elasticities are likely to be larger. On the contrary, Ben sita (2012) finds that price and income elasticities for gasoline demand increase when the study adjusts for single and multiple structural breaks in Lebanon. There is less evidence regarding how price and income changes have changed in developing countries. Particular in Africa, the empirical evidence on how price and income elasticities for the transport sector have changed is lacking.

The asymmetric price response studies basically argue that; consumers respond differently to price increases and decreases. The existence of asymmetry in price response has important policy and welfare implications. For instance, if price increases are passed on to consumers more than price decrease, a government tax reduction policy intended at improving the welfare of the people will not result in the necessary welfare improvements. Though standard economic price theory does not provide any information in support of the fact that prices will adjust asymmetrically to cost upturns relative to cost downturns, there is empirical evidence to support the claim of asymmetric price adjustment. This means that, if we fail to account for this asymmetric behaviour, our estimate of the price elasticity will be biased. Ajavonic and Haas (2012) analyse the asymmetric price response problem for European countries. The study first examines the effect of fuel price and fuel intensity on gasoline fuel and diesel fuel consumption. Their approach is based on the Autoregressive Distributed Lag model (ARDL) developed by Pesaran and Shin (1999) and Pesaran et al., (2001). The result shows that, in the long-term, the price elasticity is significant only for France, Italy and the EU-6. In the short-term, however, the price elasticity is significant for all countries except Sweden. The long-run income elasticity is significant for all countries except France. Also, the short-term income elasticity is significant for all countries except France and Italy. However, they could not find a strong support for significant asymmetry of response between fuel price increases and decreases. Karagiannis et al., (2015) also examine the nature of price adjustments in the gasoline markets for Germany, France, Italy and Spain. Also, they did not find a strong support for the fact that crude oil price increases are passed along to the retail customer more fully than crude oil price decreases. Gately and Huntington (2001) and Adeyemi et al (2008), however, provide evidence in support of asymmetric price response for OECD energy demand. The mixed result suggests the need for more empirical evidence on the subject. From an Africa perspective, evidence of asymmetric price response in the transport sector is missing.

Finally, transport energy forecast studies address the critical issue of long-term demand planning. Several techniques have been developed in this regard to obtain the best forecast of energy demand, but none of these techniques has emerged as superior. This is because; the choice of the forecast technique is context dependent. Murat and Ceylon (2006) employ the artificial neural network technique to forecast energy demand in Turkey over a 20 year period. The model arguments include population, gross national product and Vehicle-km travelled. Geem (2011) employs a similar forecasting technique to forecast transport energy demand in South Korea. Contrary to Murat and Ceylon (2006), Geem (2011) include as covariates gross domestic product, population, oil price, number of vehicle registrations and amount of passenger transport. Zhang et al., (2009), on the other hand, employs a partial least square regression (PLSR) to forecast transport energy demand in China. Their study includes as controls gross domestic product, urbanization rate, passenger-turnover and freight-turnover. Limanond et al., (2011) employs log-linear regression models and feed-forward neural network models to forecast transport energy demand for Thailand between 2010 and 2030. Their model includes gross domestic product, population and the number of registered vehicles as controls. Xu et al., (2015) employs the GM-ARMA model to forecast energy consumption for Guangdong in China from 2013 to 2016. Their result shows that, the GM-ARMA model provides a better forecast than the GM and ARMA models. Using data from 154 countries, Keshavarzian et al., (2012) develop a forecast model for worldwide oil demand in road transportation based on the projection of vehicle ownership. They find that oil demand will increase, but the increase will be more under the business as usual scenario than under the policy scenario (i.e. fuel efficiency improvement by 20%). Studies on potential future transport energy demand in developing countries are limited. In Africa, the empirical evidence on trends in future transport energy demand is missing.

In terms of scope, each of these categories of studies is limited since they target a particular policy goal. However, in order to fully inform policy, a complete analysis of transport energy demand that touches on all key policy areas is necessary. Second, the issue of the persistence profile of transport energy demand to shocks is not fully addressed in the literature. Though Polemis (2006) attempts to address this issue, the application of cointegration models that assume half-way adjustment makes it incapable to know when full adjustment will be attained. Having knowledge about the complete persistence profile of transport energy demand to shocks is necessary to inform the government about the optimal timing for public interventions in the economy. Despite its importance, there is lack of empirical evidence on the complete persistence profile of transport energy demand to shocks in the transport sector.

1.7 Contribution

This thesis makes the following contributions:
First, it determines the income or economic state that is compatible with energy conservation behaviour. Second, it provides evidence in support of the fact that the goals of long-term sustainable economic growth and environmental quality can co-exist, if industrialization moves parallel with technological change. Third, it provides country-specific evidence about the influence of technology absorptive capacity and industry structure on the energy-saving effect of foreign direct inflows. Fourth, it tests for structural effects in parameters. Fifth, it provides an estimate of the transition probabilities and duration of energy efficient and energy inefficient states. Finally, it estimates the complete persistence profile of road energy demand to shocks in the system, price, income and consumption and provides a comprehensive analysis of transport energy demand.

2 Summary of Papers

2.1 Business cycle and economic-wide energy intensity: The implications for energy conservation policy in Algeria

Algeria is one of the major players in the African energy market. Currently, the country is the biggest supplier of natural gas and among the top three oil producers in Africa. This makes the hydrocarbon sector the backbone of economic growth contributing about 96% to export earnings and about 46% to GDP. Though the high concentration of the hydrocarbon sector makes the economy highly undiversified, the prospects of the energy sector have culminated into economic fortunes causing a per capita gross domestic product of US$5360.7 as of 2013. One would expect that the current economic prospects will induce technological investment; improve economic-wide efficiency and cause energy intensity to decline. On the contrary, energy intensity has risen for most parts of the years not discounting some noticeable decline between 1983 and 1995. Consequently, carbon dioxide emissions from energy sources have risen from a level of 83.6 million metric tons in 2000 to 133.9 million metric tons in 2012 (Energy Information Administration Statistics). With the fall in energy supply due to maturing of fields, emphasizing the management of energy demand is critical to the sustainability of the energy system and environmental sustainability in the country.

In the case of Algeria, there are several possible reasons that might explain the low energy productive nature of the country. First, fuels are highly subsidized in Algeria. The average fuel subsidy is about 77.5% of the total cost of total fuel supply. While fuel subsidies help make energy accessible to the poor (International Energy Agency, 2014), in particular, it discourages further investment in energy efficient appliances (El-Katiri and Fattouh, 2015); deters energy conservation behaviour (Al-Daud, Prince Abdulaziz Bin Salman, 2014) and promotes fuel smuggling between neighbouring countries (see Ghobari and

El Gamal, 2014; El-Katiri and Fattouh, 2015). People in favour of withdrawing fuel subsidies have argued so from the fiscal and welfare perspective. They argue that fuel subsidies drain the government budget and cause public deficit and consequently government debt to increase. For example, expenditure on energy subsidy in Yemen for the 2013/2014 fiscal year has most recently been estimated at US$3.5 billion, which is about a third of the government expenditure and above the budget deficit of US$3.2 billion (Ghobaro and El Gamal, 2014). In Egypt, total spending on energy subsidy is about US$21 billion which is almost equivalent to the total aid received from Middle Eastern donors since mid-2012 (El-Katiri and Fattouh, 2015). In Morocco, total expenditure on energy subsidy is almost equal to the size of the overall fiscal deficit and spending on investment but more than total spending on health and education according to IMF estimates (El-Katiri and Fattouh, 2015). From a welfare perspective, they have argued that the policy does not achieve its intended purpose since the poor who are targeted are not the actual beneficiaries of the policy. A recent study by IMF shows that the poorest quintile in Egypt, Jordan, Mauritania, Morocco and Yemen gets about 1-7% of total diesel subsidies but the richest quintile gets 40% of total diesel subsidies (El-Katiri and Fattouh, 2015). Sdralevich et al (2014) note that, in Egypt, the poorest 40% receives 3% of gasoline subsidies, 7% of natural gas subsidies and 10% of diesel subsidies (in El-Katiri and Fattouh, 2015). Del Granado et al (2012) reveal that the richest household benefit more from energy subsidies than the poorest households in 20 developing countries. However, withdrawing the policy entirely may hit the poor more than the rich. This is because; the share of the cost of energy in the income of the poor is more than the rich (see International Energy Agency, 2014). Therefore, withdrawing the policy may deepen the already existing income disparity. This has made the issue of withdrawing government fuel subsidies a more complex issue especially in the case of developing countries where the number of people who live below the poverty line is outrageously high. Reactions to energy subsidy reforms have been mixed. While it has achieved some success in some countries like Morocco and Iran ((El-Katiri and Fattouh, 2015) it has caused political riots in some countries like Yemen (Abdullah, 2014; El-Katiri and Fattouh, 2015). However, if the poor can adequately be compensated by the gains from withdrawing the policy, then withdrawing fuel subsidies in developing countries would be justified. But this is an empirical question that has to be investigated on country-by-country basis.

Having a more opened economy is important for several reasons. First, it opens the domestic economy to external competition. From the domestic economy perspective, this can boost knowledge acquisition about efficient technologies and how to operate them. Therefore, it will be easy for the domestic economy to adopt and implement technologies transferred via foreign direct investment. In the long-term, the existence of greater technology absorptive capacity of the domestic economy achieved through developing a more opened market will facilitate the energy-saving effect of foreign direct inflows. In the case of Algeria, trade/markets are highly restricted and foreign investment policy is highly restrictive. Currently, there are attempts by the government to make foreign investment policy more flexible. The 2013 amendments, for instance, have introduced a profit-based tax instead of a revenue-based tax and lowered tax rates for unconventional resources. However, the low technology absorptive capacity of the economy may limit the country's ability to seek, acquire, evaluate, adopt and implement energy efficient technologies. Therefore, higher inflow of foreign direct investments may not translate to efficient management of energy use in the country. But whether the technology absorptive capacity of the country has important implications for the energy-saving effect of FDI remains unknown.

Though income levels have increased in recent times, it could be that they do not exceed the income threshold beyond which economic agents would want to be energy efficient and energy conservative. Knowing the income state that may induce energy efficiency and energy conservation is very important for the evaluation of the government voluntary and involuntary energy efficiency policies. But whether there exists this income threshold is an empirical question. Finally the structure of the industrial sector in Algeria could contribute to the less energy productive nature of the economy. The industrial sector is dominated by the heavy industrial sector that is more energy-intensive. In order to improve the energy productivity of the country, one would recommend a shift to the less energy intensive sectors. While this may help improve the energy productivity of the country, it will not integrate other sectors to cause an integrated growth. This makes the goal of sustainable growth and environmental quality mutually exclusive. Higher industrialization is required in Algeria to ensure long-term sustainable growth. For long-term sustainable growth and environmental quality not to be substitutes but complements, the drive for industrialization must move parallel with technological change in the industrial sector. However, how effective can technological change in the industrial sector integrate the goals of long-term sustainable growth and environmental quality in Algeria remains an important empirical question yet to be answered.

This paper seeks to answer four empirical questions.

1. What is the benefit of withdrawing government fuel subsidies?

2. What income or economic state is consistent with energy conservation behaviour?
3. Does the technology absorptive capacity of the country affect the energy-saving potential of FDI?
4. Are the goals of sustainable growth and environmental quality mutually exclusive?

From these research questions, the objectives of the paper are:

1. Simulate the benefit of withdrawing government fuel subsidies.
2. Determine the income state that is consistent with energy conservation behaviour.
3. Examine the effect of technology absorptive capacity on the energy-saving effect of FDI.
4. Test the hypothesis that the goals of long-term sustainable growth and environmental quality are mutually exclusive.

This paper uses annual time series data covering 1971 to 2010. This paper makes the following contributions. First, it provides empirical support to the fact that the goals of long-term sustainable growth and environmental quality are not mutually exclusive if industrialization moves parallel with technological change. Second, it provides empirical support to the fact that, there is an income state that is compatible with energy conservation behaviour. Below this state consumers will not find it worthwhile to invest in energy efficiency. Third, it provides empirical support to the fact that whether FDI can effectively induce energy efficiency is dependent on the technology absorptive capacity of the host country. Finally, it provides empirical support to the fact that the gains from withdrawing government fuel subsidy can adequately compensate any social-economic and equity problems that the policy may create. In terms of the context study, this study is the first attempt.

In this study, I fit regression models which are estimated as fully modified ordinary least squares (see Phillips and Hansen, 1990; Phillips, 1995) and canonical cointegration (see Park, 1992) regressions. These econometric methods are preferred due to their ability to correct for problems of endogeneity/simultaneity bias and serial correlation. Thus, with these econometric methods, I fit regression models that mimic strict exogenous regressors. In order to investigate how the effect of income on energy productivity evolves with the business cycle, I use the Hodrick-Prescott filter to determine the underlying long-term trend and the cyclical movements in income per capita. I then construct a dummy variable which takes one if in a low income state (recession) and zero if in a high income state (boom). This dummy is interacted with the income variable and included as an additional regressor. To simulate the benefit of withdrawing government fuel subsidies, I use the following equation:

$$SIEI = \beta\left(\frac{SA}{VWAP}\right) * 100$$

Where SIEI is the simulated impact on energy productivity, and SA is the subsidy reduction amount, which is captured as crude oil price inflation, VWAP is the value weighted average of price of crude oil and β is the crude oil price elasticity. The unit of measurement of SIEI is percentage. Using the average oil consumption of 223,634 barrels per day for 1971 to 2012 and the value weighted average of crude oil price of US$110; I calculate the amount of energy saved and the corresponding potential export revenue for the energy saved. I proceed to estimate a simple quadratic relation between energy productivity and income per capita to determine the income threshold beyond which economic agents would want to be energy efficient. I use trade openness as a proxy for technology absorptive capacity. This is informed by Lai et al (2006). I interact the trade openness variable with the FDI variable to determine whether technology absorptive capacity is an important inducement for the energy-saving effect of FDI. Last, I interact the technology variable with the industry valued added variable to test if long-term sustainable growth and environmental quality are mutually exclusive. Preliminary analyses showed evidence of unit root in levels but not in first difference and cointegration. The evidence of cointegration suggests that there is a level energy intensity equation.

The main results of the paper are as follows. First, higher energy price, improvement in technology, higher foreign direct inflows and a more opened economy contributes significantly to energy efficiency improvement. However, a shift to the more energy intensive sector decreases energy productivity. This result is consistent with a number of studies such as Hang and Tu (2007), Lin and Moubarak (2014), Elliot et al (2013), Herrerais et al (2013), Fisher-Vanden et al (2004). The rank ordering provided based on the commonality coefficient (commonality coefficient determines the variance accounted for by each predictive variable in a model. it partition the regression coefficient into unique and common effects) shows that technology and income are the two most important drivers of energy productivity, and these variables share a significant amount of variance with the regression effect.

The results further show that reducing government fuel subsidies enhances energy efficiency and causes export revenue surplus. This is because; there is a twin income effect of the policy; i.e. savings on government budget and extra export revenue. Therefore, the study argues that, though the policy may create some socio-economic and equity problems, the gains from the policy could adequately compensate these negative effects.

There is evidence to support the fact that the effect of income on energy productivity follows the business cycle. In recession periods, higher income does not stimulate energy efficiency. However, in boom periods, higher income does stimulate energy efficiency. The possible reason is that during recessions economic agents are less likely to dispose existing energy-inefficient appliance than during periods of boom. Even if they have to invest during recessionary periods, it will be on second-hand products; many of them have outlived their optimal efficiency lifespan. This is because the cost of investing in energy efficient appliance relative to income during recession is high. This result supports the survey result by Polk (2009) and OECD/IEA (2009). Further, the result shows an inverted U-shaped relationship between energy productivity and income per capita, and the country is locked below the turning point. The income threshold that is consistent with energy conservation is estimated at US$2,730. This result has important implications for government energy conservation policies. For instance, the result suggests that voluntary energy conservation policies would not be adhered to during periods of recession. Rather involuntary energy policy such as reducing fuel subsidy will promote energy efficiency. However, such a policy would deepen the woes of poverty but the effect may be adequately compensated by the gains from the policy. An alternative approach would be to use government fuel subsidies to target technology during recession periods.

The energy-saving effect of FDI is significantly dependent on the technology absorptive capacity of the host country. This means that instituting trade restrictions might impose an important limiting constraint on the extent to which foreign direct inflows can induce energy efficiency in Algeria. Therefore, it is not enough to institute a flexible foreign investment policy. The result suggests that they should be combined with developing markets. Last, the study finds that the goals of sustainable growth (via higher industrialization) and environmental quality (via energy efficiency improvements) are jointly feasible, only if industrialization moves parallel with technological change. The social responsibility of investing in technological innovation may solely rest with the government, but the cost share can be distributed between the public and private. Therefore, creating the environment that is receptive to private participation can help greatly. An alternative would be to tax externalities from energy production in the industrial sector. However, this may not be healthy for developing country firms in terms of their comparative advantage. In order to maintain the drive for industrialization, government would have to create the incentive for investment in new energy efficient technologies by providing tariff relief on imported equipment and instituting efficiency labelling standards.

2.2 Asymmetric impacts of the determinants of energy intensity in Nigeria

Nigeria is a dominant economy in Africa with huge deposits of oil and gas. Despite her richness in oil and gas, inefficiencies in the production side have limited energy supply. Unfortunately, growth in energy demand continues to increase partly due to the proliferation of inefficient equipment and appliances and demand mismanagement (see Oyedepo, 2012; Aderemi et al, 2009; Aiyedun et al., 2008). Together, the growth in energy demand and the limited supply of energy have culminated into energy shortage. In the electricity sector, for instance, the energy situation has caused frequent blackouts in the country (see Oyedepo, 2012; oyedepo 2013). Consequently, industry production cost has increased causing loss of production hours and industrial unemployment. There is evidence to support the claim that the energy insecurity situation in Nigeria has caused some firms to shutdown (see Oyedepo, 2012). Due to the sub-regional dependence on Nigeria's energy, the situation has also led to huge energy shortages and blackouts in countries like Ghana and Togo. Therefore, emphasizing and promoting energy efficiency in Nigeria both has internal and external benefits. Though some attempts have been made to improve energy efficiency in the country, according to Uduma and Arciszewski (2010), the benefits of energy efficiency remain untapped in all sectors of the economy.

Understanding the driving forces of energy productivity is crucial to the effective design of a broad-based economic-wide energy efficiency policy. However, Nigeria has undergone several structural reforms in the trade and industrial sector, inter alia. In this instance, as argued by Lucas (1976), the parameters of the model, which reflects individual decisions, would respond to the policy shifts/changes. Therefore, according to Engle and Watson (1985), Cooley and Prescot (1973), Terasvirta and Anderson (1992), Stock and Watson (1996), Phillips (2001), and Dargay (1992), fitting a linear regression model to the problem in the presence of structural breaks would be tantamount to model misspecification.

The energy sector since 1970 has dominated the Nigerian economy. Certainly this has been a site attraction to many foreign investors looking for a place to invest their capital. Also, Nigeria has become more opened following the liberalisation in 1989. This has improved the knowledge acquisition and competitive advantage of the country. Therefore, with the greater technology absorptive capacity, it is expected that the country can easily seek, acquire, evaluate, operate, adopt and implement foreign energy efficient technologies. But the empirical evidence to support the claim that industry structure and greater technology absorptive capacity are important inducements for the energy-saving effect of FDI remains unknown in Nigeria.

This paper addresses three empirical questions:

1. What drives energy productivity trends in Nigeria
2. Do the effects of energy price, foreign direct inflows, economic structure and trade openness exhibit significant structural effects in their parameters?

2. Is the effect of foreign direct inflows conditional on industry characteristics and the technology absorptive capacity of Nigeria?

Thus, the objectives are:

1. Investigate the drivers of energy productivity in Nigeria
2. Test for the existence of structural effects in the model parameters
3. Determine the effect of industry structure and technology absorptive capacity on the energy-saving effect of FDI

This paper makes the following contributions. First, it provides a more comprehensive analysis of the effect of structural breaks on model parameters. Second, it contributes to the scarce literature related to country conditions and the energy-saving effect of FDI. Third, the study is new in the context of Nigeria.

I use annual time series data covering 1971 to 2011. I fit linear and nonlinear regressions and estimate them using the fully modified OLS (see Phillips and Hansen, 1990) and Canonical cointegration (see Park, 1992). Thus, I estimate equations that mimic strict exogenous regressors. I use Phillips-Perron unit root test (see Phillips and Perron, 1988) and Johansen cointegration test (see Johansen, 1991) to test for unit root and cointegration. Preliminary analyses show evidence of unit root in levels and cointegration. I use the Quandt-Andrews unknown structural breakpoint to determine structural break location. I chose the Quandt-Andrews test due to its objectivity and ability to pick multiple breakpoints in the data set. The test picked 1989 as the likely maximum structural breakpoint location. To estimate the main model, I proceed in two ways. First, I estimate a baseline equation using the specific-to-general way of modelling. In the baseline equation, I create the interaction of FDI and industry structure and FDI and trade openness (proxy for technology absorptive capacity) and include them successively into the model. Second, I construct a dummy variable which takes one from 1989 to 2011 and zeroes for periods other than that. I then interact this structural break dummy with each of the regressors. I introduce the interaction variables successively into the model.

Thus, for each estimated model, I assume structural effects only in one of the parameters. I did this basically to avoid the dummy-trap problem.

The baseline result shows that an increase in crude oil price and FDI and opening up trade stimulates energy efficiency, but shifting to the energy-intensive sector decreases energy efficiency. This result is confirmed in studies by Hang and Tu (2007), Birol and Keppler (2000), Cornillie and Fakhanser (2004), Zhang and Chen (2009), Lin and Moubarak (2014) and Eskeland and Harrison (2003). Also, greater technology absorptive capacity and industry structure are important inducements for the energy-saving effect of FDI. The result suggests that reducing government fuel subsidies which causes energy prices to increase, will stimulate energy efficiency in Nigeria. Also, a 'one-size-fits-all' FDI policy may be inadequate to produce desirable energy-savings. The result suggests an integrated FDI program that considers country-specific conditions.

There is evidence in support of the fact that the parameters for price of crude oil, foreign direct inflows, trade openness and industry structure exhibit a significant structural break. An increase in the price of crude oil by one percent post-1989 saves 0.126% more in energy. Also, an increase in trade openness and foreign direct inflows save 0.8% and 11.2% more energy post-1989. On the contrary, the industry sector consumes 1.8% less in energy for every one percentage point increase in output post-1989. This reflects improvements in the technical characteristics and change in the output composition of the industry sector in Nigeria. Adom and Kwakwa (2014) also found evidence of a structural shift in the effects of manufacturing output and trade openness on energy intensity in Ghana. Also Li and Lin (2014) found that beyond a certain industry structure threshold, energy intensity decreases. The results suggest that future research should pay particular attention to the effect of structural breaks on model parameters.

2.3 Determinants of energy intensity in South Africa: Testing for structural effects in parameters

South Africa is a leading economy in Africa and a major player in Africa's energy market. But it is the continent's major emitter of greenhouse gas emissions. In terms of per capita greenhouse gas emissions, South Africa is ranked 46th in the world and 1st in Africa. This is because coal is a major fuel source for extractive activities and for the production of electricity. There have been attempts to diversify energy sources in order to reduce the country's dependence on coal energy. Though income levels and energy use have increased in South Africa, it is interesting to see why energy productivity has improved consistently since the last two decades. During the last two decades, energy efficiency measures have improved significantly in South Africa, and this may account for the consistent improvement in energy productivity. The use of Compact Fluorescent Light bulbs, installation of ceilings to reduce space heating, switching from fuel to gas and solar heated water technologies, and the use of energy efficient appliances have increased. Nonetheless, the de-industrialisation since 1980 and the changes in trade structure in favour of more imports following liberalisation of the economy in 1992 might be other important sources for the improvement in energy productivity since the last two decades. But to what extent these two phenomena have contributed to the energy productivity improvement for the last two decades remains an empirical question yet to be answered. This motivates the following empirical questions:

1. What are the driving forces of energy productivity in South Africa?
2. Has the de-industrialisation and shift in trade structure contributed to energy productivity improvement in South Africa
3. Is the structure of industry an important inducement for the energy-saving effect of FDI?

South Africa has experienced several structural reforms since 1970. Therefore, it is natural to expect that these reforms will affect individual decision making and change the estimation decision rule. But to what extent, the reforms have affected behaviour and alter the decision rule is an empirical question. This leads to the next major empirical question:

4. Does structural reform in South Africa significantly affect the energy-saving effect of price of crude oil, FDI, trade openness and industry structure?

Therefore, the objectives of this paper are:

1. Investigate the driving forces of energy productivity in South Africa.
2. Determine the contribution of the de-industrialisation and shift in trade structure to energy productivity improvement.
3. Determine the effect of industry structure on the energy-saving effect of FDI
4. Test for the existence of significant structural effects in the parameters for FDI, trade openness, industry structure and price of crude oil.

There has been an earlier attempt by Inglesi-Lotz and Pouris (2012) to study energy productivity in South Africa using the decomposition technique. The decomposition technique basically decomposes the total change in energy productivity into different effects. Therefore, the approach is more descriptive and offers no clue to the cause and effect analysis. Also, the approach is incapable to accommodate the effects of structural breaks, which is a prominent feature of long span time series data. This paper contributes to the literature on South Africa by providing a cause and effect analysis of energy productivity. The effects of structural breaks are also considered in the cause and effect analysis. Therefore, this paper also contributes to the scarce literature relating to structural effects and energy productivity.

I use annual time series data covering 1970 to 2011. I first examined the data for a unit root, structural breaks and cointegration. The Phillip-Perron test (see Phillips and Perron, 1988) confirms a unit root in levels but not in first difference, and the Hansen cointegration test (see Hansen, 1992) confirms cointegration. The Quandt-Andrews test picked 1989 as the likely maximum breakpoint location in the data. In this paper I follow these steps. First, I estimate a baseline model of energy productivity. In order to evaluate how the de-industrialisation and shift in trade structure has contributed to energy productivity in South Africa, I construct two dummies. The first dummy for the phenomenon of de-industrialisation takes one from 1980 to 2011 and zeroes otherwise. The second dummy for the phenomenon of shift in trade structure takes ones from 1992 to 2011 and zeroes otherwise. I then create an interaction of the de-industrialisation dummy and industry structure variable and the shift in trade structure dummy and trade openness. These interaction variables are included as additional variables in the baseline model but in a successive manner. In order to examine the effect of industry structure on the energy-saving effect of FDI, I create an interaction of the two variables and include it as a regressor. Finally, to test for structural effects in parameters, I create a structural break dummy variable which takes ones from 1989 to 2011 and zeroes otherwise. I then create an interaction of the structural dummy variable with each of the regressors and include them as additional covariates in the baseline model but in successive manner. This is to avoid the dummy trap problem. I estimate the equations using the Fully-modified OLS (see Phillips and Hansen, 1990). Thus, the models are designed to mimic strict exogenous regressors. In order to examine variable importance, I estimate the beta weights, structure coefficients and the commonality coefficients.

The baseline result shows that industry structure and crude oil price are the two most important drivers of energy productivity. This result is confirmed by the beta weights, structural coefficients and commonality coefficients. The commonality coefficient, however, shows that though trade openness and FDI have little unique effects, combining these contributions with the total involvement in common effects reveals a different picture. Trade openness and FDI share a significant amount of variance with the regression effect. This implies that these variables should be jointly targeted for policy purposes. The result that higher crude oil price improves energy productivity confirms other studies such as Hang and Tu (2007) and Lin and Moubarak (2014), Birol and Keppler (2000) and Cornillie and Frakhanser (2004). Also, the result that shifts to energy-intensive sectors decrease energy productivity confirms the findings by Lin and Moubarak (2014), Su-yun and Zhen-yu (2010), Herrerais et al (2013).

The de-industrialization post-1980 and the change in trade structure in favour of more imports after 1992 have contributed significantly to energy productivity improvement in South Africa. Relative to the baseline, a shift in trade structure saves 0.2% more in energy for every one percentage point increase in trade openness. This means that the penetration of more imports into the country has facilitated technological transfer causing energy productivity improvement. Relative to the baseline, the de-industrialisation has reduced the energy requirements by 0.2% for every one percentage point increase in industry output. This result confirms Inglesi-Lotz and Pouris (2012) who attributed the improvement in energy productivity to changes in economic structure. Further, the result reveals that industry structure significantly affects the energy-saving effect of FDI.

Finally, the result confirms significant structural effect in the parameters, and this has rendered the effects of variables non-constant. An increase in the price of crude oil by one percent causes energy intensity to fall more by 0.042% post-1989. This could be attributed to the different pricing structures for the two time periods. Crude oil price post-1989 has been high and combined with the decrease in government fuel subsidy; this has contributed to the high energy-saving potential of price of crude oil. The industry sector consumes 0.33% less in energy for every one percentage point increase in industry output post-1989. This can be explained by the shift to the less energy intensive sectors post-1989. Foreign direct inflows save 4.8% more energy for every one percentage point increase in foreign direct inflows post-1989. This may be explained by the fact that the structural reforms facilitated the inflow of high-tech FDIs that are energy efficient. Last, trade openness saves 0.3% more in energy for every one percentage point increase in trade openness. This could be explained by the high penetration of imports which has increased technological diffusion in the country. The shift in the effects of trade openness and industry output confirms the result of Adom and Kwakwa (2014) and Lai et al (2014). The result suggests that future consideration of the subject should not ignore the role of structural breaks.

2.4 The transition between energy efficient and energy inefficient states in Cameroon

Cameroon faces a huge energy shortage created by the twin problems of limited energy supply and increased energy demand. For instance, between 2006 and 2009, while total energy demand increased by 13.1%, net production increased marginally by 1.4% (Abanda, 2012). Energy demand is projected to reach 5000MW in 2020 (Mas'ud et al., 2015). Albeit, government planned to add 2500MW between 2012 and 2020, this has not been fully implemented (Ayompe and Duffy, 2014). This has decreased per capita electricity consumption below the average for Africa (Wandji, 2013). It is estimated that about 20% of the population in Cameroon do not have access to electricity (Wirba et al 2015; Mas'ud et al 2015). The energy situation in Cameroon poses a serious threat to the country's sustainable growth. For example, according to Kenfack et al (2011), lack of access to electricity cost the economy about 2% of GDP growth. Also, according to Wandji (2013), the lack of energy is a major bottleneck to the development of the Cameroon economy. This has made the development of renewable energy and promotion of energy efficiency a top priority in the country's sustainable growth agenda. But the complex regulatory system[1], high corruption[2], undeveloped markets[3] and low income status[4] of Cameroon suggest that energy efficiency even when achieved is bound to be less persistent. Therefore, estimating the transition probabilities between energy efficiency and energy inefficiency is important to provide better insights for government policy. This paper basically finds answers to the following questions:

1. How persistent are energy efficient and energy inefficient states?
2. Do the effects of price, income and globalization switch between energy states?

The objectives of the paper are:

1. Estimate the transition probabilities for energy efficient and energy inefficient states
2. Estimate the duration of energy efficient and energy inefficient states

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1. In 2015, Cameroon business freedom score is estimated as 41.6 compared to a score of 48.3 and 73 in Nigeria and South Africa, respectively (source: Heritage Organization, 2015). Also, Cameroon obtained an investment freedom score of 35 which is lower than 40 for Nigeria and 50 for South Africa.

2. Cameroon and Nigeria obtained corruption free score of 25 which ranks them as the 144th most corrupt countries in the world out of 177 countries compared to a score of 42 for South Africa (source: Heritage Organization, 2015 and Transparency international, 2013).

3. Recent estimate of trade freedom for the country is 59.6 compared to scores of 63.8 and 76.6 for Nigeria and South Africa, respectively (Data source: Heritage Organization, 2015).

4. Cameroon has a per capita income of $2,423 compared to $2,831 and $11,259 for Nigeria and South Africa, respectively (Data source: Heritage Organization, 2015)

3. Test for symmetry in the effects of price of crude oil, income per capita and trade openness

This study contributes to the literature in the following ways. It forms a probabilistic inference about the processes that may be responsible for observations in any particular year. Thus, it deviates from the traditional approach of assuming that the process that may be responsible for any observation in a particular year is known with certainty. Second, it relaxes the assumption that the transition from energy inefficient state to energy efficient state follows a smooth and fast process. This means that this paper provides opportunity for other important mechanisms that may obstruct the smooth transition process.

I use annual time series data covering 1971 to 2012. I employ the two-state Markov-switching dynamic method (see Hamilton, 1989; Hamilton, 1994; Hamilton, 1996; Godwin, 1993) to study the persistence of energy efficiency and energy inefficiency. This method is preferred over other methods for several reasons. The single structural change method permits only one abrupt change. However, if the process changed in the past there is every reason to believe that the process can change again in the future, and this prospect should be taken into account in the modelling. There are ways to make this approach incorporate multiple changes, but the estimation process and hypothesis testing is pretty cumbersome (see Bai and Perron, 1998; Bai, 1999). Also, the single structural change method assumes that the regime or outcome is a perfectly foreseeable, deterministic event. However, in many practical cases, the regime or outcome is a random process. The random switching model developed by Quandt (1992) and the threshold model Balke and Fomby (1997) are examples of other techniques that can be applied in this case. However, they are incapable of characterizing the time series dynamics in different regimes. For the random switching model, the state variable remains exogenous to the dynamic structures in the model although it permits multiple changes. The threshold model is dependent and endogenous and results in multiple changes, but choosing the appropriate threshold is relatively difficult. The Markov-switching method provides a description of the probability law governing the change from one process to another process. Compared to the threshold method, the Markov method is easy to implement since it does not require choosing the appropriate threshold. I first examined the data for a unit root using Augmented Dickey Fuller (see Dickey and Fuller, 1979), Elliot-Rothenberg-Stock (see Elliot et al., 1996), weighted symmetric augmented Dickey Fuller (see Park and Fuller, 1995), and Phillip-Perron (see Phillips and Perron, 1988) unit root tests and found evidence of unit root in levels but not in first difference. Therefore, I model the Markov model as a growth model.

The results show that energy inefficient states are more prevalent and persistent than energy efficient states. There is a natural difficulty for Cameroon to escape the energy inefficient state which could be attributed to mechanisms such as high incidence of corruption, regulatory inefficiencies and poor infrastructural development. Further, the result shows that the low income state, the high prevalence of subsidies and the less integrated nature of markets deepen the energy inefficiency trap making it more difficult for Cameroon to escape this trap. The estimated duration for an energy inefficient state is twice as long as the duration for energy efficient state. This explains the sluggish transition away from an energy inefficient state and the faster transition away from an energy efficient state. The implication of the result is that, given another 41 years, Cameroon may observe a similar pattern in the persistence of energy inefficient/efficient states.

Higher crude oil price is an important incentive drive towards energy efficiency improvements. The price effect is, however, found to be state-dependent. In an energy efficient state, higher price only worsens energy efficiency since this creates more scale effects than technical effects. On the other hand, higher price in an energy inefficient state leads to efficiency improvement. This means that increasing crude oil price in an energy inefficient state will drive investment in energy efficient equipment and appliances and hence improve efficiency in energy usage. A government decision to withdraw fuel subsidies will drive consumers' incentive towards improving energy efficiency in Cameroon. Higher income unambiguously leads to energy efficiency improvements both in the energy inefficient and energy efficient states. However, the income effect is more pronounced in the energy inefficient state. A government cash transfer program targeted at energy efficient technologies will help improve energy efficiency in Cameroon. Opening up trade unambiguously improves energy efficiency in both energy efficient and energy inefficient states. But the energy saving effect of trade is more pronounced in the energy inefficient state. This means that a more flexible trade scheme will lead to energy efficiency improvements. Finally, price, income and trade openness have distinct energy saving effects irrespective of the state the economy finds itself in.

To escape from an energy-inefficient state a broad policy overhaul is needed. Trade liberalization and related growth policies together with the removal of fuel subsidies are useful, but insufficient policy measures; the results suggest that they should be combined with structural policies, aiming at institutional structure, regulatory efficiency and investment in infrastructure.

2.5 Shift in demand elasticities, road energy forecast and the persistence profile of shocks in Ghana

Global transport energy consumption constitutes 26% of total world energy use, and it is responsible for 23% of world energy related emissions (World Energy Council, 2012). It is projected that, from 2010 to 2040, global transport energy demand will increase by 40%. Much of this increase is expected to come from developing countries. While transport energy demand is expected to fall by 10 percent in OECD countries, it is expected to double in developing countries (ExxonMobil, 2015). Re-emphasizing and promoting energy efficiency in developing countries should therefore be an issue of a global concern. This is because the consequences of climate change do not pertain to a single region or country. In poor developing countries, energy efficiency improvement can serve as a catalyst to poverty alleviation. This is because money that is not spent on energy could be saved or directed towards other productive sectors in the economy.

The transport sector in Ghana contributes significantly to gross domestic product in the country. In 2009, the sector’s contribution to total GDP was 12.8%, but this increased to 13.9% in 2014 (see Okudzeto et al., 2015). However, inefficiencies abound in the sector, and this has caused a rise in transport energy consumption. Estimates show that Ghana’s road transport energy intensity is twice that of Thailand (Ghana Energy Commission, 2006). The consequence is that related carbon dioxide emissions have increased. According to a survey by the Environmental Protection Agency (EPA, Ghana), carbon dioxide emissions from the road sector are about three times the EPA target. Recent developments, such as higher than average fuel consumption per kilometre travelled, sharp rise in road bulk haulage vehicles; rising vehicular traffic, and changing urban structure imply that there is no hope for a downward trend in energy use by the road sector. These worrying trends require re-emphasizing energy efficiency measures in the road transport sector in Ghana. With the recent renewed interest in pricing policies in the road transport sector, it is important to analyse consumers’ response to price and income changes and how that has changed in the long-run.

Government tax policies for diesel and gasoline in the road sector have been uniform in Ghana. This has been based on the premise that consumers treat both fuels the same and therefore respond the same way to price changes. However, given the differences in consumption productivity per mile for diesel and gasoline driven cars, there could be differences in consumers’ response in which case discriminatory tax policy might be preferred. Recently, in 2014, the government reduced subsidies on gasoline and diesel fuel, and this caused a symmetric increase in the price of both fuels by about 25%. Are the energy efficiency gains for both energy types induced by the policy likely to be symmetric or asymmetric?

There are two contrasting arguments when it comes to a government fuel subsidy – economic and social grounds. The political dimension is often not discussed. But this could also be another important motive for government intervention in the pricing of energy products. In Ghana, energy affordability and availability has become an important issue that affects the voting pattern. Though the market has been allowed to operate on its own recently, historically, there have been occasional interventions by the government. The political factor may be important in the case of Ghana, yet we do not know with certainty what the real motive for intervention in the petroleum sector has been.

In the long-term, changing consumer preference and income patterns, government policies and innovation could affect how consumers behave in a particular market. Structurally, a lot has happened in Ghana after the reforms in

1983. Income patterns have changed, innovations have improved and development structures have improved relatively. Yet we do not know empirically to what extent income and price elasticities have changed after this period. Finally, with the growing urbanization and increasing ownership of cars in Ghana, road transport energy will keep up with the increase. This requires making long-term, strategic decisions about the optimal investment required to meet future demand. This further requires information on what future energy needs are likely to be.

These questions are essential policy questions in the road energy sector in Ghana which require an empirical investigation. This paper has four broad objectives:

1. Determine the symmetric or asymmetric consumer response to price and income changes for gasoline and diesel fuels.
2. Investigate how price and income elasticities have shifted after the eighties for gasoline and diesel consumers.
3. Examine the persistent time profile of road energy demand to system-wide, price, income and consumption shocks.
4. Predict gasoline and diesel consumption from 2012 to 2030.

Previous studies on energy demand in Ghana have focused on transport energy demand (see Ackah and Adu, 2014; Annan et al., 2015), electricity demand (see Adom, 2013; Adom and Bekoe, 2012; Adom and Bekoe, 2013; Adom et al., 2012), natural gas demand (see Ackah, 2014) and liquefied petroleum gas (see Mensah, 2014). In the case of road sector diesel and gasoline demand, we are not aware of any study on Ghana. This makes the current study different from Ackah and Adu (2014) and Annan et al., (2015). The current study also makes the following contributions to the general transport energy demand literature. The present study is much broader in scope in terms of the policy issues it addresses compared to earlier attempts in the literature (see Polemis, 2006; Akinboade et al., 2008; Broadstock and Hunt, 2010; Brons et al., 2008; Sene, 2012; Limanond et al., 2011; Xu et al., 2015; Keshavarzian et al., 2012; Ajanovic and Haas, 2012; Ben sita et al., 2012; Karagiannis et al., 2015*inter alia*). Second, contrary to previous attempts that employ half-way adjustment cointegration models (see Dahl and Kurtubi, 2001; Alves and Bueno, 2003; Polemis, 2006; Iwayemi et al; Ajanovic and Haas, 2012), we employ the Structural Cointegration Vector Autoregressive (SCVAR) method (see Lee and Pesaran, 1993; Pesaran and Shin, 1996; Pesaran and Shin, 2002). The SCVAR allows for complete adjustment to equilibrium. Third, we contribute to the scarce literature on shifts in income and price elasticities (see Dahl, 2011; Goodwin et al., 2004; Small and Van Dinder, 2007; Hughes et al., 2008; Al Dossary, 2008; Fouquet, 2012), which has been, at present, biased towards developed economies.

We use annual time series data covering 1971 to 2011. We proceed in four ways. First, we estimate a baseline demand model for aggregate, diesel and gasoline fuels using the autoregressive distributed lag method (see Pesaran and

Shin 1999). Second, based on the estimated error correction model, we obtain step-ahead forecasts from 2012 to 2030 for diesel and gasoline fuels for three different price scenarios – a reference scenario, a low price scenario and a high price scenario. Third, we test for shifts in the price and income elasticities in the long run using the fully modified OLS. Finally, we employ the structural cointegration VAR (see Lee and Pesaran, 1993; Pesaran and Shin, 1996; Pesaran and Shin, 2002) to investigate the persistence profile of road energy demand to shocks in price, income, consumption and in the system. We performed preliminary analysis of unit root, test for structural breaks and cointegration. The result confirms a unit root in levels but not in first difference and a significant structural break in 1983. Also, there is evidence of cointegration based on the bounds (Pesaran et al., 2001; Pesaran et al., 1996) and Johansen tests (see Johansen, 1991). We tested for asymmetric price response, but the results do not support the claim that energy demand responds differently to price increases and decreases. This confirms the conclusion of Karagiannis et al., (2015) and Ajanovic and Haas (2012). According to Sorell et al (2009), the existence of symmetric price responses implies that we can interpret the price elasticity as the direct upper bound rebound effect. The main result reveals the following:

First, demand for energy is price inelastic in the short- and long-run, but these elasticities differ for diesel and gasoline energy. Consequently, the resultant direct upper bound rebound effects also differ. We have shown that government policy to fade out subsidies will increase the efficiency gap in the diesel sector more than the gasoline sector. By implication, if nothing is done immediately, the country's carbon budget is expected to increase. Investing in renewables and other clean energy forms in the transport sector could help bridge this gap and curb the nation's carbon budget. Our estimate of price and income elasticities compares well with Samini (1995), Dimitropoulos et al (2005), Iwayemi et al (2010), Ajanovic and Haas (2012), Polemis (2006), Akinboade et al (2008), Sene (2012), Dahl and Kurtubi (2001) and Brons et al (2008).

Second, diesel and gasoline consumption are expected to increase at a decreasing rate with diesel fuel expected to take the lead. This signals a likely improvement in consumption productivity in the road sector and a switch to a more efficient transport. We conclude that the market is effective to induce efficiency improvement in the road sector, and the least a policy should do is to facilitate this mechanism. Reducing tariffs on imported gas-fired and electric-fired cars in the future will help create a more efficient transport sector.

Third, the long-run income and price elasticities have increased after the eighties, but the shift differs for diesel and gasoline fuel. By implication, government tax policies should adjust accordingly to accommodate these behavioural changes. This result confirms the conclusions of Dahl (2011) and Ben sita (2012).

Fourth, at the aggregate level, it takes a longer time for the system to fully adjust to equilibrium when shocked. Also, it takes a longer time for the diesel sector to adjust fully to equilibrium when shocked than it takes the gasoline sector. We have argued, based on the estimated persistence profile of shocks that it makes no sense to intervene in the pricing of petroleum products. However, government interventions have so far been partly politically motivated; a situation that may either suggest we look into the country's period of democratic rule again or not.

Finally, the impulse response analyses showed that positive income shocks increase road energy use at a decreasing rate, but the effect dies of faster for gasoline than diesel fuel. Negative price shocks have permanent effects on road energy use, but the effect stays longer for diesel fuel. We conclude that diesel and gasoline consumption respond differently to shocks, and the effects of shocks are more persistent in the diesel sector than the gasoline sector. Therefore, taxes on these fuels should not be uniform but discriminatory in nature.

In sum, we have shown that diesel and gasoline fuels differ in many aspects. As a result, both fuels should be treated differently. From the perspective of demand-side management, a uniform tax policy as we have shown in this study will affect the diesel sector (the most energy efficient sector) more than the gasoline sector. In order to improve demand management in the road sector, taxes should be discriminatory between the two fuels. We recommend that, fuel taxes, income taxes on cars, import duties for cars, road taxes, and registration fees for cars should discriminate against gasoline fuel. These will help drive incentives towards diesel-fuelled cars, which is much economical in terms of fuel consumption.

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