Essays on Energy Demand and Renewable Natural Resource Management

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Abstract

This thesis is a collection of five self-contained papers in the area of energy demand and renewable natural resource management. Paper 1 analyzes the dynamics in cooking fuel choices among Ghanaian households over the period 2005 and 2013 and further investigate the main forces driving households' choice of cooking fuel. Evidence from this paper reveals a significant transition from fuelwood use towards LPG over the period. Results also reveal factors such as price, reliability in supply of LPG, income and other household attributes as significant factors influencing households' choice of a given energy type for cooking.

Paper 2 investigates the long and short run demand drivers of liquefied petroleum gas (LPG) in Ghana and presents a 10-year forecast of future trends in demand. Results identify income, price and urbanization as the main drivers of demand. Projections from three scenarios suggest that demand for LPG will reach a minimum of 5.9 million metric tons by the year 2022.

Paper 3 examines the causal dynamics among energy use, real GDP and CO_2 emissions in the presence of regime shifts in six emerging African economies. Results confirm the presence of regime shift effects in the long run inter-linkages among energy use, real GDP and CO_2 emissions in the countries considered. This suggests that structural shifts have both economic and environmental effects.

Paper 4 develops a stage-structured bioeconomic model to analyze the effects of interspecies competition between roe deer (*Capreolus capreolus*) and fallow deer (*Dama dama*) on net present value of harvesting, and the associated harvesting strategies. Our analysis shows that unilateral interspecies competition of the fallow deer on the roe deer reduces the marginal benefit of holding an additional individual of both species. Our numerical calculations suggest interspecies competition has a small impact on total net present value, compared to the impact on roe deer population density. Results are also sensitive to assumptions made about trophy prices and discount rate. Inclusion of trophy benefits implies reduced harvest of both young males and females. For the fallow deer, pulse harvesting is optimal, whereas this is not the case for roe deer.

Paper 5 presents an analysis of the hunting lease market in Sweden. The determinants of hunting lease prices are analyzed using spatial and non-spatial hedonic price models.

From the hedonic model, the associated hunting values are also derived. Results from the paper suggest the presence of spatial spillovers in lease prices. It also indicate factors such as proximity to urban centers, income, size of the hunting field, and congestion cost as key drivers of hunting lease prices. Further, the results indicate high hunting values for moose and fallow deer.

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Dedication

To the memory of my [only] beloved sister
Monica Quarcoo (*Yaa Monica*).

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"..Through all the changing scenes of life, in trouble and in joy, the praises of my God shall still my heart and tongue employ.." The dream of attaining quality and higher education has finally been realized on this day. However, this couldn't have been achieved without the grace and mercy of God. I therefore wish to express my sincere gratitude to the Almighty God for wisdom, protection, favor and guidance throughout my education. There were "high and low" moments, but the Lord was with me.

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List of Publications

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

I   Mensah, J.T., and Adu, G. (2015). An Empirical Analysis of Household Energy Choice in Ghana. *Renewable and Sustainable Energy Reviews 51:1402-1411*

II   Mensah, J.T. (2014). Modelling demand for Liquefied Petroleum Gas (LPG) in Ghana: Current Dynamics and Forecast. *OPEC Energy Review 38(4): 373–495*

III   Mensah, J.T. (2014). Carbon emissions, energy consumption and output: A Threshold Analysis on the Causal Dynamics in Emerging African Economies. *Energy Policy 70: 172–182*

IV   Mensah, J.T. and Elofsson, K. (2015). Optimal Management of Two Deer Species Competing for Food (*Manuscript*)

V   Mensah, J.T. and Elofsson, K. (2015). An Empirical Analysis of Hunting Lease Pricing and Value of Game in Sweden (*Revise & Resubmit, Land Economics*)

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Introduction

This thesis is a collection of five (5) research articles under two broad thematic areas: energy demand and management of renewable natural resources. The first part of the thesis consist of three (3) papers on energy demand while the second part contain two (2) papers on managing renewable natural resources, specifically, wildlife.

In the area of energy demand, household energy use has received considerable attention in the literature owing to their implications on household welfare, labor allocation, education outcomes, health and environment (see: Heltberg, 2004; Hosier and Dowd, 1987; Akpalu et al, 2011). The recognition of these associated impacts has led many governments of developing countries and development agencies to implement strategies to encourage households to switch from dependence on biomass energy to modern and efficient fuels or use relatively clean technologies such as improved cooking stoves, among others. However, fuel switching decisions are not simplistic, as it entail trade-offs in terms of income, preferences and culture; thereby creating inertia in fuel switching patterns of households. The implication is that, for policies seeking to promote households' use of clean energy to be successful, a clear understanding of the factors influencing fuel choices is important.

One important factor influencing the choice of a given fuel is reliable access to the fuel. Thus, in seeking to promote adoption and utilization of 'relatively' clean fuel(s) such as LPG, it is important to ensure that the requisite infrastructure are provided to offer reliable supply of the product to end users. In Ghana, a pro-LPG policy has over the years succeeded in creating a huge demand for the gas. Unfortunately however, growth in the supply side has not been commensurate to the surging demand, leading to recurrent shortages on the market. Solving these supply side challenges require a

thorough understanding of the demand dynamics and a short-to-medium term outlook.

Further, energy consumption has implications on economic growth and the environment with possible feedback effects. As a result, the relationship between energy use and economic growth has been widely acknowledged in the literature (eg. Apergis and Payne, 2009; Esso, 2010). In many developing and emerging economies, structural reforms have become rampant. These reforms are often regarded as important conduits of growth and development. While reforms target specific sectors of the economy, they have implications on the level of energy consumption and environmental performance. For example, reforms that seek to boost the industrial sector of an economy is likely to result in higher demand for energy and increase pollutant emissions, unless strict environmental laws are enforced to avert the possibility of creating a "pollution haven" economy. Thus it is important for policy makers to identify the environmental implications of policy reforms so as to ensure that reforms engender greater socioeconomic benefits to society while minimizing the associated ecological footprints.

In line with the above, the first part of thesis addresses three important research questions that have hitherto not been fully answered elsewhere in the literature. They include: i). What has been the dynamics in fuel choices among Ghanaian households over time? What factors account for these fuel choices? ii). What are the determinants and future outlook of aggregate LPG consumption in Ghana? iii). How does structural reforms influence the relationship(s) among energy consumption, economic growth and carbon emissions?

These questions are addressed in three separate papers (i.e. papers 1-3). Paper 1 tracks the dynamics in cooking fuel choices among Ghanaian households over the period 2005-2013 and further investigates the main factors that influence a household's choice of a given energy type as its main cooking fuel. In paper 2, we narrow down the scope to consider LPG consumption. The

main goal of the paper is to gain an understanding of the dynamics in aggregate LPG consumption since introduction of government policies to incentivize LPG use in the early 1990s. The paper further provides a forecast of future demand to aid policy design and planning. Paper 3 investigates the effects of structural reforms on the relationship between energy consumption and economic growth and their associated carbon dioxide emissions in six emerging economies in Africa. The methodological approach used in this section of the thesis is largely empirical. Using time series and household survey data, appropriate econometric techniques are applied.

In the second part of the thesis, I focus on wildlife management. Renewable resources such as wildlife are important resources for society. The benefits and costs of wildlife are myriad. The benefits from wildlife species include meat, recreational hunting, aesthetic values, employment, maintenance of ecosystem balance, and as symbols of religious and cultural practices (Brandner et al., 1990; McInnes et al., 1992; Andrén and Angelstam, 1993; Bradshaw, 1996; Angelstam et al., 2000; Chardonnet et al., 2002). The associated costs also include browsing damages to agricultural crops and forestry, dispersal of invasive pests and road traffic accidents (Olaussen and Skonhoft, 2011; Chardonnet et al., 2002). The presence of these benefits and cost enforces the need for society to optimally manage wildlife populations in order to ensure that society derives the maximum net gains from them.

In doing so, two important considerations arise. First, the manager of the resource must understand and appreciate the ecological interrelationships between wildlife species and how such interactions can affect the net benefits from the wildlife. Such interrelationship has been observed among two ungulate species: roe (*Capreolus capreolus*) and fallow (*Dama dama*) deer. Meanwhile, there is still limited knowledge about the implications of such interspecies interactions for the economically optimal management of wildlife. Paper 4 therefore seeks to gain understanding on the effect of interspecies competition in multispecies management by examining the impact of

interspecies dependence between roe and fallow deer on the net present value of hunting when species are jointly managed. The paper is a blend of theory and empirics using operations research methods. In this paper, a stage-structured bioeconomic model is developed, from which analytical and numerical solutions are used to analyze the importance of interspecies competition on economic value of the two species.

Secondly, the development of wildlife policies requires knowledge about the economic benefits generated by different game, as well as knowledge about the functioning of markets for hunting related activities. Knowledge about hunting lease prices is also important to landowners in taking decisions on land improvements. Paper 5 therefore presents an economic valuation of multiple game species hunted in Sweden. To achieve this goal, the paper uses spatial and non-spatial econometric techniques to estimate a hedonic price model for hunting leases from which hunting values are derived.

Summary of Papers

In the section herein, I present a summary of each of the 5 papers contained in this thesis.

Paper I: An empirical analysis of household energy choice in Ghana

For many years, Ghana among other "energy poor" economies have relied heavily on forest resources to meet their energy requirements, particularly for cooking and to a lesser extent, lighting. In Sub-Saharan Africa, about 80% of the population rely on biomass as main cooking energy fuel compared with 49% for all developing countries (IEA and OECD, 2014). However, the heavy dependence on biomass comes at a price. Traditional solid fuel use is associated with severe health and environmental hazards. Forest resources are fast depleting due to the unsustainable harvesting of wood for fuel. Smoke from combustion of biomass is also associated with acute respiratory infections (ARI) such as cough and flu among children and obstructive pulmonary diseases in adults (WHO, 2002; Duflo et al. 2007; Ezati and Kammen, 2001).

In consequence, attempts have been implemented to reduce the risks associated with biomass use via incentivizing households' use of improved cook stoves and/or switching to relatively "cleaner" and efficient sources such as LPG and electricity. In Ghana, two landmark policies have been implemented– National LPG Promotion Campaign and the Unified Petroleum Price Fund (UPPF) – since the 1990s. The goal of these policies was to encourage households to

switch to LPG via expanding access to the fuel, maintaining a uniform and subsidized price, *inter alia*.

Further, evidence from the literature suggests that income is a major constraint in fuel switching in most low income economies. Thus it is expected that rising standards of living will influence household switching behavior towards relatively cleaner and efficient fuels. Interestingly, the Ghanaian economy has over the past two decades, witnessed significant developments, growing from low-income to a lower-middle-income economy. Poverty levels have subsequently reduced by more than half from 52% in 1999 to 24.2% in 2013 (GSS, 2007; 2014). At the same time, urban population has been increasing with the rate of urbanization averaging 3.9% per annum (World Bank, 2014). These developments lead us directly to a very important question for policy design: What has been the dynamics in terms of household fuel choice over the period? Has the various energy and developmental policies engendered any significant transition from traditional fuels to modern fuels among Ghanaian households? More so, what are the driving factors behind households' choice of a given cooking fuel type?

To answer these questions, this paper utilizes data from two nationally representative household surveys, to track the trends in household cooking fuel choices over the period 2005/6 and 2012/3. We further, analyze the main factors driving these fuel choices over the two periods using the multinomial probit model (MNP). The use of the MNP allows us to overcome the problems of the assumption of "Independence of Irrelevant Alternatives (IIA)" implicit in variant models such as the multinomial logit model (MNL).

Results from the paper show a significant reduction in biomass energy use with a corresponding increase in use of modern energy, particularly, LPG: an indication of the relative success of LPG programs implemented over the period. Nonetheless the analysis reveals that biomass energy sources still dominate as the major cooking fuels in Ghana, accounting for 76.4% of total households in 2012/13.

On the determinants of household fuel choice, our paper shows interesting results: First, factors such as income, educational attainment, household size and household residential attributes are shown to be key factors driving the transition from traditional to modern fuels. Again, supply side factors such as reliability in supply of LPG is observed to be a key factor determining whether a household will decide to adopt LPG as a main cooking fuel or otherwise. The

most striking results from the paper are that we find a positive price effect for LPG use and an aberrant sign asymmetry in the cross price elasticities between LPG and fuelwood.

The positive price effect is potentially driven by among others, a price subsidy on LPG. Also, the LPG campaign policies appear to have engendered high interest in LPG among most urban households as being a relatively "cleaner" and efficient fuel. The combined effect of these factors can explain to a greater the extent the positive price effect for LPG. The cross-price asymmetry between LPG and fuelwood can be attributed to the quality differences between the two energy types especially in terms of fuel efficiency and associated emissions from combustion. Thus, even though the two energy types are expected to be substitutes, differences in income effects between the high quality fuel (LPG) and low quality (fuelwood) fuel may result in sign asymmetry in cross-price elasticities between them (Allenby and Rossi, 1991).

Paper II: Modelling demand for liquefied petroleum gas (LPG) in Ghana: current dynamics and forecast

Unlike paper 1 which focuses on households' cooking fuel decisions, paper 2 presents a more detailed analysis of the dynamics in aggregate LPG consumption. In so doing the paper considers LPG consumption by both residential and commercial users.

Even though demand for LPG in Ghana for both domestic and industrial uses have soared since the implementation of the National LPG campaign program in the early 1990s, the LPG market in Ghana is fraught with several challenges. One principal obstacle has been the erratic shortages in supply of the gas. It is common to observe long queues of people and vehicles at gas stations owing to shortages in LPG supply. Also, even though the original intended beneficiaries of the LPG promotion policies were households, the programs have generated some unintended beneficiaries, the transport sector. Driven by relatively high price subsidies on LPG, many commercial vehicles (particularly taxis) and private vehicles have converted to "*autogas*". The transport sector demand for LPG increased over time accounting for nearly 37% of total demand (Edjekumhene, 2011).

Aside these developments, there is still great uncertainty surrounding the size of market for LPG. As a result, there has been very little addition to installed capacity and gas infrastructure than levels required to meet available demand. It is argued that the recurrent shortages if not curtailed has the potential to

erode the gains made so far in encouraging fuel switching to LPG. Therefore, supply side management is crucial if the current demand for the gas created is to be sustained. However, efficient supply side policies requires a thorough understanding of demand drivers and crucially, knowledge of the possible future trends in demand, at least in the short-to-medium term.

The aim of this paper therefore is to identify the key drivers of LPG demand in Ghana, and further provide a future outlook of demand. This is necessary to inform policy makers on the potential market outlook over the medium-to-long term and thus make the necessary investments into infrastructure to boost the production capacity of the available installed capacity.

The empirical strategy of the paper is summarized as follows: First, I estimate the long run demand model for LPG to establish the presence of cointegration using the Auto Regressive Distributed Lag (ARDL) model. As a next step, I proceed to estimate the long and short run elasticities using the ARDL and partial adjustment model (PAM) techniques. The forecast ability of each model is tested to determine the best model for an ex-ante forecast. Finally, a 10 year forecast is made to predict future trends in LPG demand based on the appropriate econometric model using three scenarios. The analysis is undertaken using quarterly time series data between 1992 and 2012.

Results from the analysis reveal that economic variables such as price, income and degree of urbanization are principal factors driving LPG demand in both the short and long run. One noticeable result from the paper is that the impact of urbanization dominate the price and income effect in the long run. This suggest that the rapid urban sprawl in the country has implications on the energy sector, resulting in higher demand for efficient fuels such as LPG relative to traditional fuels like biomass, especially for cooking purposes.

To understand the future dynamics, three scenarios are estimated: i. a baseline scenario where real price of LPG, income and urbanization is projected to grow at -0.07%, 1.4%, 0.3% respectively, every quarter; ii. A high growth scenario where income projected to grow at 1.7% per quarter; and iii. A low growth scenario with a quarterly growth in income projected at 1%. Projections from the three scenarios reveal that demand for LPG in the country will reach a minimum of 5.9 million metric tons by the year 2022 with a growth rate of 7.8% every quarter, thus significant investment into infrastructure will be required to meet the looming demand.

Paper III: Carbon emissions, energy consumption and output: a threshold analysis on the causal dynamics in emerging African economies

The nexus among energy consumption, economic growth and their associated carbon emissions have received considerable attention in the literature (see: Apergis and Payne, 2009; Esso, 2010). However, in many of the extant empirical studies on this relationship, the role of structural reforms is often ignored. This issue is of particular importance in emerging countries where significant changes in the structure of the economies are witnessed. For instance, the exposure of many African economies to economic crises and their ensuing structural adjustment policies rigorously pursued in the 1980s and 90s have the potential to affect GDP and energy consumption with rippling effects on carbon dioxide emissions.

The contribution of this paper therefore, is to account for the role of structural reforms on the trivariate relationship between energy consumption, economic growth and emissions. Specifically, the paper estimates the impact of relationship among energy use, carbon emissions and economic growth in the presence of policy regime shifts in six (6) emerging African economies − Egypt, Ghana, South Africa, Senegal, Nigeria, and Kenya− using the Gregory and Hansen (1996) threshold cointegration approach and the Toda and Yomamoto (1995) Granger causality test. The essence of the study is to generate deeper understanding into the potential influence of structural reforms on the interactions between economic systems and the environment to aid optimal policy design especially in emerging and developing countries where these reforms are rigorously being implemented.

The econometric strategy for this paper is outlined as follows: First, I examine the unit root properties of the series with and without the presence of structural breaks as well as examining the stability of the long run relationships using the Hansen (1992) stability test. In the second step, I test for the presence of threshold cointegration for all cases treating each variable as endogenous, using the Gregory and Hansen (1996) threshold cointegration approach. Finally, the short run causality among the variables is examined using the Toda and Yomamoto Granger causality test.

Results confirm the presence of regime shifting effects in the long run inter-linkages among energy use, real GDP and CO_2 emissions in the countries considered, thus indicating that structural reforms have both economic and

environmental effects. Therefore, to ensure optimal outcomes, policy reforms and/or national development plans should give sufficient considerations to the energy and environmental implications of the various strategies the reforms seek to implement.

Paper IV: Optimal management of two deer species competing for food

In many of the extant studies on wildlife management, the focus has been on examining the optimal management strategies (i.e., harvest, feeding, conservation) for single species populations, with very little consideration for strategies for joint management of multi-species. As a result there is limited knowledge about the importance of ecological interactions among species in managing wildlife. Such interactions can include, e.g., competition between individuals of different species which utilize common resources that are in short supply, i.e. resource exploitation; or when members of a particular species prevent members of the other species from accessing a resource through their behavior, even if the resource is not in short supply, i.e. interference competition.

To this end, this paper seeks to examine the impact of interspecies dependence between two deer species, roe (*Capreolus capreolus*) and fallow deer (*Dama dama*), on the net present value of hunting when the species are jointly managed. This is motivated by the fact that the presence of fallow deer exerts negative effects on the foraging behavior of roe deer, but not vice-versa (Focardi et al., 2006); thus making fallow deer superior relative to roe deer in terms of competition for food and other resources. Our choice of species to study is also motivated by roe deer being the second most valuable hunted species in Sweden (Mattsson et al., 2008), and by the recent public debate on the possible advantages and disadvantages of deliberate efforts to establish viable fallow deer populations in additional locations.

In order to evaluate the economic consequences of species interaction, we identify the impacts on economically optimal harvesting strategies, and on population densities of the two species. We also recognize that the two species provide different types of hunting benefits, including meat, recreation and trophies, and therefore examine how the role of species interdependences is affected by the choice of benefits to include in the analysis. To these ends, we develop a numerical stage-structured bioeconomic model, where we use data from an estate in south-western Sweden, where multiple species are actively co-managed on a commercial basis.

Our findings suggest that the effect of interspecies competition on total net economic value of the two species depends strongly on the relative hunting value of the two species involved in combination with the direction of the competition effect. The impact of interspecies competition on total hunting benefits is small when competition is unilateral and borne by the economically less valuable species, in this case the roe deer. On the other hand, the effect of competition on population densities is significant, which highlights the need for further research on the economic values provided to society by the species in their habitat, through the provision of ecosystem services of different kind. Further, our study reveals that competition implies that the optimal harvesting strategy includes pulse harvesting.

Paper V: An empirical analysis of hunting lease pricing and value of game in Sweden

In developing sufficient policies to manage wildlife, knowledge of the benefits of wildlife to the various stakeholders is important. Also, given that hunting is to large extent a recreational activity, the economic values are not fully reflected in market prices (Boman et al., 2011). It is therefore necessary to employ the relevant economic techniques to estimate such values and identify market properties. It must be emphasized that even though hunting value of two species (roe and fallow deer) are considered in paper 4, the values obtained used in that paper applies for only commercial hunting and does not reflect the true hunting value for the more common recreational hunting. Therefore in paper 5, we seek to provide a comprehensive analysis of the hunting values of multiple hunted wildlife species in Sweden.

To this end, we estimate the economic values of game species to hunters by estimating a hedonic price model for hunting leases. From this model, marginal implicit values are derived. The approach used in this paper is summarized as follows: first, we present a simple theoretical model to explain the bargain between a representative hunter and landowner in determining equilibrium hunting lease prices. We proceed to the empirical section where we estimate demand for hunting leases via the hedonic pricing approach. Finally, from the hedonic price model, marginal implicit values are estimated which reflects the economic values attached to the harvest of one unit of game. Four main game species are considered: moose, fallow deer, roe deer and wild boar.

It is noteworthy to emphasize that, recent advances in the literature on hedonic price models suggest that amenity prices often tend to be spatially correlated

(Brasington and Hite, 2005). This suggests that accounting for such spatial interactions is important towards obtaining robust estimates. In line with the above, this paper contributes to and refines the extant literature on hunting leases and economic valuation of game by demonstrating the effects of accounting for potential spatial spillovers in lease prices on the estimated implicit values from a hedonic price model. As a result, we estimate two variant hedonic price models: a non-spatial pooled ordinary least squares model and a spatial-autoregressive with auto-correlated errors model. Estimates from the two models are then compared.

Findings of our study indicate that moose and fallow deer hunting have high economic values in Sweden. Also, there are significant spatial spillovers in the equilibrium hunting lease prices across municipalities. Further, we observe that factors such as proximity to urban areas, income, forest share of hunting area, and harvest rates are significant factors driving equilibrium hunting lease prices in the study area. Finally, our results suggest that even though hunters prefer game diversity, preference is higher for deer species relative to wild boars.

Conclusion

In sum, this thesis provides an attempt to address a number of important issues regarding energy demand and the management of wildlife populations. Despite the diversity in terms of the issues covered in the thesis, the respective papers nonetheless offer significant contribution to the literature and provide relevant policy prescriptions as well.

The section hereafter presents the five full length articles that constitute this thesis.

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