Analysis of Energy Efficiency Practices of SMEs in Rural Ghana: An Application of Product Generational Dematerialisation

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Abstract

Energy is a key input in industrial production, education and health, and is one of the main drivers of economic growth in developing economies. However, expanding energy access in the rural areas is one of the key challenges faced by policy makers in developing countries such as Ghana. In this regard, small and medium-sized enterprises (SMEs) in developing countries face the hydra-headed challenges of energy access, power outages, access to finance and access to market. In some cases, whilst energy efficiency appears to be improving at the national level, the story at the rural areas are different due to overdependence on biomass and other traditional forms of energy and relatively low access compared to urban areas.

This research is structured in three steps. In the first step, the PGD method is applied to examine the energy efficiency consumption of electricity and fossil fuels. In a second step, the energy efficiency practices of small and medium scale enterprises are investigated. In a third step, the general unrestricted model (GUM) is employed to investigate the relationship between energy efficiency, productivity and carbon emissions. The key findings of the study i) confirm that the consumption of energy has not been efficient, ii) show that the reduction in energy consumption among SMEs can be attributed mostly to blackouts and not efficiency, and iii) productivity is a major driver of energy efficiency. In a nutshell, the national analysis shows that improved productivity from more energy efficient technologies is not responsible for energy reduction. Rather, an analysis of the rural energy situation, shows that that blackouts render energy reductions unintentionally. Moreover, energy efficient practices are observed to be nearly non-existent within rural SMEs. The study recommends that public education on energy efficiency is increased and that new appliances rather than second-hand one are used to save energy.

Keywords:

Energy Efficiency, Energy Consumption, Ghana, Product Generational Dematerialization, SMEs

1. Introduction

The effects of climate change – a by-product of an alleged overuse of energy resources – have been subject to heightened debate during the last two decades among energy and environmental economists, and policy makers. Instrumental in international response to climate change has been a pledge to clean sources of energy and energy efficiency. In particular, energy efficiency promotes energy security and reduces costs, outcomes highly critical in rural areas of developing economies. For instance, in Ghana, one of the leading countries according to electrification, 50% of rural communities do not have access to electricity (Aglina et al., 2016). These challenges adversely affect productivity, hinder their competitiveness and stifle growth. Thus, for SMEs to maintain their competitiveness, they need to be energy efficient, insofar as energy efficiency reduces the costs of production through reduced energy bills (Worrell et al., 2003). At the national level, energy efficiency is the cheapest way of reducing energy-related carbon emissions. At the firm level, energy efficiency can be a key means of enhancing productivity growth (Jorgenson, 1984; Thollander et al., 2007). The dependence on the traditional sources of energy, especially in rural areas, is also associated with increasing air pollution and adverse health outcomes (Aglina et al., 2016).. Therefore, environmental policies that seek to curb carbon emissions have positive health effects due to improved air quality. In this regard, the Johannesburg Plan of Implementation (United Nations Department of Economic and Social Affairs – UNDESA, 2002) called on all countries to develop policies and measures contributing towards the reduction of carbon emissions. Energy efficiency can lead to improvements in energy security and ensure a firm’s profitability and competitiveness (Gboney, 2009).

A major drawback is that most studies in this field are either carried out in developed economies or at the aggregate level. Furthermore, energy efficiency gains are constrained by the market mechanism and rely upon the extent to which the energy market can be restructured (Jaffe and Stavins, 1994). Indeed, asymmetric information and imperfect information, among other inhibitors, can hinder the viability of energy price changes as a major efficiency tool. More generally, economic, behavioural and organizational barriers to energy efficiency gains have been identified (Sorrell, 2007). For instance, Sutherland (1991) studied the market economic barriers to energy efficiency and identified the external cost to energy consumption as one of the reasons governments should initiate in energy efficiency measures. Indeed, Shirley (2005) summarised the barriers into firm profitability, consumer concerns about prices and the preparedness of regulators to restructure energy markets. These different findings call for SME-specific initiatives, behavioural changes and policy intervention especially in the context a developing country like Ghana.

The Ghana Shared Growth and Development Agenda (2010–2013) confirms the status of a secure and reliable supply of high quality energy services in all sectors of the economy as a prerequisite for Ghana's development. This notwithstanding, Ghana suffers from a recurrent power crisis, which has led to the loss of a significant amount of output in the country. According to Braimah and Amponsah (2012), this loss in output is a build-up of time lost in production and joblessness created as a result of lack of alternative sources of power to bridge the gap between supply and demand. The Institute of Statistical, Social and Economic Research (ISSER, 2015) estimates that $55.8 million per month due to the power crises. This implies that, cumulatively, Ghana lost about 2% of its GDP in 2014 as a result of the unreliable power supply. According to Gyamfi (2007) and Adom et al. (2012), the electricity problem in Ghana could easily be solved if attention were paid to the demand side of electricity in the country, as is done in this study. Adom et al. (2012) and Adom and Bekoe (2012) are the only authors who tried to estimate the demand dynamics for electricity in Ghana. However the authors' inability to measure the impact of certain significant factors of demand and the price of electricity weakened their analysis.

In 2011, Ghana grew at an astonishing rate of 14.4% – one of the highest rates of growth in the world – and it attained middle-income status (Aiyar et al., 2013). To sustain such growth, various measures have been undertaken by policy makers, businesses and researchers. First, the government recently established a fund (Youth Enterprise Support Fund) to help the country's youth start businesses. Second, researchers and policy makers are calling on the government to remove energy price subsidies. The removal of such subsidies will increase energy prices. The cheapest way of offsetting the impact of energy prices on a firm's performance is through energy efficiency (Patterson, 1996). To this end, the Energy Commission of Ghana encourages energy-efficient practices through education and other measures, such as 'swapping old freezers for new ones' and the replacement of 40 W fluorescent lamps with energy-efficient 36 W fluorescent lamps. Although these policies have been well received, they mostly target household energy consumption. Even at the household level, to the best of our knowledge, no study has yet attempted to evaluate the effects of such energy efficiency policies on energy consumption and productivity in both rural and urban areas. Gboney (2009) is perhaps an exception. He finds that energy efficiency activities undertaken by the Energy Foundation in Ghana within the residential and business sectors have yielded significant monetary savings for consumers. However, Gboney's (2009) study makes a critical untested assumption that the impact of energy efficiency practices in Accra can be generalized and extended to other regions in Ghana, thus neglecting the potentially important effect of geographical location.

According to Shipley and Elliot (2001), SMEs (i) often face difficulties in obtaining the necessary information on new and already existing energy technologies and (ii) lack the capital and technical expertise to invest in energy-efficient technologies. These difficulties are amplified by the relatively low level of attention directed at non-energy-intensive SMEs in policy (Ramirez et al., 2005). Although an increase in energy prices is necessary for energy efficiency, Bertoldi et al. (2005) suggest that this is not always an effective mechanism. Energy-efficient technologies have many advantages, including lower maintenance costs, increased productivity and safer working conditions. Despite these advantages, there is dearth of energy efficiency studies focusing on Ghana. The few attempts that have been made (Van Buskirk et al., 2007; Gboney, 2009; Apeaning and Thollander, 2013) are either sector-specific or focused only on electricity consumption.

This study uses the product generational dematerialization (PGD) indicator to investigate energy efficiency practices in Ghana. The PGD has been applied to dematerialization or decoupling (Recalde et al., 2014), resource use such as that of water (Fiksel et al, 2012) and waste reduction, for example of food waste (Guidat et al., 2015; Van Ewijk and Stegemann, 2014). The PGD indicator measures a change in population in relation to changes in the energy used by this specific population (Ziolkowska and Ziolkowski, 2010). The PGD therefore measures a decrease or an increase in energy consumption by a given population. When energy consumption decreases, it is assumed that the population exhibit energy-saving behaviour which implies efficiency. When energy consumption increases, it is assumed that the population exhibits energy-using behaviour. ‘Materialization’ refers to a higher level of energy consumption compared to the reference year, while ‘dematerialization’ depicts a lower energy consumption compared to the reference year. This study extends recent boundaries in the application of the PGD indicator by considering the efficiency of current electricity, fossil fuel and total energy consumption by comparing changes in energy consumption and changes in population. In this respect, the PGD indicator has three main advantages. First, it allows a dynamic analysis of energy consumption. Second, it helps create a new interpretation and visualization method. Finally, it provides a model that is easily comprehended by the public, policymakers and investors.

In a nutshell, there are three main objectives of this paper. These are:

1. Apply the product generational dematerialization (PGD) indicator to investigate energy efficiency practices in Ghana

2. Examine the energy efficiency practices of SMEs and the barriers to energy efficiency in rural Ghana.

3. Employ a general unrestricted model (GUM) to examine the relationship between energy efficiency, carbon emissions and productivity.

2. Methodology

To achieve the objectives of this study, we build on three different methodologies. The first methodology comprises the PGD, similar to the work of Ziolkowska and Ziolkowski (2015), but departs from existing literature by applying a dynamic dematerialization model to study energy efficiency in Ghana. Unlike Ziolkowska and Ziolkowski (2015), who focus on the transport sector, this study focuses on the efficiency of the aggregate use of different kinds of energy (fossil fuel, electricity and total energy consumption). Second, the study goes further to identify energy efficiency practices of small- and medium-scale enterprises in rural Ghana and ascertain the barriers to energy efficiency by means of questionnaires. To this end, 15 industries were selected from 4 regions: Central, Eastern, Greater Accra and Volta. The choice of the industry and regions was dictated by energy consumption rate, energy access rate and the selection of electric utility provider. Based on the classification of the Regional Project on Enterprise Development, the study categorizes small enterprises as those with 5–29 employees and medium-sized enterprises as those with 30–99 employees (Regional Enterprise Development, 2008). Third, we also employ Autometrics to study to examine the relation between energy efficiency, productivity and carbon emissions at the national level.

2.1 Product generational dematerialization

Following the work of Ziolkowska and Ziolkowski (2015), a PGD which involves changes in population and changes in electricity and gasoline consumption is used. The data span the period from 1971 to 2013. The PGD is measured as follows:

$$PGDE_t = \Delta POP_t - \Delta EC_t \tag{1}$$

where $PGDE_t$is the product generational dematerialization of electricity consumption at time t and ΔPOP_t is the population change of Ghana at time t. In a similar vein, we derive the following equation for the efficiency of gasoline consumption:

$$PGDG_t = \Delta POP_t - \Delta GC_t \tag{2}$$

where ΔGC_t represents the change in gasoline consumption in Ghana. Other variables (product generational dematerialization and change population) are as defined in Equation (1). Alternatively, PGD can also be defined as follows

$$PGDE_t = \left(\frac{POP_t}{POP_{t-1}}\right) \times 100\% - \left(\frac{EC_t}{EC_{t-1}}\right) \times 100\% \tag{3}$$

$$PGDG_t = \left(\frac{POP_t}{POP_{t-1}}\right) \times 100\% - \left(\frac{GC_t}{GC_{t-1}}\right) \times 100\% \tag{4}$$

A positive PGD value means that energy consumption has decreased in the years analysed compared to the preceding years relative to what would have happened if all the population consumed energy in the same way. Conversely, a negative PGD value means that energy consumption has increased relative to what would have happened if all the population consumed energy in the same way. Both outcomes would deliver policy-relevant information for decision making. Data for the PGD analysis were collected from the World Development Indicators (WDI) of the World Bank.

2.2 Energy efficiency of SMEs in rural Ghana

To achieve the third objective, we collected data from SMEs in rural Ghana by means of a questionnaire and observation. Observation is employed to to minimize the impact of social desirability biases, i.e. when respondents report things that may not be the fact on the ground or reflect actual behaviour (Brace, 2004). The sample consists of 160 SMEs in rural area as defined by the Ghana Population Census. The coastal zone of Ghana, which comprises the Western, Central, Greater Accra, Volta and Eastern Regions, is generally humid and is home to most energy-intensive SMEs. Four regions were selected: Central, Eastern, Greater Accra and Volta. The questionnaire was pre-tested to ascertain whether the respondents understood the questions asked and whether they were consistent with the aims and objectives set out by the study. The qualitative variables were allocated numerical values for a more intuitive interpretation. Parametric (Bonferroni) and non-parametric tests (Mann–Whitney and chi-squared tests) were used to test for non-response bias between the respondents and the non-respondents. In this research, the questionnaires and interview guides were pre-tested on a related sample to ensure validity and reliability before the data collection started. According to Lufumbi, (2010), reliability means that the measure yields a consistent result. The primary data were further compared to data from the Ghana Statistical Service.

2.3 The determinants of energy efficiency

Further, the study also investigates the determinants of energy efficiency, with a particular emphasis on productivity and carbon emissions at the national level by means of Autometrics. Hendry and Krolzig (2005) suggest that model selection is a vital step in empirical research, especially when there are extant arguments over the choice of variables that affect a given phenomenon. As different sets of factors can potentially influence productivity, it is important to have an econometric approach that automatically selects the significant factors based on some predefined criteria. In Africa, Bhattacharya and Timilsina (2009) suggest that due to factors such the transition from traditional sources of energy to modern commercial sources and the economic structure, productivity functions may be the same as those specified for developed countries. Automatic variable selection works by first specifying a general model based on previous findings, geographic and demographic characteristics and technological and economic trends. A misspecification test, lagged forms, significance levels and the desired information criteria are then established. This allows valid inference from the specification (Hendry and Krolzig, 2005). This step is followed by the elimination of insignificant variables.

To ascertain the relationship between energy efficiency and productivity, a general unrestricted model (GUM) consisting of all predictors is specified. *Autometrics*™ then uses a tree search to remove insignificant variables and select the final model (Pellini, 2014). According to Patterson (1996) and Ang (2006), energy efficiency (EE_t) can broadly be defined as the ratio of output (Y_t) over energy input (E_t) as follows:

$$EE_t = \frac{Y_t}{E_t} \tag{5}$$

Therefore the greater is the output a country produces with a given amount of energy, the higher its energy efficiency. With regard to productivity, this study uses total factor productivity (TFP) as a proxy. In this regard, Zaman et al. (2011) argues that the strong relation between energy productivity and capital use indicates that energy efficiency may be augmented by optimizing capital use. Data on TFP for the period 1971 to 2010 were collected from the UNIDO global productivity database. TFP is calculated using growth accounting and is obtained by attributing to productivity the excess of the combination of capital and labour contribution to economic growth. For instance, using Hicksian growth accounting, we assume that a change in income (Δy_t) is the result of changes in capital (Δk_t), labour (Δl_t), productivity (Δa_t) and other factors (Δx_t), such as health, energy and quality of inputs. Thus:

$$\Delta y_t = \Delta a_t + \alpha \Delta k_t + \beta \Delta l_t + \rho \Delta x_t \tag{6}$$

Therefore, productivity becomes:

$$\Delta a_t = \Delta y_t - \alpha \Delta k_t - \beta \Delta l_t - \rho \Delta x_t \tag{7}$$

where a_t is a Hicksian demand function.

According to Boyd and Pang (2000), energy efficiency improvements have positive effect on worker productivity and the general productivity of companies through cost savings. In this paper, the Hicksian demand function is applied since it captures the effects of re-allocation of resources by examining the intuitive appeal of the Pareto improvements through the Kaldor-Hicks efficiency (Alston and Larson, 1993). We begin by specifying a GUM error correction model saturated with impulse indicators and step dummies with 'ee_t' as the dependent variable:

$$\beta_{EE}(L)ee_t = \beta_0 + \beta_1 t + \beta_Y(L)y_t + \beta_A(L)a_t + \beta_{EC}(L)ec_t + \beta_{CO2}(L)co2_t + \sum_{j=1}^{J}\left(\beta_j I_{j,t} + \delta_j S_{j,t}\right) + u_t \quad (8)$$

Where i indexes country, t indexes time, $I_{j,t}$ is the impulse indicator dummy and $S_{j,t}$ is a step dummy. For all dummies, j is the indicator index. For instance, $I_{2004,t}$ means the impulse indicator dummy variable for 2004 that takes on the value 1 for 2004 onwards and 0 prior to 2004. $\beta(L)$ is a lag polynomial. The use of energy consumption (EC_t) is in Equation (8) accounts for the finding that reduction in energy consumption improves productivity (Kander, 2002). Moreover, since one of the goals of productivity is to reduce carbon emissions (CO2), this paper examines how carbon emissions influence productivity (reverse causality). Specifically, it is expected an inverse relation between carbon emissions and productivity. Data on fossil fuel and energy consumption in kilotons of oil equivalent (ktoe) for the period 1971 to 2011 and on electricity in kilowatts per hour (kWh) and population figures from 1971 to 2011 were obtained from the WDI.

3. Analysis and Discussion

3.1 Product generational dematerialization

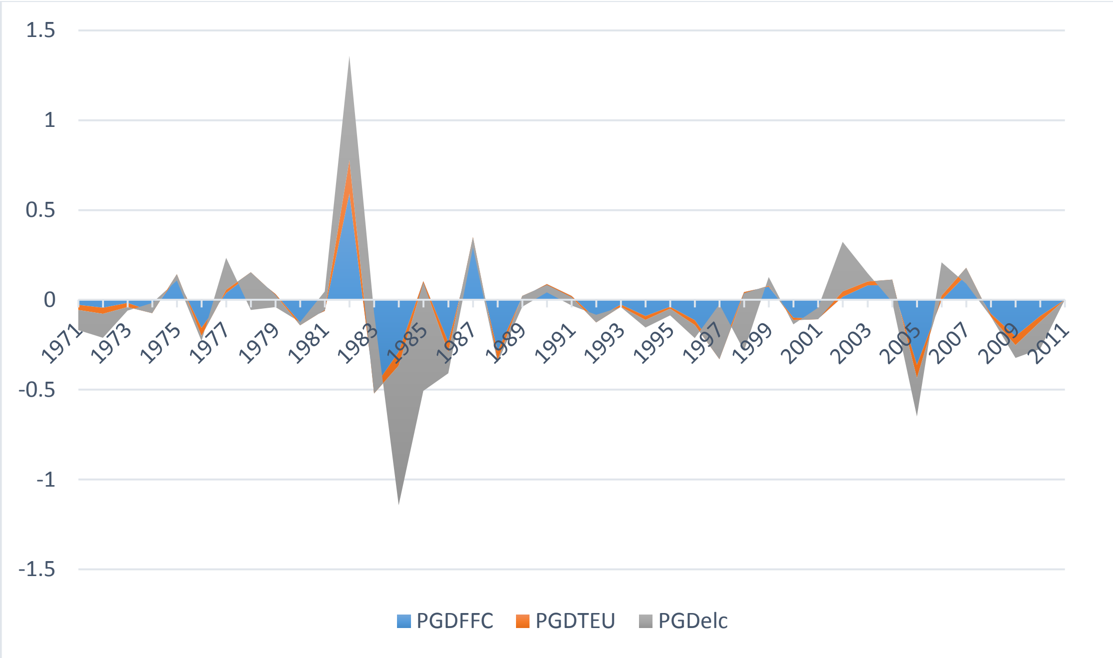

Figure 1. Results of product generational dematerialization

Figure 1 shows the PGD of fossil fuel consumption (PGDFFC), total energy consumption (PGDTEU) and electricity consumption (PGDelc) in Ghana from 1971 to 2011. The trends for all three variables show structural breaks and follow a similar pattern. Fossil fuel consumption showed a positive trend of generational dematerialization in 1975, 1981 to 1983, 1988, 1990, 2000, 2003 to 2004 and 2007. These changes in the trend could have been influenced by certain economic and political events that have impact on energy consumption. For instance, Ghana experienced a major drought from 1981 to 1985 which affected the water level of the Akosombo Dam, the main producer of electricity then. In addition, 1981 was associated with the end of the ascension to power of Flight Lieutenant Jerry John Rawlings of the Provisional National Defense Council (PNDC) and changes resulted in the suspension of the Constitution of Ghana and the banning of political parties. The economy suffered a severe decline soon after and the implementation of the World Bank sponsored structural adjustment plan and economic recovery programs changing many old economic policies. The structural adjustment programme witnessed a shift from agrarian based economy to gradual movement to industry based economy through divestiture of poorly managed public owned companies and, public-private investments. These structural changes had energy consumption implications. However, the general pattern suggests inefficiency in fossil fuel consumption. Finally, the PGD of total energy consumption is -0.27%. This implies that there is high efficiency in non-fossil fuel energy consumption such as renewables. As energy efficiency improvements rely on technological progress and behavioural changes, there should be systematic investments in energy efficiency measures and education to save money, save energy and also curb carbon emissions.

Overall, fossil fuel consumption recorded a PGD of -1.51% over the estimated period. This finding is in line with the PGD of Estonia (-1.5%) and Sweden (-1.4%) for non-renewable energy consumption reported by Ziolkowska and Ziolkowski (2015). The negative PGD for fossil fuel implies that energy consumption is growing faster than population growth. With carbon emissions from liquid fuel consumption increasing, there is a need for policy initiatives that will encourage efficiency in fossil fuel consumption.

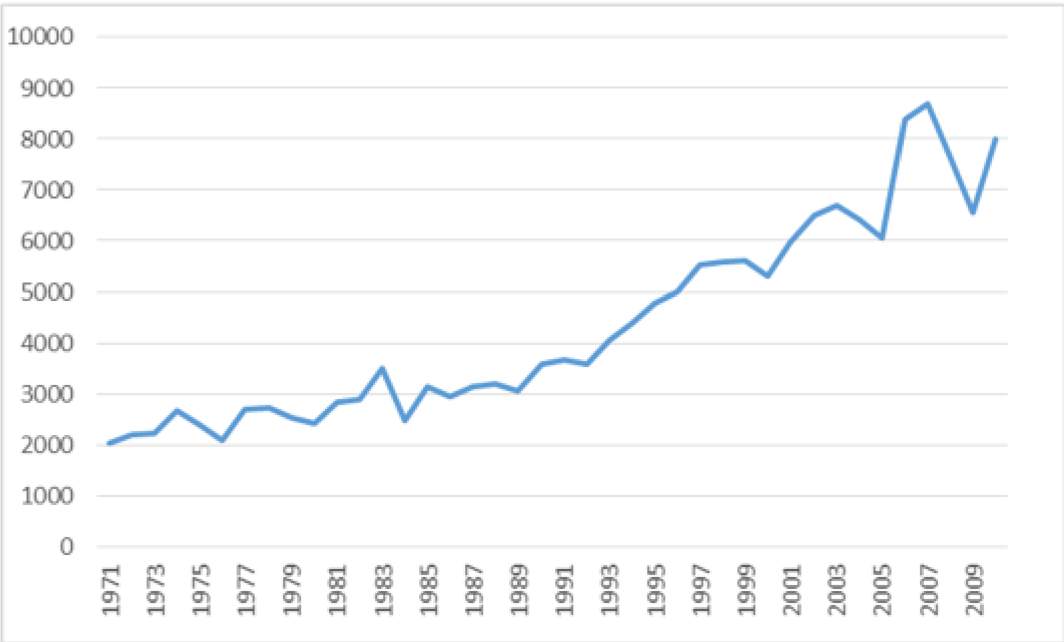

Figure 2. Carbon emissions of fossil fuel consumption

Figure 2 shows carbon emissions from liquid fuel consumption of 2016.85 kt in 1971. As at 2010, this had jumped to 7990.39 kt. Therefore, there is a need to implement measures that will promote investment in technology, reduce the imports of used vehicles and introduce efficient mass transportation systems to reduce the number of cars on the road, as well as educational promotion to target behavioural changes.

In 1997, the Ghana Energy Commission was launched as an agency to promote standards and efficiency in the use of energy. However, it has focused predominantly on the efficiency of electricity consumption at the expense of other fuel sources such as gasoline. For instance, the Ghana Energy Commission has introduced the ‘old fridge for new’ campaign to minimize waste in electricity consumption, coupled with educational campaigns that inform on the need to adopt efficient practices with regard to electricity. The PGD for electricity consumption was -1.11%, which is lower than that for fossil fuels. This means that more has to be done, especially in rural areas where some of these campaigns do not reach.

3.2 Energy efficiency of SMEs in rural Ghana

The study uses a survey conducted from November 2014 to March, 2015 in 4 out of the 10 regions of Ghana through a questionnaire. The essence of the study is to identify energy efficiency practices of SMEs in rural Ghana and ascertain whether these practices influence productivity. The reason for the rural emphasis is that few works that have been conducted on energy efficiency are concentrated in the urban areas (see Gboney, 2009). In addition, energy efficiency education is usually carried on televisions which may not be accessible by the rural population. Finally, since the Ghana Energy Commission is not decentralised, the old fridge for new one policy is centred in cities. In all, 200 questionnaires were distributed but only 160 were completed. The questionnaires were semi-structured with both closed and open-ended questionnaires. The high rate of response may be attributed to the high interest of the public in energy matters at the time of the study as a result of the Ghana power crises. A sample of the questionnaire is provided in Appendix 1. The industries were selected based on their connection to the electricity grid, operations within the rural Ghana and their preparedness to answer the questionnaires. The industry distribution is summarized in Figure 3.

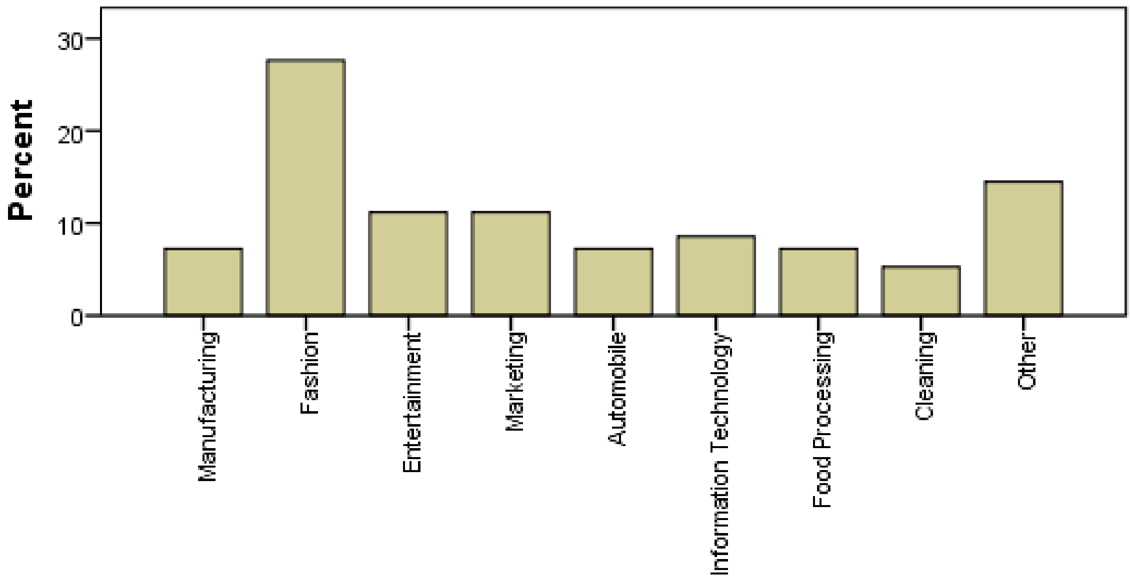

Figure 3. Industry distribution for data collection

Figure 3 highlights the industry categorisation of the respondents. Because hair dressing saloons, barbering shops and dress making shops are predominant in rural areas, the fashion industry provided the highest number of respondents, followed by the catering industry.

The results indicate that approximately 60% of the SMEs studied recorded a reduction in their electricity consumption over the preceding six months. However, 72% of these attributed the reduction in electricity consumption to blackouts (unreliable power supply).

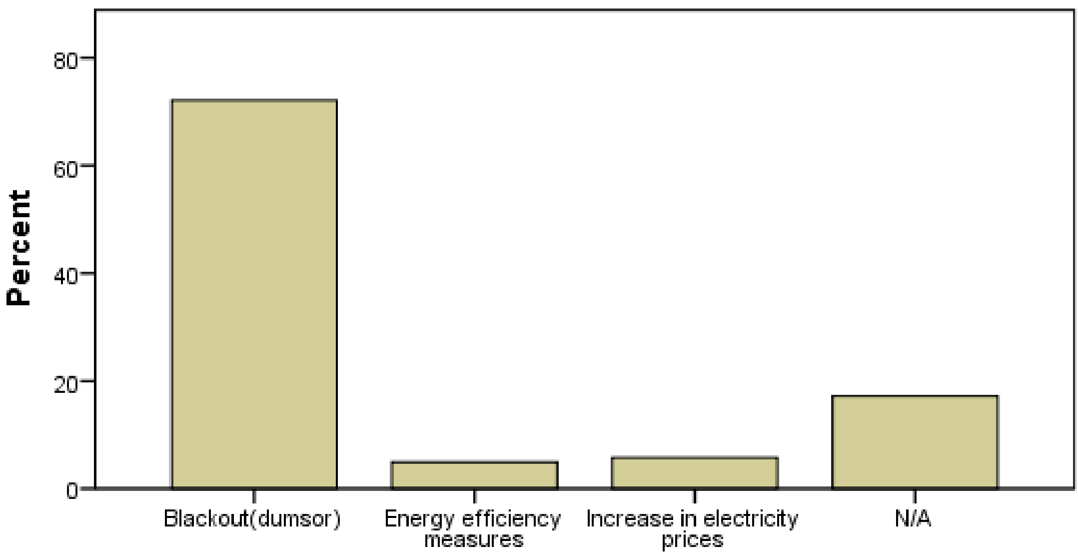

Figure 4. Causes of reduction in electricity consumption

The study further finds that second most important driver of reduction in electricity consumption was increases in prices (5.7%). This confirms the findings of Adom et al. (2012), who found that price is a major driver of electricity consumption in Ghana. Finally, only 4.9% indicated that their reduced consumption resulted from energy efficiency. This finding has two important policy implications. First, policy makers can use price as a tool to achieve energy efficiency and climate change measures. Since consumers will have to pay more for a given unit of energy consumed, higher energy tariffs can serve as an incentive for consumers to make improvements in energy efficiency and lower their electricity use by investing in more efficient lighting and heating appliances or by installing higher quality insulation or windows. Second, the Ghana Energy Commission, the main body charged with enhancing energy efficiency should adopt more pro-rural mechanisms and media to target and educate rural SMEs.

In Figure 5, the reasons for energy efficiency are identified. This is important for policy makers to use appropriate mechanisms such as price, mass communication and subsidies to encourage energy efficiency behaviour.

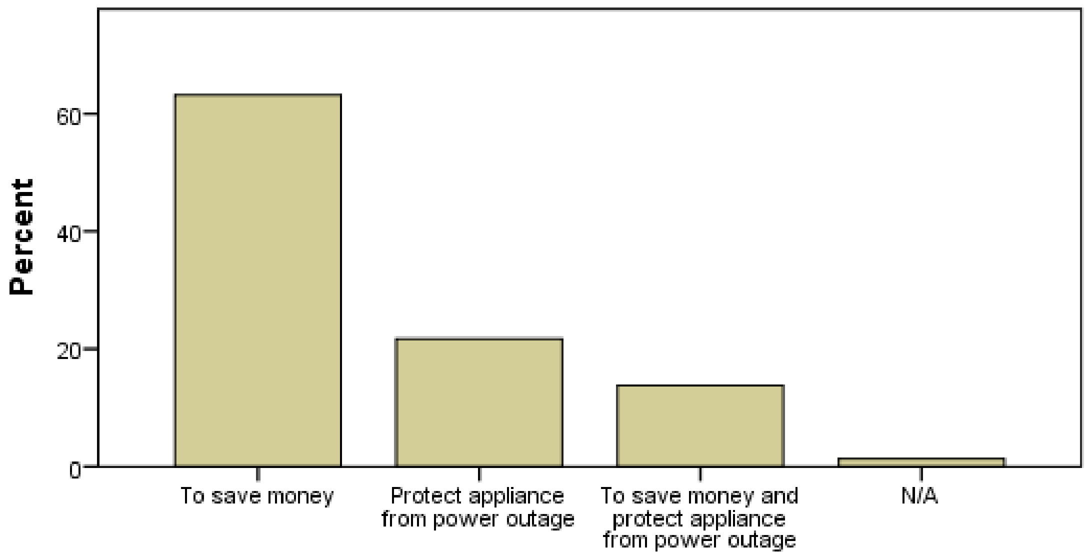

Figure 5. Reasons for energy efficiency behaviour

In terms of where the respondents first heard about energy efficiency, 53% indicated radio and television, whilst 36.8% reported using their instincts in deciding whether they should adopt energy efficiency or not. Despite the effort of successive governments to encourage Ghanaians to use energy-saving bulbs by distributing 5,000 bulbs in 2007, approximately 54% of the respondents use the incandescent ('onion') bulbs, are found to be inefficient. The IEA estimates that CFL (energy saving bulbs) uses less than one-third to one-fifth the energy of incandescent bulbs. It is recommended that subsequent distribution of the energy-saving bulbs should consider SMEs in rural areas.

According to the findings, 60.5% turn off their appliances when not in use, 11% use fewer appliances to consume less and 8.3% of the respondents avoid the use of old or second-hand electrical appliances. Moreover, the three most important barriers to energy efficiency are lack of information on energy efficiency measures, lack of staff awareness and lack of technical skills. These barriers fall under the institutional and organizational barriers highlighted by Weber (1997). These findings mean that the Energy Commission needs to look at its communication strategy and devise means of training SMEs in energy efficiency measures. Whilst commendable efforts are being made by the Ghana Energy Commission and Ghana Energy Foundation to promote energy efficiency, most of these efforts seem to be concentrated in urban areas. In addition, the media used by the Energy Commission, such as TV3 and Metro TV, do not have nationwide coverage, depriving rural SMEs of opportunities to learn of energy efficiency measures.

Respondents were asked for their views on how to improve energy efficiency. For instance, 26.4% of the respondents called for public education on energy use and management, whilst 8.4% called on the government to resolve the power crises. Whilst public education on energy efficiency through mass media is ongoing, efforts should be made to include rural areas. In addition, the provision under the Renewable Energy Act (2011) that calls for subsidized solar panels should be operationalized to allow rural SMEs to minimize the impact of the power crises through sales and energy efficiency efforts.

3.3 The determinants of energy efficiency

The output of the GUM shows that there is a significant relationship between energy efficiency, energy-related carbon emissions and productivity (see Table 1).

Table 1. The determinants of energy efficiency

Predictors	Coefficient	Std. Error
1982 (Outlier)	-0.07	0.041
A	0.41	0.065
A(-4)	0.31	0.015
Diagnostics		
Std. Error		0.0011340
Normality test		1.5842
Normality test Chi 2(2)		2.135
Hetero test F(6,30)		0.551
Observations		37
DW		1.55
R^2		0.84

The results reveal that productivity is a major driver of energy efficiency in Ghana. Specifically, Table 1 suggests that a 1% increase in productivity increases energy efficiency by 0.41%. This confirms the findings of earlier studies (see Boyd and Pang 2000, Worrell et al,. 2003). This finding implies that as labour and capital spend less time and effort to achieve the same output, energy consumption reduces. Ghana experienced its first power crises in 1981/82. It is not surprising that the results indicate an inverse relationship between the outlier in 1982 and energy efficiency. Usually, power crises lead to excessive power consumption from inefficiency behaviour. For instance, if the lights go off on Friday, workers may not turn off the switch before leaving to the house. Therefore, if the light should be on by Saturday morning, there will be no one to put air conditions, bulbs and other appliances off until morning.

To enhance the robustness of the model, a battery of misspecification tests are used for its evaluation. These tests include the autocorrelation test (Breusch and Godfrey, 1981) where the null hypothesis stipulates no serial correlation in the residuals. Moreover, the ARCH test (Engle, 1982) where the null stipulates no serial correlation in the squared residuals is employed.

Other tests include the normality test (Bera and Jarque, 1982), which tests the normality assumption in residuals, the heteroskedasticity test of Breusch and Pagan (1979) that tests the assumption of constant error variance, and finally, the Reset test (Ramsey, 1974), which tests for linearity in the functional form of the regression.

Figure 6 depicts variation over time in the energy intensity of Ghana. Ghana's energy intensity decreased from 1971 to 1983; it increased between 1983 and 1985, then remaining constant until 2001. The increasing trend after 2001 can be attributed to inefficiency in energy consumption, the increased share of heavy industrial manufacturing companies, structural changes and obsolete technology (Ma and Stern, 2008).

Even though Ghana is gradually moving towards a service-based economy, the consumption of energy is increasing. This may be driven by urbanization, economic growth and increased population.

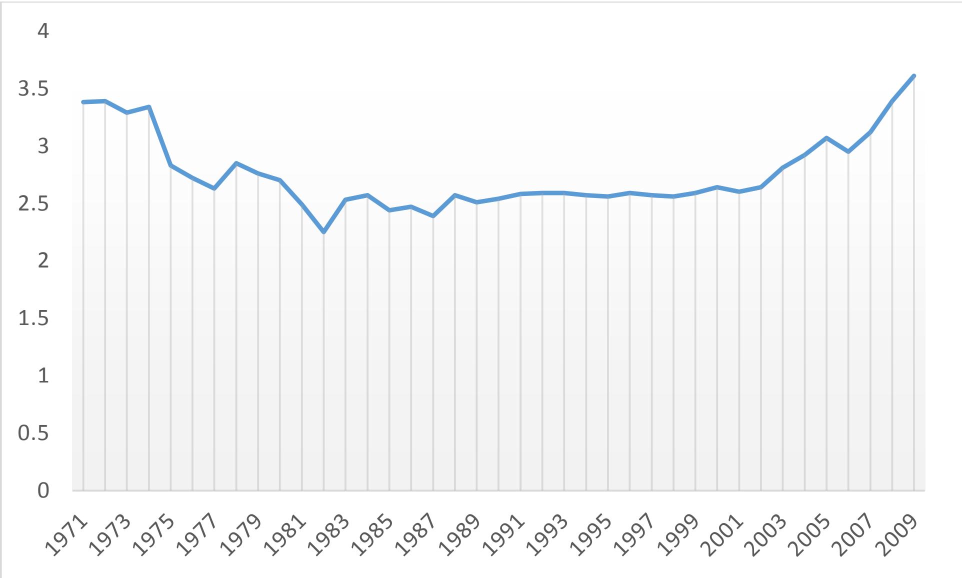

Figure 6. Ghana's energy intensity from 1971 to 2011

In terms of energy-related carbon emissions, the lagged values have a direct relationship with productivity. Finally, the lagged dependent variable has a positive relationship with the current value of productivity.

Figure 7. Underlying energy efficiency trend

Figure 7 shows the underlying energy efficiency trend of Ghana. This is adapted from Hunt et al. (2003), who measured the underlying energy demand trend. According to Dilaver and Hunt (2011), the slope of the line determines the extent to which behaviour is efficient. When the line slopes downwards, it shows generally efficient behaviour. According to Figure 7, Ghana was not particularly efficient until 1982, when the slope began to decline. This may be due to several factors. There was a downward trend in 2006 which can be attributed to the government distribution of six million energy saving incandescent bulbs in 2007 which saved 162.7 GWh annually. Post 2010 saw a sharp decline. Whilst this can be attribute to energy efficiency, it may also be due to the reduction of the manufacturing sector's contribution of GDP. The service sector, which consumes relatively less energy, is now one of the key contributors to GDP. Generally, the efficient periods were minimal, implying that energy consumption has inefficient. This confirms the finds of Appeaning and Tholander (2013) who found that energy consumption in Ghana is generally inefficient.

4. Conclusion and Recommendations

The purpose of this study was in threefold. First, the product generational dematerialization (PGD) indicator is used to investigate energy efficiency practices in Ghana. Second, the study examines the energy efficiency practices of SMEs and the barriers to energy efficiency in rural Ghana. Finally, a general unrestricted model (GUM) is employed to examine the relationship between energy efficiency, carbon emissions and productivity. The key findings i) confirm that the consumption of energy has not been efficient, ii) reveal that the reduction in energy consumption among SMEs can be attributed mostly to blackouts and not efficiency, and iii) productivity has a major driver of energy efficiency.

The study recommends that the Ghana Energy Commission intensify its energy efficiency education and extend this to rural areas. In addition, associations and organizations such as churches and mosques can be used to train SMEs in rural areas on energy efficiency measures. Furthermore, the 'old freezer for a new freezer' programme should be extended to cover common appliances used by SMEs. As price is a vital factor in reducing energy consumption, policy makers should charge realistic prices for electricity to enhance efficiency. Moreover, policies should also target worker and capital productivity since this can reduce energy inefficiency. Finally, Ghana Energy should educate the public on the need to be efficient in terms of fossil fuel consumption to save energy, save money and curb carbon emissions. Finally, it is recommended that future studies should adopt Sorrell et al., (2004)'s questionnaire to undertake a thorough study of the barriers to energy efficiency in Ghana.

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Appendix A. Questionnaire & Interview Theme Questions

University of Portsmouth, UK/United Nations University, INRA, Accra

Topic: Does efficiency lead to productivity growth? A study of energy efficiency practices and productivity growth in small and medium-sized enterprises in rural Ghana.

Dear Respondent,

This questionnaire is to collect primary data from respondents that will help to ascertain whether efficiency leads to productivity among rural SMEs in Ghana. It is part of my PhD thesis that is been facilitated by the United Nations University. It is in this respect that I am soliciting your cooperation to complete the questionnaire. The research is purely an academic work and information provided will be treated with utmost confidentiality. No part of the information will be made disclosed without prior consent from you.

I wish to express my sincere gratitude to you for taken time to participate in this research as a respondent.

Kind Regards.

QUESTIONNAIRE

PART A : COMPANY PROFILE

1. Identification

1. Name of Company……………………………………………………………………………………..
.....

2. Industry………………………………………………………………………………………

3. Company location (town and region)

……………………………………………………………………………………………...

4. Number of employee

……………………………………………………................................

5. Monthly turnover

(Approximation)……………………………………………………………………………........

6. The company is owned by (a) male (b) female

PART B: ENERGY CONSUMPTION

7. Please indicate your company‘s approximate monthly expenditure on:

Petrol……………………………………………

Electricity…………………………………………

8. Do you use generator? (A) Yes (b) No

If no, kindly go to number 10

9. If yes, how many gallons do you buy in a day?

……………………………………………………………………………………

10. Do you check your energy consumption? (a) Yes (No)

If no, kindly go to 12

11. If yes, how frequent is your energy use generally recorded/checked? (a) Daily (b) Weekly (c) Monthly (d) Yearly

12. Are consumption records adjusted to energy price change? (a) Yes (b) No

13. Is a monitoring and targeting scheme employed? (a) Yes (b) No

14. Do you use post- paid metre or pre-paid (a) Post- paid (b) pre-paid

15. Why? (a) regulation (forced on you by law) (b) economic reasons (lower prices) (c) cannot access pre-paid metre (shortage on market)

(d) other, please specify……………….

16. Who connected your electricity for you?

(a) Myself (b) ECG staff (b) private electrician (d) other, please specify

PART C: ***ENERGY EFFICIENCY INDICATORS***

17. Over the past six months, has your energy changed? (a) Increased (b) decreased (c) the same

18. What accounted for the change?

(a) blackout (dumsor) (b) energy efficiency measures (c) increase in electricity prices (d) acquired new electrical gadgets (e) please specify……………………………………………………….

19. Do you have Automatic switch off of pumps, fans, conveyors & other Equipment when not required? (a) Yes (b) No

20. Do you Purchase of energy efficient computers, photocopiers & other office equipment? (a) Yes (b) No

21. Are your electrical gadgets second hand or brand new (a) second hand (b) new (c) home use

22. Which type of electrical bulbs do you use ?

23. Where did you first hear about energy efficiency (a) TV and radio (b) Books   (c) Instinct (d) other, please specify

24. Do you off your electrical gadgets when you close from work?   (a) Yes   (b) No

If no, explain

25. If yes why? (a) to save cost (b) protect it from damage in case of power outage (c) because others do it (d) other, please specify……………………………………….

26. What are the barriers to energy efficiency improvement in company?

(a) Lack of information on energy efficiency measures
(b) lack of funds
(c) I feel it's not important
(d) Lack of technical skills
(e) Lack of staff awareness
(f) other, please specify

26. What three things do you do to save energy?

1.
2.
3.

PART D: ENERGY EFFICIENCY AND PRODUCTIVITY GROWTH

27. How has been your profit over the past 6 months? (a) Increased   (b) decreased (c) same

If decreased, why

If increased, why………

28. Do you think energy savings enhance profit in your company? (a) Yes   (b) No

If yes,

explain…………………………………………………………………………………………

………

29. What energy efficiency measures are there in your company? (a) Training (b) Reward/punishment   (c) other, please specify

30. Do you have any further comments on driving forces for energy efficiency improvement?

…………………………………………………………………………………………………

……

…………………………………………………………………………………………………

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Thank you.