

**THE IMPACT OF POWER OUTAGES ON FIRM OUTPUT AND LABOUR  
PRODUCTIVITY: EMPIRICAL EVIDENCE FROM MALAWI'S  
MANUFACTURING SECTOR**

**MASTER OF ARTS (ECONOMICS) THESIS**

**By**

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**OCTOBER, 2016**

## **DECLARATION**

I, the undersigned, hereby declare that this thesis is my own original work which has not been submitted to any other institution for similar purposes. Where other people's work has been used acknowledgements have been made.

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**Name**

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**Signature**

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**Date**

## **CERTIFICATE OF APPROVAL**

We, the undersigned, declare that this thesis is an outcome of the student's own work and effort. Where other people's work has been used, it has been acknowledged. This thesis has been submitted with our approval.

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## **DEDICATION**

To my Father, Hastings Banda, Mother, Melifa Banda, Brothers, Dingi and Rodgers and Sisters, Stella and Yilinase, for their encouragement and support throughout my academic endeavors.

May GOD Almighty bless you all.

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## **ABSTRACT**

The primary objective of the study was twofold: Firstly, to establish the extent to which power outages affect firm's labour productivity and secondly to establish the extent to which power outages affect firm output in the manufacturing sector in Malawi. Using OLS, the statistical analysis undertaken for this study supports empirical findings that power outages tend to negatively affect output and labour productivity of manufacturing firms. The significance of the power outage variable suggests that the government should put in place deliberate strategies of improving electricity generation and supply as well as mitigating the negative impact of power outages. In the short term, since the study has established that generator ownership ameliorate the impact of power outages, the government should find ways of ensuring that firms can easily or cheaply access these machines. This can be done by encouraging firms to participate in generator production locally or through tax waivers on imported ones so as to ultimately push prices down. At the same time, it is important for ESCOM to ensure that outages follow a reasonably regular pattern (through provision of consistent load shedding schedules). This will enable firms to change production schedules to correspond to power supply. Obviously, proper maintenance of existing electricity infrastructure by ESCOM could also in the short term ensure steady supply of electricity to firms. In the long term, the government should consider such strategies as tax incentives so as to attract investors into power generation using such other resources as coal and solar.

## TABLE OF CONTENTS

|                                                           |     |
|-----------------------------------------------------------|-----|
| ABSTRACT .....                                            | vi  |
| TABLE OF CONTENTS.....                                    | vii |
| LIST OF FIGURES .....                                     | x   |
| LIST OF TABLES .....                                      | xi  |
| LIST OF ACRONYMS AND ABBREVIATIONS .....                  | xii |
| CHAPTER ONE .....                                         | 1   |
| INTRODUCTION .....                                        | 1   |
| 1.0 Background .....                                      | 1   |
| 1.1 Problem Statement and Significance of the Study ..... | 6   |
| 1.2 Research Objectives .....                             | 10  |
| 1.3 Research Hypotheses.....                              | 10  |
| 1.4 Rationale of the study.....                           | 10  |
| 1.5 Organization of the paper .....                       | 11  |
| CHAPTER TWO .....                                         | 12  |
| OVERVIEW OF ELECTRCITY SECTOR IN MALAWI .....             | 12  |
| 2.0 Introduction .....                                    | 12  |
| 2.1 Overview of the electricity sector in Malawi .....    | 12  |
| 2.1.1 Electricity demand.....                             | 14  |
| CHAPTER THREE .....                                       | 16  |
| LITERATURE REVIEW .....                                   | 16  |

|                                                             |    |
|-------------------------------------------------------------|----|
| 3.0 Introduction .....                                      | 16 |
| 3.1 Theoretical Literature Review .....                     | 16 |
| 3.2 The endogenous growth theory or new growth theory ..... | 19 |
| 3.3 The Ecological Economics Approach .....                 | 22 |
| 3.4 Solow Growth Model with Energy .....                    | 23 |
| 3.5 Literature Review .....                                 | 25 |
| 3.6 Summary of Literature Review .....                      | 30 |
| CHAPTER FOUR.....                                           | 32 |
| METHODOLOGY .....                                           | 32 |
| 4.0 Introduction .....                                      | 32 |
| 4.1 Estimated model.....                                    | 32 |
| 4.1.1 Model Specification.....                              | 32 |
| 4.2 Description and Measurement of the Variables .....      | 37 |
| 4.3 Diagnostic Tests .....                                  | 38 |
| 4.3.1 Multicollinearity Test .....                          | 39 |
| 4.3.2 Heteroskedasticity Test.....                          | 39 |
| 4.3.2 Functional Specification Test .....                   | 39 |
| 4.4 Data Sources.....                                       | 40 |
| CHAPTER FIVE .....                                          | 43 |
| EMPIRICAL RESULTS AND ANALYSIS .....                        | 43 |
| 5.0 Introduction .....                                      | 43 |
| 5.1Diagnostic Tests .....                                   | 43 |

|                                                                                  |    |
|----------------------------------------------------------------------------------|----|
| 5.1.1 Heteroskedasticity Tests .....                                             | 43 |
| 5.1.2 Multicollinearity Test .....                                               | 44 |
| 5.1.3 Functional Specification Test .....                                        | 45 |
| 5.2 Summary Statistics .....                                                     | 46 |
| 5.3 OLS Estimation Results of Power Outages Effects on Labour Productivity ..... | 49 |
| 5.3.1 Whether Generator Use Mitigate the negative effects of power outages ..... | 52 |
| 5.3.2 Effects of power outages on firms of different sizes .....                 | 54 |
| 5.3.3 Effects of power outages on firms in different sectors .....               | 56 |
| 5.4 Effects of power outages on firm output .....                                | 58 |
| CHAPTER SIX .....                                                                | 60 |
| CONCLUSION AND POLICY IMPLICATIONS .....                                         | 60 |
| 6.0 Introduction .....                                                           | 60 |
| 6.1 Summary of Results .....                                                     | 60 |
| 6.2 Policy Recommendations .....                                                 | 62 |
| 6.3 Limitations of the study .....                                               | 63 |
| 6.4 Area of Further Study .....                                                  | 63 |
| REFERENCES .....                                                                 | 64 |

## LIST OF FIGURES

|                                                                                                                 |    |
|-----------------------------------------------------------------------------------------------------------------|----|
| Figure 1: Percentage of firms perceiving obstacles to be "major" or "very severe" to operations and growth..... | 7  |
| Figure 2: Median percentage of sales lost due to power disruptions.....                                         | 8  |
| Figure 3: Breakdown of Manufacturing Firms by subsector.....                                                    | 42 |

## LIST OF TABLES

|                                                                                            |    |
|--------------------------------------------------------------------------------------------|----|
| Table 1: Electricity Infrastructure Problems (2000-2008).....                              | 3  |
| Table 2: Hydroelectric power generation installed capacity by ESCOM.....                   | 14 |
| Table 3: Variance Inflation Factors .....                                                  | 45 |
| Table 4: Ramsey Reset Test F-statistic & probability values .....                          | 46 |
| Table 5: Power Infrastructure Indicators for Malawi .....                                  | 46 |
| Table 6: Descriptive statistics on firm characteristics .....                              | 47 |
| Table 7: Effects of power outages on labour productivity of all Manufacturing Firms ...    | 49 |
| Table 8: Effects of power outages on labour productivity of firms of different sizes ..... | 55 |
| Table 9: Effects of power outages on labour productivity of different sectors .....        | 57 |
| Table 10: Effects of power outages on output of all Manufacturing Firms.....               | 58 |

## **LIST OF ACRONYMS AND ABBREVIATIONS**

|       |                                          |
|-------|------------------------------------------|
| ESCOM | Electricity Supply Corporation of Malawi |
| GoM   | Government of Malawi                     |
| MGDS  | Malawi Growth and Development Strategy   |
| MCA   | Millennium Challenge Account             |
| MW    | Megawatts                                |
| ICS   | Investment Climate Survey                |
| OLS   | Ordinary Least Squares                   |
| SSA   | Sub-Saharan Africa                       |
| UNDP  | United Nations Development Programme     |
| WTA   | Willingness to Accept                    |
| WTP   | Willingness to Pay                       |

## CHAPTER ONE

### INTRODUCTION

#### 1.0 Background

The significance of electricity to economic development of any nation cannot be overemphasized. Access to reliable electricity supply increases the productivity and welfare of society. Allcott, *et.al* (2014) observed that one of the potential contributors to the large productivity gap between developed and developing countries is low quality infrastructure, and one of the most stark examples of infrastructure failures in most developing countries is electricity supply.

A number of other authors (Oseni 2013; Singh & Mangat 2012; Scott *et.al* 2014, Moyo 2012) have endeavored to document the role and significance of electricity in production. For instance, Oseni (2013) undertook a study on power outages and the costs of unsupplied electricity and made a number of observations: He noted that virtually all business activities, especially industrial units, require constant and effective flow of electricity. Besides serving as an input in production processes, electricity also contributes greatly to product marketing. In many cases, electricity plays important roles in storing finished goods ahead of demand, and therefore enhances consumers' satisfaction by assisting in making the goods available to consumers when needed. This

also helps in building firm's image and protects firm's reputation because customers can be assured of having their demand met.

Singh and Mangat (2012), on the other hand, observed that reliability and consistency of electricity supply is critical to many industrial and service activities. For the continuous process industries, an unreliable power supply not only slows down or damages production or results in shut down of plant but also leads to equipment damage, additional maintenance and the organization's reputation for the quality of product. The effect of these interruptions can be quite costly to the industry and consequently to the country.

Despite the fore-going discussion, electricity provision in Africa and most developing countries has been marred by low generation, poor supply and frequent power outages. According to Jyoti, *et al* (2006) , for many developing countries the unreliable supply of electricity is the norm rather than the exception. Scott, *et.al* (2014) observes that poor electricity supply has proven to be the major constraint to the business sector in Africa and has contributed to the low productivity and poor competitiveness of the manufacturing sector in the continent. Between 2006 and getting worse 2010, more than 50% of the Sub-Sahara African firms identified electricity as a major constraint to their businesses compared to just 27.8% which face transportation as the most critical problem.

Oseni (2013) in his study also made a number of notable observations on the electricity situation in Africa: He observed that earlier in 2007, about 25% of firms in Sub-Sahara

Africa identified electricity as the biggest obstacle followed by financial constraint identified by 20% of the firms. Furthermore, an average Sub-Sahara African firm suffers loss of economic activities of about 77 hours a month due to power outages. He further observed that the situation is even more pronounced in some countries and more worrisome when compared with other developing regions of the world. In 2007 for instance, an average firm in Nigeria experienced an outage of 8.2 hours 26.3 times in a typical month, which is almost every day. This translates to loss of economic activities for 216 hours (9 days), on average, in every month. Meanwhile, an average firm in East Asia & Pacific experiences power outages of less than 15 hours a month. Similarly, a typical firm in Latin America and Caribbean only suffers electricity cuts of about 6 hours a month. As shown in Table 1 below, available statistics from the World Bank investment climate surveys also show that South Asia, Sub Saharan Africa, the Middle East and North Africa are parts of the world that are most affected by power outages.

**Table 1: Electricity Infrastructure Problems (2000-2008)**

| Country/Region             | Number of Power Outages Per Month | Duration of Outages in Hours | % Output Lost Due to Power Outages | Electricity From Generator(if Generator is used) in % | Delay in Obtaining Electrical Connection |
|----------------------------|-----------------------------------|------------------------------|------------------------------------|-------------------------------------------------------|------------------------------------------|
| Sub Saharan Africa         | 10.3                              | 6.7                          | 5.8                                | 26.7                                                  | 31.9                                     |
| East Asia & Pacific        | 5.2                               | 3.1                          | 2.8                                | 12.3                                                  | 21.7                                     |
| Latin America              | 2.7                               | 7.6                          | 4.2                                | 18.4                                                  | 34.5                                     |
| South Asia                 | 42.2                              | 4.6                          | 10.8                               | 25.9                                                  | 48.4                                     |
| Middle East & North Africa | 2.9                               | 3.5                          | 4.2                                | 16.2                                                  | 49.1                                     |
| World                      | 8.6                               | 5.6                          | 4.9                                | 19.8                                                  | 36.7                                     |

*Source: Moyo (2012)*

According to Lineweber & McNulty (2001), technically, businesses could suffer from two types of power disturbances: poor quality, and power outage. The first refers to the fluctuations in voltage, which could result in severe damage to machinery and equipment, and a corresponding high cost of frequent repair and replacement. The second relates to a complete loss of power, lasting from one second to hours. The extent of power outages can be measured by their frequency, their duration, or firms' self-assessment of the severity of the issue or the associated losses (Jyoti R; Ozbaflı A; Jenkins, G.P, 2006). The first two are referred to as objective measures, while the last ones are subjective measures.

Power outages can affect business activities through a variety of channels, which eventually lead to negative effects on productivity (Cissokho & Seck, 2013). First, there is the efficiency channel, through which discontinuous power provision is synonymous with disruption in the production process, causing productive resources to lie idle, resulting in lower output level and high operating costs. Second, there are the costs associated with the replacement or repair of broken machines and equipment on the one hand, and the cost related to the spoilage of raw materials and finished products or inventory on the other. Furthermore, power shortages lead to extra cost to firms, because they often have to rely on alternative sources of energy, like rented or self-owned generators.

Third, there is the quality channel, which is related to the rush to meet deadlines due to anticipated power outages, spoiled inventories, or malfunctioning machines. These phenomena could all affect the quality of a good or service produced by a business. This

means businesses have to produce more goods to replace the low-quality units, or discarded units. Consequently, production cost increase further. Fourth, there is the uncertainty channel, which comes about because businesses could not predict with any accuracy the occurrence of power outages. This situation translates into uncertainty in meeting deadlines, getting materials from suppliers on time, or profiting from new market opportunities. In the end, it could lead businesses to idle more capital, and hire fewer workers consequently.

Malawi remains one of the countries in Africa with consistent electricity deficits and high levels of electricity blackouts (Gamula, 2012). Evidence of electricity generation and demand between 1999 and 2011 reveal persistent power supply shortages. Between 1996 and 2011, the average maximum demand for electricity had increased from 190.2 MW to 277 MW (Gamula, 2012). According to the Mining & Trade Review report (2016), Malawi's current electricity demand is projected in the region 400 MW against the installed power generation capacity of 351.75MW. Understandably, demand is higher than supply and this has culminated into frequent power outages being experienced by both households and industries.

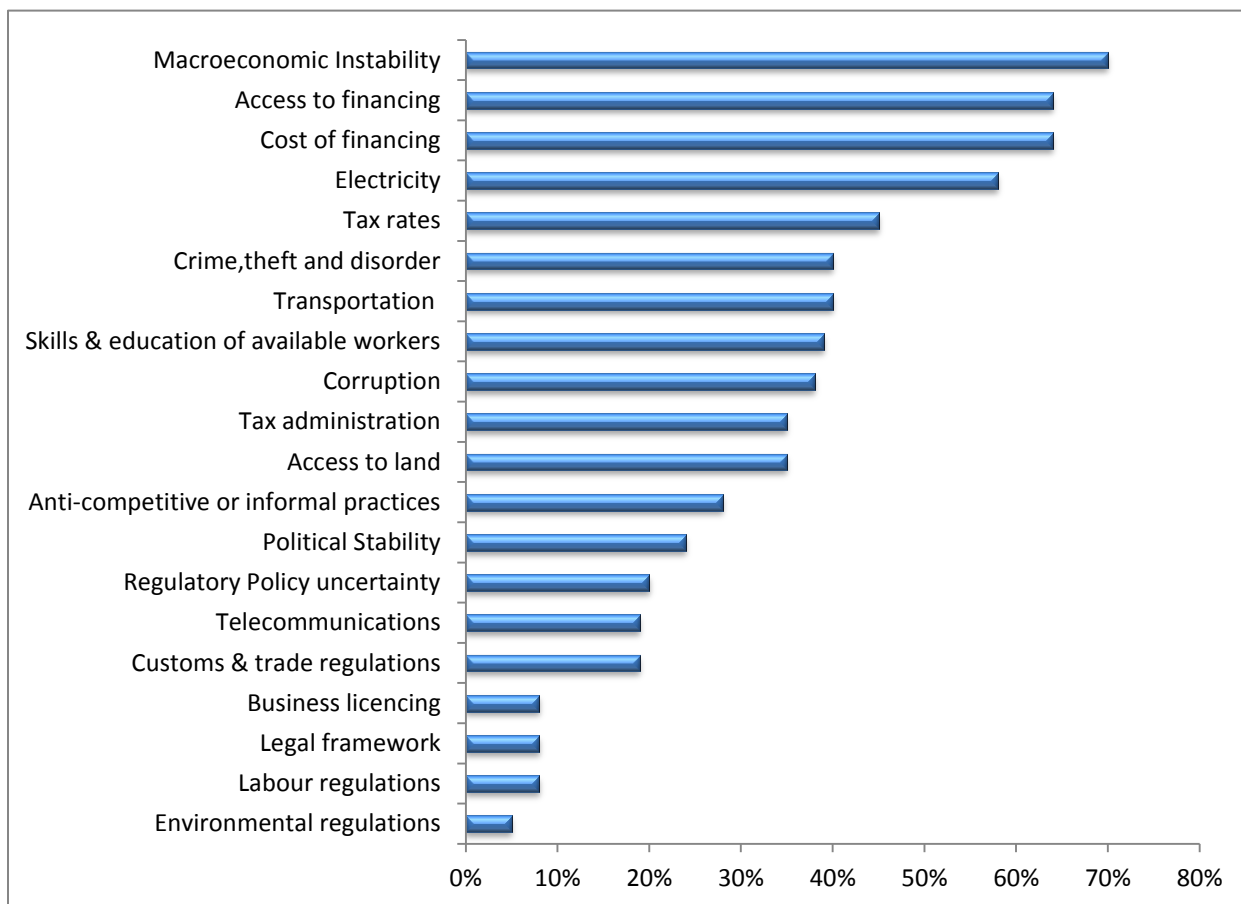
The persistent imbalance between electricity supply and demand which has characterized the electricity sector during the study period has tended to forcefully constrain productivity and expansion of economic activities in the country (Kadammanja, 2014). However, evidence on the effects of these power outages on the economy, in particular industries is unavailable.

The main aim of this paper , therefore, is to investigate the extent to which power outages affect firm's labour productivity and output in the manufacturing sector in Malawi, because power plays a very important role, not only in facilitating the use of electric machinery, but in enhancing the productivity of other factor inputs such as labour. In the absence of good empirical evidence it is difficult to know what impact electricity insecurity actually has on firm productivity and output (Scott et.al, 2014).

### **1.1 Problem Statement and Significance of the Study**

It is well documented in the literature that electricity plays a critical and positive role in economic development. For instance, Rud (2012) observed that consumption of electricity is generally positively correlated with productivity and economic growth. Scott *et.al* (2014), on the other hand, observed that access to a reliable electricity supply is widely considered to be vital to the operations of most small and medium-scale businesses.

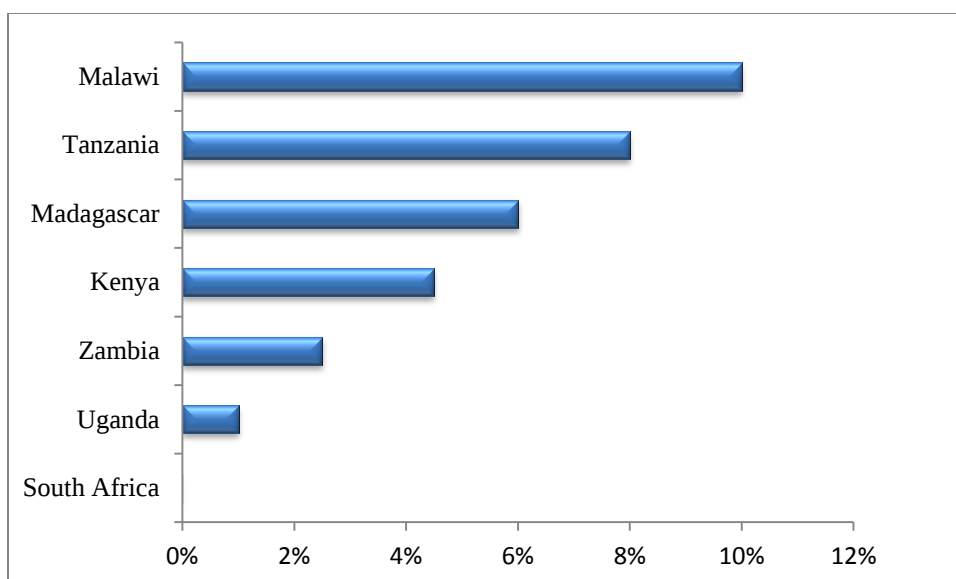
Just like most developing countries, Malawi's electricity sector is marred by supply constraints which have resulted in intermittent power supply to both households and industry. The investment climate assessment (ICA) survey carried out in 2006, for instance, singled out electricity as one of the top constraints to the investment climate in Malawi as perceived by enterprise (see figure 1).



**Figure 1: Percentage of firms perceiving obstacles to be "major" or "very severe" to operations and growth**

*Source: world Bank summary of Malawi Investment Climate Assessment (ICA) (2006)*

According to the ICA summary report (2006), over 50% of managers surveyed perceive electricity as a major business constraint and that around 10% of sales are lost by Malawian firms due to power outages, a much higher percentage than in comparator countries (see Figure 2 below). Furthermore the report reveals that firms with a generator are 60% more productive than those without and that generators cost is around 0.5% of average firm sales, a cost that half of firms can afford. Furthermore, firms without a generator lose as much as 20% of their sales due to power outages.



**Figure 2: Median percentage of sales lost due to power disruptions**

*Source: World Bank summary of Malawi Investment Climate Assessment (ICA) (2006)*

According to ESCOM (2012), with electricity supply lagging behind growing consumption, rationing of electric energy in the commercial cities of Blantyre, Lilongwe and Mzuzu continue to be the norm. The frequent load shedding (systematic rationing of electricity consumption) has markedly characterized the electricity supply patterns in the country and is estimated to constrain daily consumption by as much as 35MW, or over 10% of peak electricity consumption (Kadammanja, 2014).

As recently as August 2015, the problem of electricity interruptions has become severe. This environment has undoubtedly affected economic activities, particularly in manufacturing production. Depending upon a firm's ability to substitute to alternative forms of energy and given that most firms in Malawi rely on electricity for their production, this reliance on electricity may result in manufacturing firms taking the full

brunt of electricity shortages. The consequences of these outages are particularly important for our society, very dependent on the availability of electricity, and may generate large economic and social costs. The Millennium Challenge Account (MCA) assessment report (2010) for instance estimated that electricity shortages cost the country around 2-3% of GDP (MCA, 2010).

Despite the foregoing, limited attempts on the academic front have been made to investigate the impact of the persistent power outages on the Malawi economy. Specifically, no attempts in Malawi have been made to investigate the impact of power outages on the manufacturing sector despite the industries heavy reliance on electricity for its production. The only relevant existing empirical studies on Malawi are one by Jumbe (2004) and Kadammanja (2014).

However, Jumbe (2004) mainly concentrated at understanding the relationship between electricity consumption and, respectively real GDP, agricultural GDP and non – agricultural GDP nexus at aggregate level. Kadammanja (2014) on the other hand, examined the nature of the relationship between electricity consumption and industrial production as well as between electricity consumption and, respectively, gross domestic investment and foreign direct investment (FDI). However, Gross (2012) argued that empirical evidence at the aggregate level may be necessary but not sufficient for policymakers to formulate appropriate policies This paper hence provides evidence on the impact of power outages on the manufacturing sector and therefore provides new insights for policy formulation.

## **1.2 Research Objectives**

The main objective of the study is to assess the impact of power outages on the manufacturing sector in Malawi. In order to achieve this, specific objectives of the study are as follows:

- i. To establish the extent to which power outages affect firm's labour productivity in the manufacturing sector.
- ii. To establish the extent to which power outages affect firm output in the manufacturing sector.

## **1.3 Research Hypotheses**

The testable hypotheses for this study are:

- i. Power outages do not significantly affect firm's labour productivity in the manufacturing sector
- ii. Power outages do not significantly affect firm output in the manufacturing sector

## **1.4 Rationale of the study**

It should be noted that while there are other studies that have analyzed the importance of infrastructure quality such as electricity in Malawi (see Jumbe, 2004; Kadammanja 2014) these studies have concentrated on country-level indicators (total electricity production and consumption per capita). However, it should be pointed out that the contributions of power infrastructure to productivity derive not from the mere existence or creation of the physical facilities, like power stations and power lines, but from their operation and the value of the services generated.

Moyo (2012) notes that, electricity consumption or generation per capita (variables commonly used in the literature) convey very little about power infrastructure quality, particularly if provision is characterized by intermittent outages or disruptions. Thus, power infrastructure is of little use to production if it is not reliable, which is why it is expected that power infrastructure reliability (how often firms go without power a day), variables used in this study, to be more important than availability (total production and consumption of electricity per capita).

### **1.5 Organization of the paper**

The remaining part of this study is structured as follows. Chapter Two gives a brief overview of the electricity sector in Malawi. Theoretical and empirical literature is reviewed in Chapter Three while Chapter Four outlines the methodology to be used in this study. Chapter Five discusses the regression results and interpretation; and finally Chapter Six gives the conclusion, outlining the summary of results obtained, policy recommendations and the limitations of the study.

## **CHAPTER TWO**

### **OVERVIEW OF ELECTRICITY SECTOR IN MALAWI**

#### **2.0 Introduction**

This chapter presents an overview of the electricity sector in Malawi.

#### **2.1 Overview of the electricity sector in Malawi**

Malawi is a sub-Saharan landlocked African country located south of the equator. It is bordered to the north and northeast by the United Republic of Tanzania; to the east, south, and southwest by the People's Republic of Mozambique; and to the west and northwest by the Republic of Zambia. The country is 901 kilometers long and 80 to 161 kilometers wide. The total area is approximately 118,484 square kilometers of which 94,276 square kilometers is land. The remaining area is mostly composed of Lake Malawi (known as Lake Nyasa in Tanzania), which is about 475 kilometers long. The lake is a fresh water body that lies in the Great Rift Valley and its main outlet is the Shire River, the biggest river in the country. Lake Malawi and the Shire River are the major sources of water for hydropower generation in Malawi (Kaunda & Mtalo, 2013).

Malawi's energy sector is predominantly traditional biomass-based. However dependency on biomass energy mix has slightly been reduced from 93% in 2000 to 80% in 2011, as a

result of some increases in the mix of modern forms of energy such as electricity, coal, liquid fuel and gas (Kaunda *et.al*, 2013). Despite the improvement, electricity sub-sector contributes very little in the energy mix, contributing less than 10% of the total energy supply (Kaunda, *et.al* 2013). The national electricity access level is between 7 to 8%, rural electricity and urban access levels being about 1% and 20 % respectively (GoM, 2012). This means that only 1% of 80% of Malawi's rural based population has access to electricity. The level of about 1% for rural electricity access is reported to have remained static over the last 16 years (Kaunda *et.al*, 2013). The annual national electricity consumption is 111 kWh per capita per annum which is obviously concentrated in urban areas (GoM, 2012).

Despite the presence of liberalized national energy policy, the whole amount of grid-based electricity capacity is generated, transmitted and distributed by the Electricity Supply Commission of Malawi (ESCOM), the only power utility company in the country. ESCOM Limited is a public utility company which was established by an Act of Parliament in 1957 which was revised in 1963 and then 1998. The total installed capacity of ESCOM is about 302 MW, of which 94% is generated by hydropower and the remaining 6% is thermal (Gamula, 2012). Almost all the ESCOM's hydro generation stations are located in the Southern region of Malawi along Shire River (the main outlet of Lake Malawi) except for a capacity of 4.5 MW which is located in the Northern region on Wovwe River (Gamula, 2012). The number of installed hydroelectric power machines and their installed capacities are shown in Table 2.

**Table 2: Hydroelectric power generation installed capacity by ESCOM**

| Plant         | River | Installed capacity (MW) | Cumulative capacity (MW) | Year installed |
|---------------|-------|-------------------------|--------------------------|----------------|
| Nkula A       | Shire | 3* 24                   | 24                       | 1966           |
| Tedzani I     | Shire | 2*10                    | 44                       | 1973           |
| Tedzani II    | Shire | 2*10                    | 64                       | 1977           |
| Nkula B (I)   | Shire | 3*20                    | 124                      | 1980           |
| Nkula B (II)  | Shire | 1*20                    | 144                      | 1982           |
| Nkula B (III) | Shire | 1*20                    | 164                      | 1986           |
| Wovwe         | Wovwe | 3*1.5                   | 168.5                    | 1995           |
| Tedzani III   | Shire | 2*25                    | 218.5                    | 1996           |
| Kapichira     | Shire | 2*32                    | 282.5                    | 2000           |

*Source: Kaunda and Mtalo (2013)*

### **2.1.1 Electricity demand**

Evidence on electricity generation and demand between 1999 and 2011 reveal persistent power supply shortages. Between 1996 and 2011, the average maximum demand for electricity had increased from 190.2 MW to 277 MW (Gamula, 2012). Currently, according to the Mining & Trade Review report (2016), Malawi's electricity demand is projected in the region 400 MW against the installed power generation capacity of 351.75MW and this partly explains why the country experiences serious intermittent power disruptions.

According to the Government of Malawi (2010), the supply and demand in the Malawi's power sector show significant shortages in the foreseeable future, due to an increase in demand averaging 7% per year. Accordingly, under the business as usual (BAU) scenario, the projected electricity demand will be 874 MW in 2020, 1193 MW in 2025, and 1597 MW in 2030 (GoM, 2010). Further, an estimated step load increase of 37 MW per year is expected for up to 2020. At the same time, the load forecast also expects an average demand increase of 5 MW per year in the residential sector alone due to increased electrification (GoM, 2010). ESCOM (2011) noted that the annual electricity consumer connections have continued to rise sharply over the last five years, increasing from 175, 167 in 2008/9 to 204, 955 in 2011/12 financial years. The total number of customers connected to electricity was 218,164 as of June 2012 representing 10% access, which still compares poorly to the average of 32% for developing countries (Kiplagat, Wang, Li, & T.X., 2011).

It is clear from the preceding discussion that Malawi suffers from huge electricity supply deficits due to insufficient supply position which has largely emerged from lack of corresponding investment in the sector. In order to meet both the currently suppressed electricity consumption as well as projected future demand, Malawi needs to have in place an estimated additional 140 MW of available capacity by 2020 (ESCOM, 2012). Generally, the persistent electricity supply deficits, which have characterized electricity consumption in the country, have tended to adversely impact returns on investment and is also argued to have significantly constrained production and provision of socioeconomic services with negative impact on the economic prospects of the country.

## **CHAPTER THREE**

### **LITERATURE REVIEW**

#### **3.0 Introduction**

This chapter presents a review of both theoretical and empirical literature on the effect of power outages on productivity and output.

#### **3.1 Theoretical Literature Review**

The lack of a theoretical basis for the role of energy (electricity) in the production process, productivity and ultimately economic growth is well documented in the literature. Toman & Jemelkova (2003) argue that most of the literature on energy and economic development discusses how development affects energy use rather than vice versa. The principal mainstream economic models used to explain the growth process (Aghion & Howitt, 2009) do not include energy as a factor that could constrain or enable economic growth, though significant attention is paid to the impact of oil prices on economic activity in the short-run (Hamilton, 2009)

According to Stern (2010) physics shows that energy is necessary for economic production and, therefore, economic growth but the mainstream theory of economic growth, except for specialized resource economics models, pays no attention to the role

of energy. Energy is important for growth because production is a function of capital, labor, and energy, not just the former two or just the latter as mainstream growth models or some biophysical production models would indicate (Stern, 2010). Furthermore, the elasticity of substitution between energy and capital is likely to be low, energy is also needed to produce the other inputs to production, and energy is available in finite quantities on the Earth's surface and is non-recyclable (Stern, 2010). To this effect, Stern (2010) argued that we cannot understand the role of energy in economic growth without first understanding the role of energy in production because thermodynamics implies that energy is essential to all economic production.

The role of energy in economic production is well documented. For instance, Ecological Economists and other researchers, point to the invention of methods to use fossil fuels as the cause of the industrial revolution. For instance, Wrigley (1988) discussed the differential development of the Dutch and British economies. Both countries had the necessary institutions for the industrial revolution to occur, but capital accumulation in the Netherlands faced a renewable energy resource constraint while in Britain domestic coal mines provided a way out from the constraint (Wrigley, 1988). Jorgenson (1984) notes that from 1920 to 1955 the unusual characteristics of electricity had made it possible to perform tasks in altogether different ways than if the fuels had to be used directly. According to Schurr, Netschert, Eliasberg, Lerner, & Landsberg (1960) the electrification of industrial processes had led to much greater flexibility in the application of energy to industrial production.

The importance of electrification in productivity growth has also been documented by Rosenberg (1983), who observed that the use of electric power in the 20th century was associated with the introduction of new techniques and new arrangements which reduce total costs through their saving of labor and capital. Rosenberg (1983) emphasized the significance of the electrification of industrial processes that took place during the first several decades of the twentieth century and he observed that electrical motors have provided greater flexibility in the supply of power to industrial processes and in the organization and layout of production processes. In linking electrification and productivity growth, Schurr, *et.al* (1979) has advanced an important subsidiary hypothesis that electrification is especially significant in stimulating the growth of productivity in the manufacturing industries.

Despite the significant role of electricity in production as highlighted above, it should be pointed out, however, that the traditional theories of production do not recognize electricity as a factor of production. For instance, classical and neo-classical economics postulate a production function in a competitive market where factors of production and the output goods are purely exogenous but do not recognize energy as a factor of production. Thus, the classical and neo-classical economists only recognize capital (K) and labour (L) as the only inputs into the production process and that technology is exogenously determined (Acemoglu, 2007). On the other hand, the endogenous growth theory or new growth theory postulates new technology as the ultimate determinant for long run growth where energy is a necessary factor which allows technology to be

utilized. Lee & Chang (2005) observed that electricity consumption is likely to have a technological progress effect on productivity and hence economic performance.

To this effect, a common methodological framework in the literature to research the electricity-productivity link is the production function. Within the framework of the production function, the impact of electricity on productivity and output is usually modeled in two main ways: firstly, directly when electricity services enter production as an additional input and secondly, indirectly when they raise productivity by reducing transaction and other costs, thus allowing a more efficient use of conventional productive inputs (Straub, 2008). Therefore to capture the role of electricity on productivity we modify the conventional production models. In particular, we revisit the endogenous growth theory or new growth theory, the ecological economics approach and the Solow growth model.

### **3.2 The endogenous growth theory or new growth theory**

The endogenous growth theory was developed as a reaction to the flaws of the neoclassical (exogenous) growth theory (Kadammanja, 2014). Romer's (1986) endogenous growth theory takes knowledge as an input in the production function. The theory aims at explaining the long run growth by endogenizing productivity growth or technical progress. The major assumptions anchoring the theory are:

1. Increasing returns to scale because of positive externalities
2. Human capital (knowledge, skills and training of individuals) and the production of new technologies are essential for long run growth.

3. Private investment in Research and Development is the most important source of technological progress

4. Knowledge or technical advancement is a non-rival good.

In the new growth theory, the savings rate affects the long run economic growth because in this framework, a higher level of savings and capital formation allows for greater investment in human capital and research and development. The model predicts that the economy can grow forever as long as it does not run out of new ideas or technological advancement. Just like the exogenous growth theory, the endogenous growth theory professes convergence of nations by diffusion of technology. That is, a situation where poor countries manage to catch up with the richer countries by gradual imitation of technology by poorer countries. Romer, (1986) states the production function of a firm in the following form:

$$Y_j = A(R)F(R_j, K_j, L_j) \quad (3.1)$$

Where: A– public stock of knowledge from research and development (R)

$R_j$  – Stock of results from expenditure on research and development.

$K_j$  – Capital stock of firm j

$L_j$  – Labour stock of firm j

In this model, new technology is the ultimate determinant for long run growth and is itself determined by investment into research. Thus technology is seen as an endogenous factor which could be related to energy. Most technology as given per time is dependent on the availability of useful energy to power it.

Evidently, the second law of thermodynamics, the efficiency law, states that a minimum quantity of energy is required to carry out the transformation or movement of matter or more generally physical work. Carrying out transformations in finite time requires more energy than these minima (Baumgärtner, 2004). All production involves work. Therefore, all economic processes must require energy and there must be limits to the substitution of other factors of production for energy so that energy is always an essential factor of production (Stern, 2007).

Energy is in this case not the sole determinant of technology but is a necessary factor to ensure that technology (at whatever level) is being utilized. Therefore, in the endogenous growth theory or new growth theory electricity enters the production function through the technological parameter. Thus following Hulten *et.al* (2006) we can specify a general production function as follows:

$$Y_i = A.F(K, L) \quad (3.2)$$

Where Y is output, A is the time-varying total factor productivity (TFP) and K and L are respectively capital and labor. As it has been discussed in the preceding paragraphs, infrastructure (electricity) denoted X in the following equations influences output through two channels: Firstly, it influences output through the technological parameter or total factor productivity:

$$A = A(X) = \tilde{A}.X^\eta \quad (3.3)$$

Where  $\tilde{A}$  is the true TFP and  $\eta$  is the elasticity of A with respect to X. Here, infrastructure raises output without any payments by firms for infrastructure services. This channel captures the externality aspect of infrastructure (Straub, 2008).

Secondly, infrastructure (electricity) enters the production function as an additional production factor as follows:

$$Y_i = \tilde{A} \cdot X^\eta \cdot F(\tilde{K}, L, X) \quad (3.4)$$

Where  $\tilde{K}$  is the stock of non-infrastructure capital.

### 3.3 The Ecological Economics Approach

Ecological economists derive their view of the role of energy in productivity and economic growth from the biophysical foundations of the economy. Some geographers (e.g. Smil, 1994) and economic historians (e.g. Wrigley, 1988; Allen, 2009) also believe that energy plays a crucial role in economic growth, as well as being an important factor in explaining the industrial revolution. Some authors such as Cleveland, *et.al* (1984), Hall,*et.al* (1986) and Hall,*et.al* (2003) also downplay the role of technological change, arguing that either increased energy use accounts for most apparent productivity growth, or that technological change is real but innovations mainly increase productivity by allowing the use of more energy. Therefore, increased energy use is the main or only cause of increased productivity and hence economic growth.

A prominent tradition in ecological economics is represented by biophysical models that consider energy to be a primary factor of production and the only such primary factor. In this view, all value is derived from the action of energy that is directed by capital and labor. The flow of energy in the economy is the service of the reservoirs of fossil fuels and the sun, which represent the primary input. In some biophysical economic models (e.g. Geveer, 1986) geological constraints fix the rate of energy extraction so that the flow

rather than the stock can be considered a primary input (Stern, 2010). On the other hand, capital and labor are treated as flows of capital consumption and labor services rather than as stocks, in other words, they are considered as intermediate inputs that are created and maintained by the primary input of energy and flows of matter.

### 3.4 Solow Growth Model with Energy

In order to integrate the different approaches on the role of energy, stern (2010) proposed to modify Solow (1956) model by adding an energy input that has low substitutability with capital and labor, while allowing the elasticity of substitution between capital and labor to remain at unity. In this model, depending on the availability of energy and the nature of technological change, energy can be either a constraint on growth or an enabler of growth.

$$Y = \left[ (1 - \gamma)(A_L^\alpha L^\beta K^{1-\beta})^\emptyset + \gamma(A_E E)^\emptyset \right]^{\frac{1}{\emptyset}} \quad (3.5)$$

$$\Delta K = s(Y - p_E E) - \delta K \quad (3.6)$$

Equation (3.5) embeds a Cobb-Douglas function of capital (K) and labor (L) in a CES function of value added and energy (E) to produce gross output Y.  $\emptyset = \frac{\sigma-1}{\sigma}$ , where  $\sigma$  is the elasticity of substitution between energy and the value added energy.  $P_E$  is the price of energy and  $\gamma$  is a parameter reflecting the relative importance of energy and value added.  $A_L$  and  $A_E$  are the augmentation indices of labor and energy, which can be interpreted as reflecting both changes in technology that augment the effective supply of the factor in question and changes in the quality of the respective factors. Equation (3.6) is the equation of motion for capital that assumes like Solow (1956) that the proportion of gross output that is saved is fixed at  $s$  and that capital depreciates at a constant rate  $\delta$ .

According to Stern (2010), as  $\sigma \rightarrow 1$  and  $\gamma \rightarrow 0$  we have the Solow model as a special case, where in the steady state,  $K$  and  $Y$  grow at the rate of labor augmentation. Additionally, depending on the scarcity of energy, the model displays either Solow-style or energy constrained behavior (Stern & Kander, 2010). For a given elasticity of substitution, when energy is superabundant the steady state level of the capital stock and output are determined apart from a scaling factor by the same functions of the same factors – the savings rate, the level of labor augmenting technology, and inversely in the rate of depreciation as the Solow model. But when energy is relatively scarce the steady state depends on the level of energy supply and the level of energy augmenting technology. Therefore, in the pre-industrial era when energy was scarce due to limited supply of land, the steady-state level of output was determined by the level of energy augmentation or energy efficiency. After the industrial revolution as energy became more and more abundant, the long-run behavior of the model economy becomes more and more like the Solow model where the growth of output is determined by the rate of labor augmentation. Additionally, if the cost share of energy falls over time more work effort can be directed to final output boosting the growth rate of GDP per hour worked.

The production function (3.5) has two limits to substitution (Stern , 1997). The “microeconomic” limit to substitution results from  $\sigma < 1$  so that a minimum quantity of energy is required to produce any given level of output and energy is essential to production. The “macroeconomic” limit to substitution results from energy being required to produce capital and as long as  $\delta > 0$ , depreciation means that maintenance of the capital stock requires an ongoing energy input.

### **3.5 Literature Review**

According to Rud (2012), electricity infrastructure and the consumption of electricity are generally understood to be positively correlated with productivity and economic growth. A number of developing country-specific studies support the general conclusion that electricity enhances productivity. For instance, Straub (2008) assessed the impact of infrastructure quality on the total factor productivity (TFP) of African manufacturing firms and found that poor infrastructure quality has a significant negative impact on total factor productivity, and that poor quality electricity supply is the infrastructure element that has the strongest negative effect on enterprise productivity, especially in poor African countries.

Fedderke & Bogetic (2006) in a study on infrastructure and growth in South Africa, using 1970-2000 panel data and a range of 19 infrastructure measures found that electricity generation is positively related to labour productivity and total factor productivity growth in South Africa.

Isaksson (2009) cites findings that output per capita and energy infrastructure are co-integrated and causation runs in two directions, but concludes from analysis of cross-country data that energy infrastructure is a significant factor in explaining differences in industrial development between countries. Using World Bank Enterprise Surveys as well as other study specific surveys and employing a variety of methods, several studies have endeavored to investigate the impact of electricity insecurity on productivity at the level of the firm. Studies look at cost of interruption, cost of back-up generators and effect on

productivity. For instance, using World Bank Enterprise Survey data for over 1,000 firms in 10 Sub-Saharan African countries, Arnold *et. al* (2006) show that an unreliable electricity supply has a significant negative impact on a firm's total factor productivity.

Kirubi *et.al* (2009) analyzed community-based micro-girds in rural Kenya, and showed that use of electricity can increase productivity per worker by approximately 100-200% for carpenters and by 50-170% for tailors, depending on the item being produced. Grimm *et al.* (2011) found that tailors in Burkina Faso with access to electricity have revenues 51% higher than tailors without electricity, and attribute this to the use of electric sewing machines and longer working hours.

Similarly, a 1987 study focusing on the effects of power outages in Pakistan estimated that the direct costs of load shedding to industry during a year, coupled with the indirect multiplier effects on other sectors, resulted in a 1.8% reduction in GDP and a 4.2% reduction in the volume of manufactured exports. In India, a 1985 study concluded that power outages were a major factor in low capacity utilization in industry, and estimated the total production losses in 1983/84 at 1.5% of GDP. Similarly, power rationing in Colombia was estimated to reduce overall economic output by almost 1% of GDP in 1992 (Kessides, 1993).

In a study of the impact of rural electrification on household income in India, Chakravorty *et.al* (2012) found that the reliability of electricity supply is more important than being connected to the grid. Results suggest that the reliability of electric supply is more important than being connected to the grid. Moving to a reliable power supply,

either starting off with no connection to the grid or with an unreliable power supply is welfare improving. In this case, a household gains an average 12.6% of extra income per year with respect to other household who did not experience this improvement (Chakravorty, 2012).

The preceding studies notwithstanding , a study examining the impact of power disruptions on firm productivity in the manufacturing sector in Nigeria by Moyo (2012) shows that power outage variables (measured using hours per day without power and percentage of output lost due to power disruptions) have a negative and significant effect on productivity. The analysis for this study found that power outages have a negative and significant impact on productivity in small firms, but an insignificant effect in large firms, probably due to generator ownership patterns.

There are also a number of other studies that have been done on Nigeria looking at electricity supply and industrialization and growth. For instance, Udah (2010), using bounds test, found the long run and error correction model showed that the index of industrial development, electricity supply, technology and capital employed are important determinants of economic development. Iwayemi (1988) argued for importance of the energy sector in the socio-economic development of Nigeria. He submitted that strong demand and increased supply would stimulate increased income and higher living standards.

Lee and Anas (1992) in a 1988 study of 179 manufacturing establishments in Nigeria found that the impact of infrastructure deficiencies of all types was consistently higher for small firms. Private infrastructure provision (for generators, boreholes, vehicles for personnel and freight transport, and radio communications equipment) constituted 15% of total machinery and equipment costs for large firms (over 50 employees), but 25% for small firms. Small firms were found to generate a larger percentage of their power needs privately than larger firms and to pay a higher premium for doing so, as measured by the excess costs of privately generated power over that of publicly provided. Thus, usually small firms bear a relatively higher cost of infrastructure failures.

Oke (2006) attributed the non-competitiveness of Nigeria's export goods to poor infrastructure, especially electricity supply, which drives the running cost of firms. Ndebbio (2006) argued that electricity supply drives the industrialization process. He submitted that one important indicator, whether a country is industrialized or not, is the megawatt of electricity consumed. He further argued that a country's electricity consumption per-capita in kilowatt hours (KWH) is proportional to the state of industrialization of that country.

Ekpo (2009) elaborated on the folly of running a generator economy and its adverse effects on investment. He strongly argued that for Nigeria to jump start and accelerate the pace of economic growth and development, the country should fix its power supply problem. In his paper, Aigbokan (1999) argued that fixing the energy sector is tantamount to shifting the production possibility curve of the country's economy. Using a

general Cobb Douglas production function, Aschauer (1989) studied the relationship between aggregate productivity and stock and flow of government spending variables in the US economy for the period 1949-85. In his estimations, he treated government spending on public capital as one of the inputs in the production function and proxy for infrastructure variables, like electricity. His results suggest that there is a strong positive relationship between output per unit of capital input, the private labour capital ratio, and the ratio of the public capital stock to the private capital stock.

Cissokho and Seck (2013) obtained quite different findings in Senegal. While investigating the link between electric power outages and the productivity of Small and Medium Enterprises in Senegal, power outages were found to have a positive and significant effect on the productivity of firms, and SMEs performed better than large-scale firms. The suggested explanation for this contradictory finding is that outages stimulated better management practices, which mitigated the negative effects of power supply interruptions, and that the more inefficient, lower productivity firms had gone out of business in the face of electricity insecurity (Cissokho and Seck, 2013).

Other enterprise level surveys conducted in several countries have found that infrastructure costs and problems of unreliability rank high among issues in the business environment. A 1991 survey of small enterprises in Ghana cited power outages, transportation costs and other infrastructure problems among the top four problems of operations (behind taxes), with this response strongest among “micro” and small firms. Electricity outage was ranked by very small firms among their top four constraints to

expansion (Steel and Webster, 1991). Thus, the issue of infrastructure supply – its adequacy and reliability – is very important for the overall performance of the business sector and deserves policy attention.

### **3.6 Summary of Literature Review**

This chapter has discussed at length the different theories on the role of electricity in production. While the classical and neo-classical economists do not recognize energy as a factor of production the endogenous growth theory recognized the role of energy through the technological parameter in the production function. Similarly, the unified models of energy and growth posit a central role for energy in productivity and growth. The Solow growth model with energy argues that a minimum quantity of energy is required to produce any given level of output and energy is essential to production.

While the study recognizes the position of the classical and neo-classical economists in postulating a production function in which labour and capital are the only inputs to production, this study subscribes to the endogenous growth theories in which electricity is recognized as an input into the production process. Jumbe (2004) recognized that energy (electricity) plays a significant role in economic development not only because it enhances the productivity of factors of production but that its increased consumption particularly for commercial use tend to promote growth in a country. According to World Bank (2010), the persistent electricity supply deficits, which have characterized electricity consumption in Malawi, have tended to adversely impact productivity, returns on investment and is also argued to have significantly constrained new investments. The

two preceding literature clearly underscore the role of electricity in production. This study therefore employs the approach propagated by the endogenous theories in which electricity enters the production function as a factor of production.

Empirical studies discussed above provide evidence on how limited supply of electricity directly and indirectly affects the economic activities of firms. It should be pointed out, however, that the only relevant existing empirical studies on Malawi are by Jumbe (2004) and Kadammanja (2014). However, these studies concentrated on country-level indicators (total electricity production and consumption per capita) .This study therefore extend a step further to investigate how the quality of the electricity service affects output and productivity at firm level.

## **CHAPTER FOUR**

### **METHODOLOGY**

#### **4.0 Introduction**

This chapter focuses on the specification of the model adopted as well as the procedure and techniques of analyses. Type of data used, sources of data and scope are also included in the chapter.

#### **4.1 Estimated model**

Electricity is a significant component of virtually any production process. As such, limited supply has the potential to, directly and/or indirectly affect the economic activities of firms. In documenting such a crucial economic role of electricity, a common approach in the literature is to measure the output loss associated with electricity outages. One of the analytical frameworks used is a production function (objective approach) in which electricity contributes directly to firms' output as a separate input, and indirectly as a determinant of the extent to which other direct inputs such as capital equipment is used (Cissokho and Seck 2013).

##### **4.1.1 Model Specification**

This study adopts an objective approach in trying to understand the effect of power outages on firm output and labour productivity in the manufacturing sector in Malawi.

Specifically, the analysis will follow the approach taken in other studies using a production function in which electricity intervenes directly as an argument in a production function and OLS regression analysis is used to determine the effects of power outages on output and labour productivity.

It should be pointed out, however, that the production approach though used extensively in the literature is not without drawbacks. Under the production function approach, it is assumed that electricity is essential for production, which is not always true. In some sectors, an electricity interruption does not necessarily imply a production break. Furthermore, production may be postponed or displaced to other locations or time slots. Therefore, this method may overestimate electricity interruption costs (Linares and Rey 2012). At the same time, in cases where we have production breaks due to power outages, the application of the production function approach may not be feasible especially where time series data is used.

Despite the drawbacks, in contrast to other methods, the production function approach provides an objective assessment of total costs. Furthermore, it relies on available data, which facilitates the analysis. The production function approach is a good method to account for production losses when they cannot be avoided by shifting production to other time, and also when electricity is critical for production. Surveys can be employed to complement this information (Linares and Rey 2012).

According to Moyo (2012), there are a number of methodologies that can be used to estimate productivity, each with its own strengths and weaknesses. One can use index numbers, parametric and non-parametric methods, data envelope analysis, and stochastic frontiers. Biesebroeck (2003) notes that index numbers and data envelopment analysis are flexible in the specification of technology but do not allow for measurement errors in the data. He argued that parametric methods, which calculate productivity from an estimated production function, are less vulnerable to measurement errors, certainly in the dependent variable, but mis-specification of the production function might be an issue. Therefore this study employs a parametric approach and uses an empirical model that borrows from the works of Moyo (2012). We derive both our output and labour productivity models from the total factor productivity model as follows:

Firm level total factor productivity is measured using a standard Cobb Douglass production function as follows:

$$y_i = \delta_0 + \delta_1 L_i + \delta_2 K_i + \delta_3 M_i + \varepsilon_i, \quad \varepsilon_i \sim \text{n.i.d}(0, \sigma^2) \quad (4.1)$$

Where  $y$  refers to the log of output of firm  $i$ ,  $K$  is log of stock of capital,  $M$  is log of material inputs, and  $L$  is log of number of workers in each firm. In order to calculate total factor productivity (TFP), the common approach is to obtain estimates of the elasticities of output with respect to inputs ( $\delta_1, \delta_2, \delta_3$ ) and then treat TFP as residuals from equation (1). Thus, we obtain TFP as:

$$\hat{LnTFP} = y_i - \hat{\delta}_1 L_i - \hat{\delta}_2 K_i - \hat{\delta}_3 M_i = \hat{\varepsilon}_i \quad (4.2)$$

Using this method, the TFP estimates from equation (4.2) would need to be regressed using a second stage model against a set of determinants, such as the quality of power infrastructure variables (power outages variable), which do not feature when estimating equation (4.1).

Newey & McFadden (1999) and Wang & Schmidt (2002) argue that using  $\hat{LnTFP}$ , based on equation (4.2) in a second stage model, results in both inefficient estimates (in the form of inconsistent standard errors and, hence, inconsistent t-values) of the determinants of TFP (Moyo, 2012). Thus, Wang and Schmidt (2002) argue that this approach results in potentially biased estimates since by omitting factors from equation (4.1) that determine output, the estimates of the estimated elasticities will suffer from an omitted variable problem and thus  $\hat{LnTFP}$  will be incorrectly measured (Moyo, 2012). At the same time, two-stage approaches are inefficient because they ignore any cross equation restrictions since they do not take into account the correlation of the error terms across equations (Harris & Trainor, 2005).

Moreover, a more serious problem associated with this approach is that of omitted variable bias. Thus the first step regression, equation (4.1) ignores other known determinants of output and standard econometric theory says that estimated elasticities from equation (4.1) will be biased as a result. Thus the estimates obtained in the second step regression will also be biased and this is true regardless of whether factor inputs and those variables that determine TFP are correlated or not. Wang and Schmidt (2002) show that in the case of two step estimators of technical efficiency using stochastic frontier

production approach, simulations indicate that the bias due to omitted variable problem is substantial. Their results are relevant even when using two step estimations of the determinants of TFP, a technique shown by equation (4.1) and (4.2) above (Moyo, 2012).

The preferred approach, therefore, is to directly include the determinants of output into equation (4.1) since this will avoid any problems of inefficiency and bias and helps in directly testing whether such determinants are statistically significant. These determinants are included directly into equation (4.1) as follows:

$$y_i = \delta_0 + \delta_1 L_i + \delta_2 K_i + \delta_3 M_i + \psi_1 OUT + \psi_2 X_i + \varepsilon_i \quad (4.3)$$

Thus equation 4.3 is the output model which we employ to investigate the impact of power outages on firm output. OUT is a variable that captures power outages and  $X_i$  is a vector of covariates that includes all other productivity effects, like firm age, dummy for foreign ownership and sectoral dummies. Generator ownership is included as one of the variables so as to ascertain whether such ownership does minimize the negative effects of power outages on productivity. This effect is captured by interacting the generator ownership dummy with the power outage variable.

However, since the study also seeks to investigate the impact of power outages on firm's labour productivity, we specify the labour productivity equation as follows:

$$y_i = \delta_0 + \delta_2 k_i + \delta_3 m_i + \psi_1 OUT + \psi_2 X_i + \varepsilon_i \quad (4.4)$$

In equation 4.4, the natural log of output per worker in 2014,  $y$ , is regressed on the natural logs of capital employed per worker,  $k$ ; material inputs per worker,  $m$ . Where

OUT a variable that captures power outages and  $X_i$  is a vector of covariates that includes all other productivity effects, like firm age, dummy for foreign ownership and sectoral dummies.

Thus using equation 4.3 and 4.4, the analysis of the study will involve four elements: (a) an estimation of the impact of power outages, measured as (yes/no) experience of outages in the previous year on labour productivity (output per worker) and on output (i.e. output measured as sales, keeping inputs fixed); (b) the same estimations, but using the frequency of outages as the measure of power outages; (c) the same estimations, but using the % of output lost as the measure of power outages. (d) An estimation of the effect of power outages on the labour productivity of firms with different characteristics. The variable of interest, power outages will be estimated using all the preceding proxies so as to determine whether the results are robust to model and variable specification.

## **4.2 Description and Measurement of the Variables**

Davies and Record (2007) investigated the determinants and impact of private sector investment in Malawi. In their study, they further investigated the impact of investment on labour productivity. The study established that investment does not significantly affect productivity and that productivity in Malawi is influenced by such factors as capital, material inputs and firm age. This study therefore takes into account these variables in estimating the productivity model.

The productivity variables, like capital, are measured using the replacement cost of plant and machinery while output and material inputs are measured using total sales value and total cost of raw materials and intermediate goods used in production, respectively. Firm age is calculated as the difference between the year the firm was established and the year the survey was done. Foreign ownership is a dummy taking the value of 1 if the firm has at least 10% foreign ownership, and zero otherwise.

Firm size is measured using the total number of permanent workers whereas power outages are measured using the number of days firms go without power per month, the percentage of output lost due to power outages in a given year and a dummy which captures whether a firm experienced power outages or not. This helps us to determine whether our results are robust to model and variable specification. Dummies are included in the model so as to capture the unobserved sector heterogeneity because some products may use less electricity than others in their production and these dummies may also capture sectoral comparative advantage based on the country's factor endowment differences. The results will be estimated using the Ordinary Least Squares (OLS) method.

#### **4.3 Diagnostic Tests**

In order for the results to be reliable, the assumptions of the OLS method of estimation must hold. To ensure this, the following diagnostic tests were used.

#### **4.3.1 Multicollinearity Test**

Regression in the presence of perfect or near perfect linear relationship among some or all explanatory variables in a regression model leads to indeterminate regression coefficients and infinite standard errors. Paradoxically though, multicollinearity is not a serious problem since even in the presence of multicollinearity the OLS estimators are still BLUE. To test the presence of multicollinearity the Variance Inflation Factor (VIF) of the variables are used.

#### **4.3.2 Heteroskedasticity Test**

Another classical assumption of OLS regression analysis is that the error terms in each model should be homoskedastic. This implies that given any value of the explanatory variable the variance of the error term should be the same for all observations. Otherwise, heteroskedasticity condition is said to exist. Just like the case for serial autocorrelation, violation of homoskedasticity assumption compromises the BLUE property of regression coefficients rendering inapplicable significance tests, inefficient predictions and invalid coefficient of determination, among others, yielding misleading conclusions (Gujarati, 2003). The common approach used in the literature, even in the absence of testing for the heteroskedasticity, is to estimate robust standard errors which are heteroskedastic corrected standard errors.

#### **4.3.2 Functional Specification Test**

One of the OLS classical regression assumptions is that the models should be correctly specified for meaningful results. The correct functional specification is in terms of no

omitted variables, correct functional form, and correct measurement of variables. Violation of this assumption renders obtained OLS coefficients biased and inconsistent. As such, Ramsey's Regression Specification Error Test (Ramsey RESET) was conducted on each regression equation to test for functional misspecification.

#### **4.4 Data Sources**

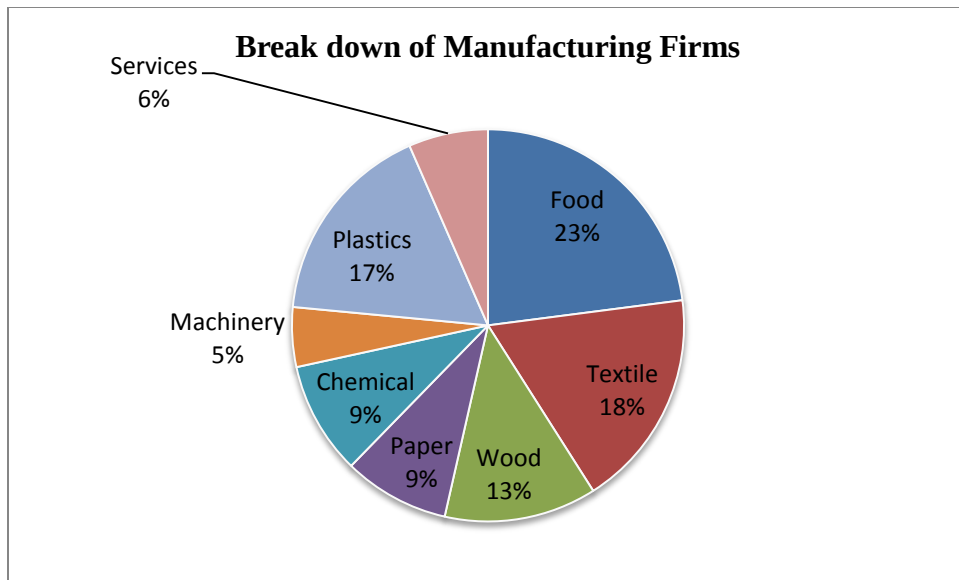
The World Bank's Investment Climate Surveys (ICS) is the main source of data to be used in this study. The World Bank has publicly available data from Enterprise Surveys in 135 countries. These are firm-level surveys of a representative sample of firms, and cover a range of topics relating to business performance and the business environment, including access to reliable electricity.

The data have been used in recent years by a number of studies examining the relationship between firm performance and the business climate (Dethier, Hirn, & Straub, 2011). The surveys use two instruments: a Manufacturing Questionnaire and a Services Questionnaire, with scope for additional questions tailored to the national context. The standard Enterprise Survey topics include firm characteristics, gender participation, access to finance, annual sales, costs of inputs/labour, workforce composition, bribery, licensing, infrastructure, trade, crime, competition, capacity utilization, land and permits, taxation, informality, business-government relations, innovation and technology, and performance measures. Electricity falls under the infrastructure label, the specific questions covering applications for connections, outages, the use and ownership of generators, and expenditure on electricity (Scott, *et. al*, 2014).

Respondents to the surveys, which are conducted face-to-face by private contractors on behalf of the World Bank, are business owners and senior managers. Some of the data collected is subjective, based on perceptions and recall, and therefore open to bias (Dethier *et. al*, 2011). This limits the potential for comparisons between countries and between surveys in one country in different years. Variations occur in the proportion of firms responding to each question, further limiting the scope for detailed statistical analysis.

The Enterprise Surveys use stratified random sampling, with strata for firm size, business sector, and geographic region within a country. Firm size levels are 5-19 (small), 20-99 (medium), and 100+ employees (large-scale firms). The surveys exclude micro-enterprises (fewer than 5 workers) and state-owned enterprises, but oversample large private firms. The size of the sample varies with country size, ranging from 1200-1800 interviews in larger countries to 150 interviews in small countries (Scott, 2014).

The latest survey for Malawi was done between April 2014 and February 2015. The whole population, or universe of the study, is the non-agricultural economy. It comprises: all manufacturing sectors (group D), construction sector (group F), services sector (groups G and H), and transport, storage, and communications sector (group I). This study will focus on the manufacturing sector which has a sample size of 183. The manufacturing sector comprises the following sub-sectors: food; tobacco; textiles, plastics; garments; non-metal; furniture; wood; paper; publishing; chemicals; machinery; electronics; fabrication; and leather.



**Figure 3: Breakdown of Manufacturing Firms by subsector**

## **CHAPTER FIVE**

### **EMPIRICAL RESULTS AND ANALYSIS**

#### **5.0 Introduction**

The aim of this chapter is to present and interpret the results of the study. For this study, data from the Enterprise Survey for Malawi was analyzed to assess the effect of power outages on labour productivity and output of manufacturing firms. At the outset of this chapter is the presentation of the descriptive statistics of the data that has been used in this study. Thereafter is the presentation of the results of the OLS regression models on the impact of power outages on firm labour productivity in Malawi followed by the results for the impact of power outages on firm total output. The regression models were estimated using Stata 12, regressing labour productivity and output on power outage variables while also controlling for other factors that affect productivity and output.

#### **5.1 Diagnostic Tests**

##### **5.1.1 Heteroskedasticity Tests**

One of the classical assumptions of the OLS regression analysis is that the error terms in each model should be homoskedastic. This implies that given any value of the explanatory variable the variance of the error term should be the same for all observations. Otherwise, heteroskedasticity condition is said to exist. While the white

heteroskedasticity test is applied to test for heteroskedasticity, the study adopted a common approach in literature where robust standard errors which are heretoskedastic corrected standard errors are estimated even in the absence of the test.

### **5.1.2 Multicollinearity Test**

Regression in the presence of perfect or near perfect linear relationship among some or all explanatory variables in a regression model leads to indeterminate regression coefficients and infinite standard errors (Gujarati, 2003). Paradoxically though, multicollinearity is not a serious problem since even in the presence of multicollinearity the OLS estimators are still BLUE (Gujarati, 2003). To test the presence of multicollinearity the VIF of each variable is used. The larger the VIF value for a variable, the more “troublesome” or collinear the variable is (Gujarati, 2003). As a rule of thumb, if the VIF of a variable exceeds 10 that variable is said to be highly collinear (Gujarati (2003). The results are presented in table 3 below. The variance inflation factor of 13.03 for the variable capital suggests that the variable is highly collinear and hence was dropped from the estimated model.

**Table 3: Variance Inflation Factors**

| <b>Variable</b>            | <b>VIF</b>   | <b>1/VIF</b> |
|----------------------------|--------------|--------------|
| Log Capital                | <b>3.72</b>  | <b>0.27</b>  |
| Log firm age               | <b>1.58</b>  | <b>0.63</b>  |
| Log firm age squared       | <b>1.49</b>  | <b>0.67</b>  |
| foreign ownership dummy    | <b>1.71</b>  | <b>0.58</b>  |
| Generator dummy            | <b>2.14</b>  | <b>0.47</b>  |
| Log material inputs        | <b>13.03</b> | <b>0.08</b>  |
| Log power outage frequency | <b>1.26</b>  | <b>0.79</b>  |
| Log output lost            | <b>1.36</b>  | <b>0.733</b> |
| Mean VIF                   | <b>3.29</b>  |              |

### **5.1.3 Functional Specification Test**

One of the OLS classical regression assumptions is that the models should be correctly specified for meaningful results. The correct functional specification is in terms of no omitted variables, correct functional form, and correct measurement of variables. Violation of this assumption renders obtained OLS coefficients biased and inconsistent. As such, Ramsey's Regression Specification Error Test (Ramsey RESET) was conducted on regression equation 4.3 and 4.4 to test for functional misspecification. Results of the test are shown in Table 4.

**Table 4: Ramsey Reset Test F-statistic & probability values**

| Equation                           | Frequency of outages* | Output lost*   | Power outage dummy* |
|------------------------------------|-----------------------|----------------|---------------------|
| 4.3 (output equation)              | 1.24<br>(0.31)        | 1.98<br>(0.12) | 1.23<br>(0.31)      |
| 4.4 (labour productivity equation) | 1.19<br>(0.32)        | 1.00<br>(0.40) | 1.24<br>(0.30)      |

*Note: Numbers in parenthesis are probability values for the F-statistic; \* are measures of power outages such that 3 different equations were estimated under equation 4.3 and 4.4.*

From the results, the associated p-values of the F-statistics in all equations are insignificant. In this case we fail to reject the null hypothesis of no functional misspecification. This implies all the regression equations are correctly specified.

## 5.2 Summary Statistics

Table 5 and table 6 below present the descriptive statistics of the variables that have been used in this study.

**Table 5: Power Infrastructure Indicators for Malawi**

| Indicator                                                       | Malawi | SSA** | World** |
|-----------------------------------------------------------------|--------|-------|---------|
| Percentage of firms identifying electricity as a major obstacle | 87.5   | 50.3  | 39.2    |
| Average number of electrical outages in a typical month         | 9.0    | 10.7  | 8.6     |
| Losses due to electrical outages (% of annual sales)            | 8.5    | 6.7   | 4.8     |
| Percentage of firms owning or sharing a generator               | 45.5   | 43.6  | 31.6    |
| Average proportion of electricity from a generator (%)          | 27.1   | 26.9  | 20.9    |
| Days to obtain an electrical connection                         | 63.0   | 31.6  | 33.6    |

*Source: Authors own calculation, \*\* Moyo (2012)*

**Table 6: Descriptive statistics on firm characteristics**

|                  | <b>Firm Size<br/>(No. of<br/>permanent<br/>employees)</b> | <b>Firm<br/>Age</b> | <b>Foreign<br/>Owned<br/>(%)</b> | <b>Number<br/>without<br/>power<br/>per<br/>month</b> | <b>% of<br/>Output<br/>Lost<br/>Due to<br/>Power<br/>Outages</b> | <b>% of Firms<br/>Complaining<br/>About<br/>Power<br/>Outages</b> | <b>% of<br/>Firms<br/>Owning a<br/>Generator</b> |
|------------------|-----------------------------------------------------------|---------------------|----------------------------------|-------------------------------------------------------|------------------------------------------------------------------|-------------------------------------------------------------------|--------------------------------------------------|
| <b>Firm Size</b> |                                                           |                     |                                  |                                                       |                                                                  |                                                                   |                                                  |
| Small (5-19)     | 8.70                                                      | 18.02               | 0.09                             | 9.83                                                  | 8.24                                                             | 74.45                                                             | 21.28                                            |
| Medium (20-99)   | 28.82                                                     | 23.01               | 0.25                             | 8.53                                                  | 10.02                                                            | 83.33                                                             | 44.78                                            |
| Large(>=100)     | 237.13                                                    | 24.70               | 0.54                             | 9.07                                                  | 7.17                                                             | 27.66                                                             | 66.67                                            |
| <b>Sectors</b>   |                                                           |                     |                                  |                                                       |                                                                  |                                                                   |                                                  |
| Food             | 89.50                                                     | 19.10               | 0.38                             | 6.63                                                  | 12.48                                                            | 83.33                                                             | 52.38                                            |
| Textile          | 98.04                                                     | 25.27               | 0.35                             | 7.79                                                  | 6.18                                                             | 76.00                                                             | 47.07                                            |
| Wood             | 78.75                                                     | 24.12               | 0.17                             | 10.76                                                 | 8.76                                                             | 87.5                                                              | 29.17                                            |
| Paper            | 53.05                                                     | 24.36               | 0.11                             | 7.87                                                  | 5.88                                                             | 94.74                                                             | 68.42                                            |
| Chemical         | 68.58                                                     | 22.16               | 0.42                             | 20.83                                                 | 12.91                                                            | 63.16                                                             | 47.37                                            |
| Machinery        | 272.67                                                    | 20.56               | 0.33                             | 9.38                                                  | 16.00                                                            | 88.89                                                             | 52.70                                            |
| Plastics         | 143.55                                                    | 23.75               | 0.20                             | 7.11                                                  | 12.19                                                            | 90.00                                                             | 52.63                                            |
| Services         | 82.35                                                     | 19.47               | 0.47                             | 8.13                                                  | 53.33                                                            | 88.24                                                             | 50.73                                            |

As it was alluded to in preceding paragraphs, erratic power supply is identified as one of the major constraint of doing business in Malawi. The statistics in table 5 support this assertion as 87.5% of the manufacturing firms identify electricity as a major obstacle to their operations. Furthermore the statistics reveal that manufacturing firms in Malawi experience power outages for about 9 times in a month far more than the world average. The severity of the power problems in Malawi is explained by the fact that about 8.5% of sales are lost due to power disruptions and 45.5% of manufacturing firms own or share a generator.

Table 6 presents the information on power infrastructure indicators with respect to firm size (measured by number of employees) and sector. Statistics from table 6 reveal that 74% of small firms complain about power outages whereas only about 27% of large firms complain about power outages. While this is the case, only 21.28% of the small firms own a generator compared to 67% of large firms that own a generator. At the sector level, firms in the food and plastic sectors register high percentages of firms complaining about power outages with the plastic sector registering as high as 90%.

### 5.3 OLS Estimation Results of Power Outages Effects on Labour Productivity

**Table 7: Effects of power outages on labour productivity of all Manufacturing Firms**

|                                                | <b>Model A</b>      | <b>Model B</b>       | <b>Model C</b>       |
|------------------------------------------------|---------------------|----------------------|----------------------|
| <b>Sector dummies</b>                          | <b>Yes</b>          | <b>Yes</b>           | <b>Yes</b>           |
| Log power outages frequency                    | -0.116<br>(0.200)   |                      |                      |
| Log output Lost                                |                     | -0.072<br>(0.147)    |                      |
| Power outage dummy                             |                     |                      | -1.120**<br>(0.444)  |
| Power outage dummy & generator interaction     |                     |                      | 3.067***<br>(0.972)  |
| Power outage frequency & generator interaction | -0.012<br>(0.045)   |                      |                      |
| Lost output & generator interaction            |                     | -0.057***<br>(0.021) |                      |
| Generator dummy                                | 0.276<br>(0.542)    | -0.762*<br>(0.434)   | -2.367***<br>(0.823) |
| Log capital                                    | 0.399**<br>(0.180)  | 0.605***<br>(0.125)  | 0.186*<br>(0.093)    |
| Log Firm Age                                   | 0.311<br>(0.321)    | 0.084<br>(0.353)     | 0.233<br>(0.299)     |
| Log Firm Age squared                           | 0.065<br>(0.131)    | 0.109<br>(0.121)     | 0.083<br>(0.103)     |
| Foreign ownership dummy                        | -0.150<br>(0.439)   | -0.385<br>(0.474)    | -0.138<br>(0.400)    |
| Constant                                       | 9.494***<br>(2.105) | 7.831***<br>(1.961)  | 13.153***<br>(1.495) |
| R-squared                                      | 0.74                | 0.69                 | 0.79                 |
| Adjusted- R-squared                            | 0.72                | 0.67                 | 0.76                 |
| F-statistics                                   | 7.81                | 7.79                 | 4.24                 |
| N                                              | 72                  | 53                   | 85                   |

Standard errors in parentheses

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 7 above reports the regression results from estimating the productivity equation which was specified in chapter 3<sup>1</sup>. Three models were estimated. In Model A power outages is captured by frequency of outages, by output lost in model B and a dummy (yes/no experience of power outages) in Model C. From the regression results, the adjusted R squared statistics of above 60% for all models show that the models fit very well. All the models are significant and better explain the variations in labour productivity since their respective F statistics are significant at all levels of significance.

Variables that are of central interest in this study are those measuring power outages. Kessides (1993) observed that power is an intermediate input and that any reduction in its costs raises the profitability of production and enhances the marginal productivity of labour and capital. In this case, high number of times without power as well as high percentage of output lost due to electricity disruptions must therefore have a negative effect on labour productivity. The regression results in table 7 above indicate that when power outages are captured using a power outage experience dummy (outages/no outages) power disruptions have a negative and significant effect on labour productivity. This is consistent with the findings of previous research (Moyo, 2012; Scott et.al, 2014). This means that firms which experience power outages have lower labour productivity than firms which do not.

However, the results reveal that when power outages are measured using number of days and output lost, these variables are insignificant and negative. This finding is however inconsistent with other studies (see Cissokho and Seck, 2013; Moyo, 2012) who found

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<sup>1</sup> Material inputs was dropped from the model on grounds of high colinearity

that using the duration of outages as well as percentage of output lost as the measure of electricity outages show a greater impact than simply the experience of outages. Thus In countries like Malawi, where power outages become almost like daily events, we may expect the outages to have significant effect on firm labour productivity and output. These results, if odd in some ways, could reveal successful coping strategies by businesses to poor electricity service.

Apparently, businesses learn to get by the electricity issues. When power outages, in a long period, become almost like daily events, as in Malawi, one would naturally expect businesses to organize their activities in ways that could cancel the rationally expected adverse effects. The strategies could come in the form of shifting workers from tasks intensive in electricity to tasks that are less demanding, or that do not need electricity; and/or businesses could intensify production at times when electricity was still running. Electricity outages, while a hindrance to production activities, appeared in this context as a source of motivation to better management practices which mitigate the adverse effects of power supply interruptions and hence the insignificant effect of the power outage variables.

From the results, the parameter estimate of capital is statistically significant in all the three models with the correct expected sign meaning that firm capital exert a significant influence on a firms' labour productivity in Malawi. The results also show that the generator dummy is significant and negative when power outage is measured using a dummy and output lost whereas it is insignificant and positive when power outage is

measured by number of times that firms experience power outages. The results show that firm age is insignificant and positive in all the three models. This suggests that being older weakly affects a firm's level of labour productivity. Age in this case might not be a factor determining firm's labour productivity in Malawi.

Apart from other advantages, it is generally argued that firms with some foreign ownership are more productive than those without (Yoshino, 2008; Griffith et al, 2004; Harris and Robinson, 2004, Moyo,2012) because foreign ownership brings with it skills and technologies that help improve the productivity of firms (productivity effect). Results from table 7 above show that the foreign ownership dummy is not only negative but is also insignificant determinant of labour productivity in Malawi. As revealed in the descriptive statistics from table 6 this may be because only about two percent of surveyed Malawian firms are foreign owned which probably explains why the foreign ownership dummy is insignificant.

### **5.3.1 Whether Generator Use Mitigate the negative effects of power outages**

For some resources, like water, storage devices can be used to manage unreliable services (Brian, Davis, Salant, & Wilcox, 2010). However, unreliable delivery of electricity requires that firms respond in other ways, such as ownership of a generator as power is prohibitively expensive to store (Vanden, Mansur, & Wang, 2014). According to (Attigah & Mayer-Tasch, 2013), in countries where electricity reliability is very low, electricity-reliant businesses have to invest in diesel generators if they want to sustain regular business operations. Foster and Steinbuks (2008) estimate that generators owned

by firms represent about 6% of total installed generation capacity in sub-Saharan Africa, and up to 20% in some countries (e.g. Nigeria). They however observed that generator ownership is greatly affected by characteristics like size, sector, corporate structure and export orientation. According to Foster & Steinbuks (2008), the probability of owning a generator doubles in large firms relative to small ones.

Evidently in Malawi, according to the descriptive statistics in table 5, 45.5% of the manufacturing firms own or share a generator. However it can be observed from the descriptive statistics in table 6 that although 74.45% of small firms complain about power outage problems only 21.28% own or share a generator. The possible explanation for the low ownership of generators by small firms might be that acquiring a generator may be costly for small firms with limited funds which may affect their productivity. However, According to Steinbuks and Foster (2008), the benefits of generator ownership are substantial as firms with their own generators report a value of load lost per hour of less than \$50, compared with more than \$150 for those without. In other words, owning a generator ameliorate the adverse effects of power outages.

This paper therefore sought to investigate whether owning or sharing a generator helps in minimizing the negative impact of power outages in Malawi. To achieve this objective, the power infrastructure quality variables (power outage variables) were interacted with the generator ownership dummy. Results from table 7 above show that when power outage is captured by a dummy, the variable is positive and significant. Thus, generally owning a generator does ameliorate power outage problems. However, when power

outage is captured by output lost the variable is negative and significant whereas the variable is positive and insignificant when power outages are captured by the frequency of outages.

### **5.3.2 Effects of power outages on firms of different sizes**

Adenikinju (2005) found that in Nigeria, small firms are more heavily affected by electricity insecurity because they are unable to finance the cost of backup generation necessary to mitigate the impact of frequent and sustained outages. Foster and Steinbuks (2008) found that the probability of large firms owning a generator is double that of small firms, and the capacity of generators used by large firms is four times larger than small firms. This points to the fact that small firms may experience the full blunt of outages compared to large firms.

The study therefore sought to establish the impact of power outages on labour productivity of firms with different sizes. To achieve this objective, we divided our firms into small (all firms with less than 20 employees) and large (all firms more than 20 employees) to learn whether power outages affect firms indiscriminately or whether the impact depends on size of the firm. The regression results are presented in table 8.

**Table 8: Effects of power outages on labour productivity of firms of different sizes**

|                                               | <b>OLS<br/>Small<br/>Firms</b> | <b>SE</b> | <b>OLS<br/>Large Firms</b> | <b>SE</b> |
|-----------------------------------------------|--------------------------------|-----------|----------------------------|-----------|
| Sector dummies                                | <b>Yes</b>                     |           | <b>Yes</b>                 |           |
| Log Capital                                   | 1.002 <sup>***</sup>           | (0.060)   | 0.068                      | (0.117)   |
| Log Firm age                                  | 0.454                          | (0.279)   | 0.601                      | (0.400)   |
| Log firm age square                           | -0.196                         | (0.118)   | 0.226                      | (0.176)   |
| Power outage dummy                            | 0.009                          | (0.500)   | -2.675 <sup>***</sup>      | (0.830)   |
| Power outage dummy<br>& Generator interaction | -1.697 <sup>**</sup>           | (0.639)   | 4.766 <sup>***</sup>       | (1.498)   |
| Generator dummy                               | 1.396 <sup>**</sup>            | (0.569)   | -3.955 <sup>**</sup>       | (1.471)   |
| Foreign ownership                             | 0.327                          | (0.443)   | -0.382                     | (0.633)   |
| constant                                      | 0.947                          | (1.364)   | 14.222 <sup>***</sup>      | (2.331)   |
| R-squared                                     | 0.95                           |           | 0.66                       |           |
| Adjusted- R squared                           | 0.93                           |           | 0.61                       |           |
| F-statistics                                  | 51.99                          |           | 116.52                     |           |
| N                                             | 43                             |           | 48                         |           |

Standard errors in parentheses

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

From the results, the power outage variable is insignificant and positive for small firms whereas the variable is significant and negative for large firms suggesting discriminate effect of power outages on firm's labour productivity between large and small firms. This

suggests that despite the majority of large firms owning generators, they are significantly affected by outages. The generator and power outage interaction variable is significant for both small firms and large firms. However, for small firms the variable is negative whereas for the large firms the variable is positive suggesting that ownership of a generator indeed ameliorates the negative impact of power outages in large firms. This is consistent with findings by Moyo (2012). The reason why the variable is negative among small firms could be that acquiring a quality generator may be costly for small firms with limited funds which may negatively affect their productivity (Moyo, 2012). In other words, the negative effect of generator ownership could be a result of additional costs associated with having one.

### **5.3.3 Effects of power outages on firms in different sectors**

Moyo (2012) noted that the presence of sector heterogeneity means that some products may use less electricity than others in their production and hence may be differently affected by power outages. The study therefore sought to establish the impact of power outages at the sector level. For the purposes of this study three sectors were considered namely: food, textile and plastics. These sectors were considered since they had reasonably large sample size and at the same time, from the descriptive statistics, more than 50% of firms from these sectors experience power outages. The results are presented in the table 9.

**Table 9: Effects of power outages on labour productivity of different sectors**

|                                            | <b>OLS<br/>FOOD</b>  | <b>OLS<br/>TEXTILE</b> | <b>OLS<br/>PLASTICS</b> |
|--------------------------------------------|----------------------|------------------------|-------------------------|
| Sector dummies                             | <b>No</b>            | <b>No</b>              | <b>No</b>               |
| Log Capital                                | -0.350<br>(0.254)    | 0.611<br>(0.317)       | 0.875**<br>(0.132)      |
| Log Firm age                               | -2.053<br>(1.130)    | -0.051<br>(0.550)      | 0.361<br>(0.407)        |
| Log firm age square                        | -0.574<br>(0.360)    | -0.317*<br>(0.155)     | 1.048**<br>(0.136)      |
| Power outage dummy & generator interaction | 4.867**<br>(1.952)   | 0.843<br>(1.021)       | 1.159**<br>(0.245)      |
| Power outage dummy                         | -3.712**<br>(1.220)  | -0.911*<br>(0.422)     | -6.335**<br>(0.641)     |
| Foreign ownership                          | -0.048<br>(1.056)    | 0.523<br>(0.704)       | 1.225<br>(1.186)        |
| Constant                                   | 25.628***<br>(6.262) | 7.959<br>(4.354)       | 1.828<br>(2.998)        |
| R-squared                                  | 0.74                 | 0.63                   | 0.98                    |
| Adjusted- R squared                        | 0.52                 | 0.59                   | 0.91                    |
| F-statistics                               | 120.66               | 109.89                 | 103.39                  |
| N                                          | 34                   | 31                     | 29                      |

Standard errors in parentheses

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ 

From the results, at the sector level, power outages have a negative and significant effect on all the three sectors namely food, textile and plastic sectors. This may be partly explained by the fact that only about 50% of firms in each of these sectors own a generator to mitigate the negative effect of power outages. The interaction variable for all the sectors is positive and significant suggesting that ownership of a generator in these sectors does ameliorate the negative effect of power outages.

## 5.4 Effects of power outages on firm output

**Table 10: Effects of power outages on output of all Manufacturing Firms**

| Variable                                   | Model A             | Model B             | Model C              |
|--------------------------------------------|---------------------|---------------------|----------------------|
| Sector dummies                             | <b>Yes</b>          | <b>Yes</b>          | <b>Yes</b>           |
| Log Capital                                | 0.605***<br>(0.125) | 0.399**<br>(0.180)  | 0.186*<br>(0.093)    |
| Log Firm age                               | 0.084<br>(0.353)    | 0.311<br>(0.321)    | 0.233<br>(0.299)     |
| Log Firm age square                        | 0.109<br>(0.121)    | 0.065<br>(0.131)    | 0.083<br>(0.103)     |
| Log firm size                              | 1.233***<br>(0.197) | 1.272***<br>(0.193) | 1.279***<br>(0.184)  |
| Generator dummy                            | -0.762*<br>(0.434)  | 0.276<br>(0.542)    | -2.367***<br>(0.823) |
| Foreign ownership                          | -0.385<br>(0.474)   | -0.150<br>(0.439)   | -0.138<br>(0.400)    |
| Log output lost                            | -0.072<br>(0.147)   |                     |                      |
| Lost output & generator interaction        | 0.088***<br>(0.020) |                     |                      |
| Log power outages                          |                     | -0.116<br>(0.200)   |                      |
| Power outage & generator interaction       |                     | 0.052<br>(0.033)    |                      |
| Power outage dummy                         |                     |                     | -1.120**<br>(0.444)  |
| Power outage dummy & Generator interaction |                     |                     | 3.067***<br>(0.972)  |
| R-squared                                  | 0.84                | 0.74                | 0.72                 |
| Adjusted- R squared                        | 0.78                | 0.67                | 0.66                 |
| F-statistics                               | 27.85               | 30.12               | 14.75                |
| N                                          | 53                  | 72                  | 85                   |

Standard errors in parentheses

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

The results of the impact of power outages on output are presented in table 10 above. Three models were estimated. In Model A power outages is captured by output lost, by frequency of outages in model B and a dummy (yes/no experience of power outages) in Model C. From the results, the variable of interest, power outages, has a significant negative effect on output when measured using a binary variable (outages/no outages) whereas it is insignificant and negative when using output lost and frequency of outages. These results are consistent with finding by Scott *et.al* (2014). The interaction variable is positive and significant when power outages are measured by output lost and a dummy whereas it is positive and insignificant when power outages are measured using the frequency of outages.

#### **5.4. Conclusion**

The statistical analysis undertaken for this study supports empirical findings that power outages tends to negatively affect output and labour productivity of manufacturing firms. However, this is not consistently found in all circumstances as in some cases the effects are not always statistically significant and findings can be influenced by how power outages are measured.

## **CHAPTER SIX**

### **CONCLUSION AND POLICY IMPLICATIONS**

#### **6.0 Introduction**

This chapter presents the conclusion and policy implications of this study. Section 6.1 gives a summary of results from the OLS models that were estimated; Section 6.2 gives the policy recommendations that can be driven from the obtained; Section 6.3 gives some of the limitations of the study; and finally Section 6.4 outlines the areas for further research.

#### **6.1 Summary of Results**

The primary objective of the study was twofold: Firstly, to establish the extent to which power outages affect firm's labour productivity in the manufacturing sector and secondly to establish the extent to which power outages affect firm output in the manufacturing sector in Malawi.

The results reveal that power outages have a negative and significant effect on output and labour productivity of manufacturing firms in Malawi. This is shown when the measure of power outages is binary (outages/no outages). Thus firms which experience outages have lower productivity than firms which do not.

The above findings have implications, on manufacturing firms on the one hand, and ESCOM as a supplier of electricity and Government as a policy holder on the other. For manufacturing firms, on the basis of the results, they have to devise ways to mitigate the negative effects of electricity. Since the study has established that generator ownership tends to ameliorate the negative effects of the outages, firms could therefore invest in backup generators as a means of coping with outages. It should be pointed out, however, that the costs of generators may be a hindrance to ownership of the same especially in small firms. Firms could therefore also consider changing processes to use manual labour and processes not reliant on electricity. At the same time, firms could further reschedule production to times when power is available.

ESCOM, as the sole supplier of grid electricity in Malawi has a role in mitigating the negative effects of power outages. Obviously, proper maintenance of electricity infrastructure could ensure steady supply of electricity to firms. At the same time, it is important for ESCOM to ensure that outages follow a reasonably regular pattern (through provision of consistent load shedding schedules). This will enable firms to change production schedules to correspond to power supply.

The severity of power outage problems in Malawi is ironical in that the country is well endowed with resources to produce power such as coal. The government should therefore put in place deliberate strategies such as tax incentives to attract investors into power generation using these other resources apart from water. Since the study has established that generators tend to mitigate the negative effects of outages, the government could find

ways of ensuring that firms can easily or cheaply access these machines. This can be done by encouraging firms to participate in generator production locally or in the short term through lowering taxes on imported ones so as to ultimately push prices down.

## **6.2 Policy Recommendations**

The role of the manufacturing sector to Malawi's social-economic development cannot be overemphasized. Manufacturing firms among other contributions play a significant role in employment and poverty reduction, especially in growing urban areas, which can be enhanced by policies that facilitate access to reliable electricity.

Policy makers concerned with the effects that power outages have on labour productivity and output of manufacturing firms can promote action to reduce negative impacts in a number of ways. The most obvious area for action is to improve the reliability of the electricity supply. This may require short-term action to reduce technical faults, for example, through maintenance of the transmission and distribution infrastructure, or it may require longer-term interventions to expand generating capacity. Notably, the Government should offer incentives to private sector players who can generate electricity from alternative sources such as coal and solar.

In the absence of a better quality supply, ESCOM can help manufacturing firms by providing reliable load shedding schedules, which would enable them to plan production around outages. Ownership of backup generators could help firms to access and use backup power during outages. However, there's need for deliberate policies to encourage

firms to participate in generator production locally or through lowering taxes on imported ones so as to ultimately push prices down.

### **6.3 Limitations of the study**

The principal data source for this study is the World Bank Enterprise Surveys for Malawi, respondents being business owners and senior managers. However, some of the data collected is based on the respondents' perceptions and recall and therefore open to a subjective bias (Dethier et al., 2011).

Another limitation of the study was the non-availability of data on electricity production and consumption from ESCOM. This data would have provided a clear picture on the trends in production and consumption of electricity in Malawi and could have enriched the analysis.

### **6.4 Area of Further Study**

While this study has extensively discussed the impact of power outages on firm's labour productivity and output in Malawi, there are areas of interests that could be the focus for other studies. It would be interesting for other studies to explore costs of power outages on both industry and households through the estimation of Values of Lost Load (VoLLs) under the macroeconomic approach.

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