TECHNICAL EFFICIENCY OF MANUFACTURING ENTERPRISES IN RWANDA

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DECLARATION

This research paper is my original work. It has not been presented for any degree award in any other university or institution of higher learning.

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DEDICATION

To my loving parents, siblings, brother in law and close friends, for the love and support throughout this masters journey.

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LIST OF ABBREVIATIONS

AfDB:	African Development Bank
DEA:	Data Envelopment Analysis
GDP:	Gross Domestic Product
GLS:	Generalized Least Squares
GoR:	Government of Rwanda
IMF:	International Monetary Fund
ISIC:	International Standard Industrial Classification
KPMG:	Klynveld Peat Marwick Goerdeles
ML:	Maximum Likelihood
NIRDA:	National Industrial Research and Development Agency
NISR:	National Institute of Statistics of Rwanda
OECD:	Organization for Economic Co-operation and Development
REC:	Rwanda Enterprise Census
R&D:	Research and Development
RDB:	Rwanda Development Board
RWF:	Rwandan Francs
SAPs:	Structural Adjustment Programmes
SFA:	Stochastic Frontier Analysis
SME(s):	Small and Medium Enterprise(s)
SSA:	Sub-Saharan Africa
TE:	Technical Efficiency
Translog:	Transcendental logarithmic
USD:	United States Dollar
WDI:	World Development Indicators

ABSTRACT

Manufacturing is widely perceived as one of the economic drivers for transformation from low to high productive activities through task-based production among the developing countries. It allows diversifying economic activities and bears the potential for significant value addition in many of the Sub-Saharan Africa economies. The sector is however still facing major challenges such as infrastructural inadequacies, the lack of skilled labour force, limited and stagnant of market demand and inefficient allocation of resources. This sector also faces insufficient technological innovation and failure to capture most of the downstream value-added to its resources-based products. Using the Rwanda Enterprise Census, (2017) firm-level data that covers 14,013 manufacturing enterprises in Rwanda, this study sought to lay out empirical findings on the determinants of technical efficiency among the manufacturing enterprises in Rwanda. The study employed the Maximum Likelihood Estimation approach and the stochastic frontier model to estimate technical efficiency and determinants of technical inefficiency among the manufacturing enterprises in Rwanda. The results show that the enterprise's age, formal status and R&D activity are statistically significant and have a positive effect on technical efficiency. Micro and small enterprises are positively associated with technical efficiency while medium and large enterprises are both negatively associated with technical efficiency in the Rwandese-manufacturing sector. In addition, direct or indirect export status and domestic ownership status have a positive but insignificant effect on technical efficiency. However, foreign technology adoption has a negative and insignificant effect on technical efficiency of manufacturing enterprises in Rwanda. Further, typical enterprises are found to be operating at about 48 % below their maximum potential output level in the manufacturing sector in Rwanda.

Keywords: *Technical efficiency, manufacturing enterprise, value addition, Rwanda*

CHAPTER ONE
INTRODUCTION

1.1 Background of the study

Industrial development has a critical part in ensuring meaningful growth and development (AfDB, 2014). Within the industrial sector, manufacturing is particularly important in raising household incomes and in creating new market opportunities through enhanced value addition processes.

Page (2011) has argued that manufacturing is a key economic driver for transformation from low to high productive activities through task-based production across Africa. The sector is also identified as a source of structural change since it is responsible for the creation of skilled jobs, poverty reduction as well as positive spillovers associated with the forward and backward linkages with other economic sectors (Tybout, 2000).

Despite its crucial role in industrialisation, the industrial sector in developing economies is still marked by major challenges. These include significant inefficiencies (Goedhuys & Sleuwaegen, 2003) and a turbulent operating condition such as technical capacity, infrastructural inadequacies and volatile macroeconomic environment, the lack of skilled labour force and insufficient investments in research and development (R&D) among enterprises in developing economies (Biggs, 1995; Tybout, 2000).

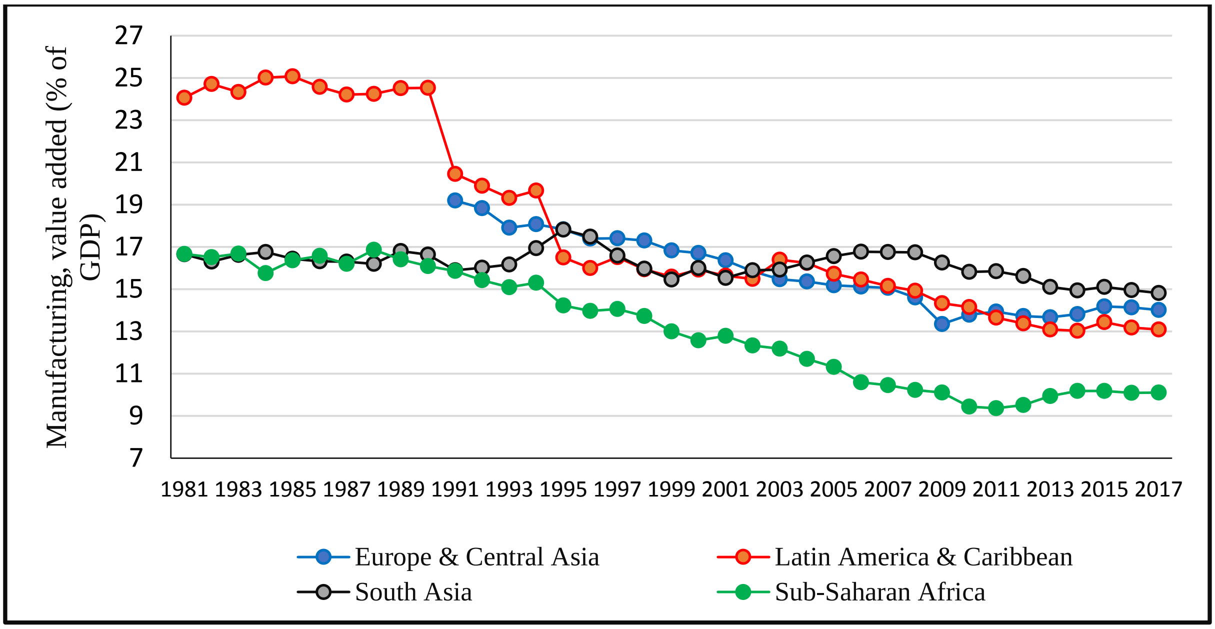
In the majority of the Sub-Saharan Africa (SSA) economies, McMillan *et al.* (2017) observe that firms are mainly small and that labour has moved more into the informal sectors as opposed to high productive formal sectors like modern manufacturing. The manufacturing sector has continuously become an alternative economic activity that helps different developing countries in terms of performance and growth. Firm turnover is the considerable and perfect condition for effective survival of the industrial sector (Soderbom, Teal & Harding, 2006). Since the 1980s, the picture of manufacturing has changed strategically and continues to influence SSA’s economic efficiency and development based on innovation, technical skills and other key drivers such as technology in R&D and business environment (Biggs & Shah, 2006; KPMG Sector Report, 2014; Sharma et al., 2016).

Performance of the firm can be estimated by the degree of productivity (Coelli et al., 2005). Particularly, it is the firm’s capability to effectively allocate resources in the sense that optimizes value addition. Aigner et al. (1977) indicate that technical efficiency refers to an optimal inputs mix that is used in the production chain to achieve the maximum potential output as an estimation of economic efficiency. The achievement of technical efficiency may be constrained by scarce resources. This is a fundamental concern faced by firms, although it is widely acclaimed that efficiency is essential in the attainment of the dual objective of output and profit maximization (Young, 2013).

Moreover, the concepts of efficiency and productivity are grounded in the production theory. Undoubtedly, output maximization requires a combination of different factor inputs. Equally important is the shift of these factors of production from low to high productivity for manufacturing firms worldwide and it is particularly beneficial for developing countries, where productivity differentials across manufacturing run deeper (Sharma et al., 2016). The classical microeconomic theory views firms as identical units (Knudsen, 1995). Therefore, it is also presumed within the theory that firms are likely to operate at a similar level of economic efficiency (Farrell, 1957).

Besides, the manufacturing sector is widely perceived as key in driving Africa's economic development. This is due to the export focus and labour intensive (KPMG, 2014). However, manufacturing value-added in the SSA region declined from 1990 to 2017 in the share of Gross Domestic Product (GDP). It accounted for only about 12.5% of GDP in 2000 and 10.1% in 2017. These statistics are smaller shares of GDP, when compared with other regions (developing countries only) (see Figure 1). In contrast, manufacturing production in SSA region has doubled in nearly two decades. The decadal increment rose to a high of USD 160 billion in 2017 from a low of USD 85 billion in 2000, which translates to about USD 5 billion annual increments due to industrial production being attracted to resource-based manufacturing (World Bank, 2018).

Figure 1: Cross-region Comparison of Manufacturing's Value Added (% of GDP)



Source: *World Development Indicators (WDI) data, 2018*

The declining trend of Africa's manufacturing base is often attributed to the adoption of import substitution strategy of industrialisation in the 1970s and reduction in the productive capacity utilization in the sector (Tybout, 2000; Soderbom & Teal, 2004). SSA lags behind in global manufacturing net exports, which fall less than 1% of the entire share. The World Bank (2018) estimations reveal that this share has declined since 2010 by 9.8%. The estimates further reveal that it is until recently that multiple reform packages were adopted including the Structural Adjustment Programmes (SAPs). However, these policies did not address the fundamental slippages in the sector such as low productive efficiency, which remains an issue of concern.

1.2 Overview of the Manufacturing Sector in Rwanda

With an annual average growth rate of 8% since 2000, Rwanda has been among the fastest-growing economies in Africa (IMF, 2018). The manufacturing sector in Rwanda is one of the drivers of economic development, poverty reduction and job creation through task-based production (Government of Rwanda [GoR], 2018).

1.2.1 Performance of Manufacturing Sector in Rwanda

Rwanda attaches importance to transforming its economy from low productive efficiency sectors like subsistence agriculture to high productive efficiency sectors with sustainable high growth and employment creation through structural change towards increased manufacturing production (GoR, 2018). However, as illustrated in Table 1, manufacturing value-added share of GDP has continued to decline since 2000. This could point to the presence of technical inefficiency. This is because according to input-oriented technical efficiency, a firm should reduce the input levels without changing the output levels. AfDB (2014) evidences presence of the technical inefficiency. This study found that labour productivity in the manufacturing sector in Rwanda decreased from USD 3857 in 2001 to USD 3750 in 2011. In addition, the study found also that labour productivity in the Rwandese-manufacturing sector was low compared to East Africa's regional average. On the contrary, the output-oriented technical efficiency requires output quantities to increase using the same set of inputs. From table 1, compared to other sectors, manufacturing has quite lagged behind. For example, between 2000 and 2017 the services sector share of GDP maintained slightly less than 50%. The agriculture had a share of GDP of 37.1% in 2000, which remained fairly stagnated up to 2005, increased in 2006 and then maintained an average of 28.9 % up to 2017. The industrial sector saw its share in GDP varied from 15.8 % to 15.7 % over the same period, a trend that is attributable to the light construction sector.

Table 1: Composition of GDP as % for the period 2000 to 2017

Sector	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Agriculture	37.1	37.3	35.3	38.2	38.5	38.3	43	30.3	28.3	29.3	28.1	28.2	29.2	28.8	28.7	28	29.3	30.9
Industry	15.8	15.5	15.1	12.7	12.9	13.4	13.3	15	14.6	14.1	14.8	16.5	16.5	17.1	17.1	16.9	16.3	15.7
Manufacturing	7.3	6.9	7.4	6.7	6.6	6.5	6	5.5	5.5	6	6.1	5.9	5.9	5.9	5.8	5.8	5.8	5.9
Services	46.8	45.5	46.9	45.1	43.8	44	44	47.4	49.1	48.4	49.2	46.9	47.6	47.7	47.1	47.8	47.2	46.3

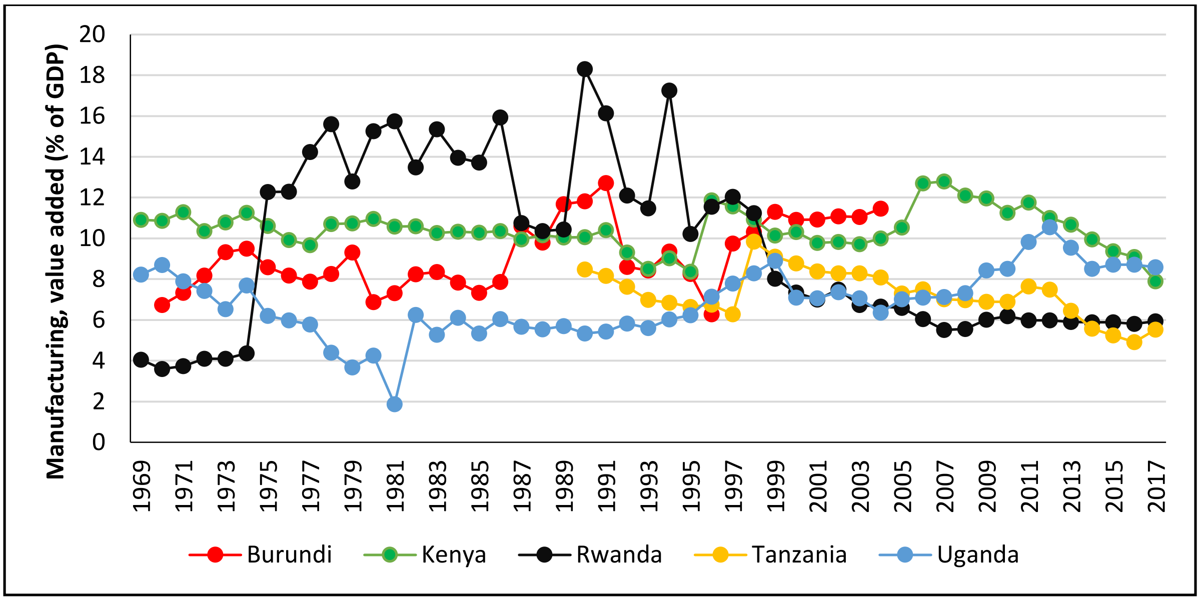
Source: *World Bank, WDI, 2018*

The manufacturing sector in Rwanda is concentrated in only seven subsectors[1] and remains largely undiversified. Statistics indicate that beverages, tobacco and food processing activities represent more than 70 % of total manufacturing output. It is notable that the strongest rise has occurred in food output where production spiked from 23.2 % in 2000 to 43.7 % in 2010 of the total manufacturing output (AfDB, 2014).

[1] Beverages and tobacco; food; furniture; non-metallic minerals; chemicals, rubber and plastics; wood, paper and printing; textiles and clothing

The evolution of a country's industrial products remained volatile from 1970 to 2017 and low relative to both regional and international comparisons. Statistics indicate that Rwanda's manufacturing sector value added accounted for about 7.3 % of GDP in 2000 and 5.9 % in 2017. Over the same time periods, that of Tanzania moved from 8.7 % to 5.5 %, Uganda's from 7.1 % to 8.9 % while that of Kenya moved from 10.3 % to 7.9 % (see Figure 2). These statistics indicate that the gap with neighbouring countries is relatively small and that East Africa's economies are mostly service driven with stagnating manufacturing sectors in terms of their share of GDP.

Figure 2: Cross-country Comparison of Manufacturing Sector's Value Added Production (% of GDP)



Source: *WDI data, 2018*

1.2.2 Challenges and Policies of Manufacturing Enterprises in Rwanda

The production sector's share of GDP in Rwanda has remained low compared to the East African region, particularly in the period between 2000 and 2017. In addition, compared to other sectors, the manufacturing sector is struggling to gain strong footage in the economy in terms of achieving the industrial growth target of 26% of GDP by 2020. Agriculture and service sectors have for decades dominated the entire economic sectors vis a vis overall production and share to GDP (Victoire, 2015).

Rwanda faces numerous obstacles on its development path, such as being landlocked, the limitation of the economic base, high production costs, decreasing output production and inadequate infrastructure (AfDB, 2014). The private sector is dominated by micro-enterprises compared to most other African countries. These microenterprises are relatively new with more than 80% of them created between 2012 and 2017. Moreover, they face challenges of incorporating the requisite technical efficiencies and capturing the most of downstream value-added by Small and Medium Enterprises (SMEs) and large enterprises engaged in the manufacturing industry (Kamarudeen & Soderbom, 2013). In addition, there is a substantial skills gap within the sector.

The GoR aspires to be an upper-middle-income country with USD 4,035 GDP per capita by 2035. To achieve its desired growth rate, the government is already working on many policies to accelerate the growth of its industrial sector by diversifying and promoting exports, value addition and quality upgrading among manufacturing enterprises (Newfarmer & Twum, 2018). To unlock her full potential, harnessing her regional and global markets will be important in overcoming the skills gap.

Notwithstanding the above challenges, Calabrese, Papadavid and Tyson (2017) have observed that Rwanda has been marked as one of SSA countries providing a good business environment. Therefore, by boosting the share of the industrial sector in GDP, the GoR has incorporated different policies including *Made in Rwanda (2017)*, which is anchored on industrialization to enhancing domestic market through value chain development. There is the *National Trade Policy (2010)*, which supports Rwandese business growing sustainable and the *National Industrial Policy (2011)*, which envisions the economy producing over USD 1.5 billion of exports by 2020. The *SME Development Policy (2010)* on the other hand supports technological innovation among SMEs, while the *National Export Strategy (2011)* mobilizes and sorts out investors to enhance export growth. In addition to these policies, the GoR has put in place the *Special Economic Zone* and four industrial parks to address the shortcomings in the business environment; and therefore helps to attract both local and foreign investors in the manufacturing sector (AfDB, 2014). However, there is limited literature on the degree of competition among enterprises in Rwanda and/or technical efficiency that contributes to the firms' competitiveness and hence their output.

1.3 Statement of the Problem

Since the inauguration of Rwanda's Vision 2020 with the aim of transforming the country into a knowledge-based middle-income country by the year 2020, the share of manufacturing value-added in GDP declined from 7.3 % in 2000 to 5.9 % in 2017 (See Table 1). If the current trend continues, the attainment of Rwanda's Vision 2020 will not be possible. This implies that the country may face challenges to produce most of the downstream value-added to its resource-based products; with only a little extent of the productivity of these subsectors[2] being produced in the manufacturing industry (AfDB, 2014). Further, failure of the manufacturing industry to grow implies a decline in the creation of new opportunities of over 200,000 jobs annually, thus leading to increased poverty levels in Rwanda (World Bank, 2017). Low manufacturing value-added in Rwanda may be explained by the failure of productivity to grow due to the inefficient allocation of resources and insufficient technological innovation among manufacturing enterprises (GoR, 2018).

Despite the government's view that technical efficiency can improve productivity in Rwanda, the measurement of technical efficiency has not received attention from researchers. Furthermore, the determinants of technical inefficiency among the Rwandese manufacturing enterprises have not been identified. Thus, policymakers are constrained by lack of knowledge of the extent of technical inefficiency and the potential determinants of technical efficiency in Rwanda. This study sought to fill the gap by analysing the levels of technical efficiency of manufacturing firms in Rwanda and the factors that drive this technical efficiency.

1.4 Research Questions

The key research question that this study sought to answer is; what determines the technical efficiency among manufacturing enterprises in Rwanda? More specifically, the study sought to provide answers to the following research questions:

i. What are the levels of technical efficiency among manufacturing firms in Rwanda?
ii. What factors influence the technical efficiency of manufacturing firms in Rwanda?

[2] Beverages and tobacco; food; furniture; non-metallic minerals; chemicals, rubber and plastics; wood, paper and printing and textiles and clothing

1.5 Objectives of the Study

The main objective of this study was to investigate the determinants of technical efficiency of manufacturing enterprises in Rwanda. More specifically, the study sought to:

i. Estimate technical efficiency among manufacturing firms in Rwanda
ii. Analyse factors that influence the technical efficiency of manufacturing firms in Rwanda
iii. Draw policy implications from the findings of the study

1.6 Significance of the Study

The study was substantial in various ways. First, the study contributes empirical knowledge to the existing literature on the level of efficiency into Rwandese firms' performance. Second, findings from the study provide implications that inform policy on areas of focus in an effort to reverse the declining trend in the value-added of the manufacturing base in Rwanda thereby contributing to the achievement of Rwanda Vision 2020, by stimulating the manufacturing sector. Specifically, given Rwanda's target of industrial output share of 26% of GDP by 2020, policy frameworks on the manufacturing sector as implied by this study are key to the achievement of this industrialization target. Third, this study serves to provide a detailed perspective on variations in technical efficiency across subsectors of the manufacturing sector. Thus, interventions can be targeted to stimulate improved efficiency gains for the identified subsectors.

1.7 Organization of the Study

The remaining chapters of this research paper are organized as follows. Chapter 2 presents a critical appraisal of the empirical and theoretical literature with an overview of the literature. While chapter 3 elucidates the research methodology adopted. In particular, this chapter 3 presents the stochastic frontier and inefficiency and empirical models, measurement of variables, data type and source used. Chapter 4 presents and discusses the results. Finally, chapter 5 presents a brief summary of the key findings, the conclusion and policy implications of the study.

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CHAPTER TWO
LITERATURE REVIEW

2.0 Introduction

The study estimates technical efficiency level of manufacturing enterprises in Rwanda. In this context, theoretical and theoretical literature aspects are revised in section 2.1 and 2.2 respectively. An overview of the literature is provided in the last section in which the research gaps are identified.

2.1 Theoretical Literature Review

Productivity and efficiency concepts are grounded in the theory of production. Production refers to the way a firm combines inputs to create an output and abstractly can be described in a production function framework represented as;

$$Q = f(x) \qquad (2.1.1)$$

Where;

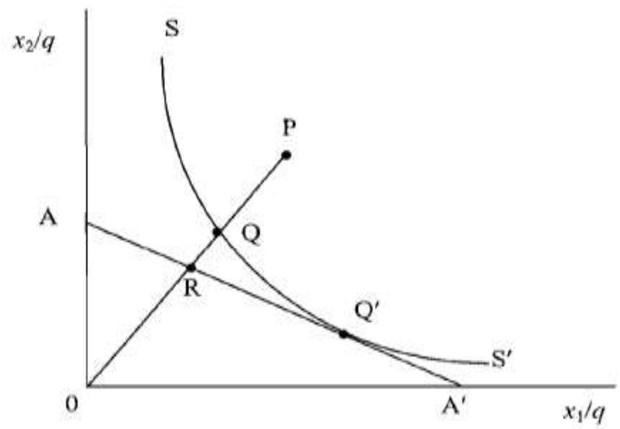
Q represents the output quantity, and x denotes a range of desirable inputs. Therefore, for each input vector (x), there is an equivalent maximum level of output (Q). The framework of production function assumes that the inputs and outputs of the firm are homogenous; in that there are no quality differences for different levels of input or output. It also assumes that the production function is consistently differentiable. But more importantly, enterprises are presumed to be fully technically efficient.

Though technical efficiency levels can vary across firms, the efficiency of a firm can be conceptualized into binary basic aspects: i.e. allocative and technical efficiency (Coelli et al., 2005). Therefore, technical efficiency is concerned with an observed output against possible output ratio from actual inputs and in this case, it is necessary for allocative efficiency to be attained. However, allocative efficiency, on the contrary, concerns the firm's capability to maximize profits.

Following scholarly works due to Farrell (1957), technical efficiency is mainly estimated in three approaches namely; scale efficiency, output-oriented and input-oriented efficiency. Scale efficiency is an approach that involves a unit of input (x), which produces a unit of output (q). However, it is problematic to conceptualise this in multiple inputs (x_i) case and multiple outputs (q_j). On the other hand, output-oriented approach supposes that a given firm employs a unit of input (x) to produce the multi-outputs (q_j). While the input-oriented approach assumes that a given firm produces only one unit of output (q), using a combination of inputs (x_i). (Where: $i, j = 1,2, \ldots, n$) . Under the assumption of constant returns to scale, Farrell (1957) also established the theory of using enterprises that use inputs vector (x_i) to yield a unit of output (q). Figure 3 helps in explaining the input-oriented approach, as a firm seeks to optimize the output level.

A number of studies have expounded and applied theoretically this approach; such as Afriat (1972), Battese (1992), Farrell and Fieldhouse (1962), Førsund, Lovell and Schmidt (1980), Meller (1976) and Seitz (1970, 1971). In addition, this approach has been used by Lundvall, Ochuru and Hjalmarsson (1999) in analysing the productive performance of sub-sectors; for example, food, wood, textile and metal of Kenyan manufacturing industry with regard to productivity and technical efficiency. Soderbom and Teal (2004) also used this approach in investigating the reasons behind inefficiency performance of manufacturing firms in Africa; specifically for Ghana.

Figure 3: Input Oriented Measure of Efficiency



Source: *Coelli, Rao, O'Donnell, and Battese (2005).*

A firm producing along isoquant SS' is presumed to be fully technically efficient. If a similar firm produces an output level by using the quantities of inputs corresponding to P, at that point, it is technically inefficient in the production process. Thus, the degree of technical inefficiency is measured along line *OP* and illustrates the extent to which a firm must proportionally decrease its input quantities without reducing its output quantities. Therefore $\mathrm{QP/OP}$ is the ratio by which a firm must reduce the input quantities to be fully technically efficient. This specifies that technical efficiency is mostly measured as:

$$TE = 1 - \frac{QP}{OP} \text{ or } = \frac{OQ}{OP} \qquad (2.1.2)$$

To determine the degree of technical efficiency, Coelli et al. (2005) provide an approach of output-oriented technical efficiency that reflects on the idea of the firm under the same assumption. This approach illustrates that the number of outputs can be proportionately extended without changing inputs levels to be used. This can be explained by holding the number of inputs constant to establish how possible it is to increase the number of outputs. Moreover, the theory of the firm also explains the input and output-oriented measurement by providing a production unit that involves dual outputs (q_1 and q_2) with a unit of input (x) (Färe & Lovell, 1978). Besides, there are other studies that have applied theoretically technical efficiency estimation by using Data Envelopment Analysis (DEA) model such as Maniati and Sambracos (2017), and Ray (2004) who explained the input and output-oriented approaches through constant returns to scale.

In terms of the production frontier, a firm can be both allocatively and technically efficient; but that firm cannot be optimal under the operation scale. Scale efficiency approach of measuring technical efficiency as earlier mentioned above is a well-defined concept of a unit of input which produces a unit of output in productive efficiency (Coelli et al., 2005).

To achieve optimality of productive efficiency among manufacturing firms, many attempts in measuring scale efficiency using DEA model have been established by some researchers; including Färe and Grosskopf (1994), Thrall and Banker (1992), and Hjalmarsson and Førsund (1979).

According to the productive efficiency theory, Kumbhakar (1987) proposed a stochastic frontier structure as an alternative approach in measuring technical efficiency through the decomposition of profit maximization into input-output oriented efficiency measures. Jovanovic’s (1982) theoretical proposition asserts that firms are more expected to be technically efficient and attributed to their competence to grow. A bulk of theoretical literature also argues that ownership structure is predicted to be more technically efficient amongst manufacturing enterprises in developing economies (Soderborn & Teal, 2004).

2.2 Empirical Literature Review

Estimation of technical efficiency has been changed over time, but two main analytical approaches in measuring productive efficiency common today are the Stochastic Frontier Analysis (SFA) and DEA. Lundvall (1999) found a general difference between the two approaches. SFA as a parametric approach in nature consists of the estimation of a specific functional form associated with the necessary components that are used in the manufacturing process with firm size i.e. observed output or inputs changes. DEA involves estimating the relative efficiency of different units where there is more than one input or output and it is not important to adopt some functional form when applying this approach as non-parametric in nature. These approaches are utilized to empirically measure technical efficiency.

The empirical literature on the levels and the factors that influence technical efficiency has revealed that these factors can be dichotomized as either relating to the firm-specific or managerial characteristics. Therefore, among the factors considered in this section are enterprise age, enterprise size, ownership structure, export status, the formal status of the enterprise, an enterprise's willingness to tap at R&D and foreign technology adoption.

A growing strand of literature in developing countries has shown that some large manufacturing enterprises tend to be more productively efficient. Battese and Lundvall (2000) estimated technical efficiency using transcendental logarithmic (translog) functions of the stochastic frontier. It was evidenced that size of the enterprises has a significant and positive effect on technical efficiency in different subsectors for Kenyan manufacturing firms. In addition, Diaz and Sánchez (2007) assessed the impact of firm size on technical efficiency in Spain using a similar approach for manufacturing firms and found that majority of the SMEs surveyed were less technically inefficient than the large firms in their operations. In contrast, Cheruiyot (2017) used a two-stage non-parametric technique to assess the technical efficiency of manufacturing enterprises in Kenya and illustrated a concave linkage between technical efficiency and firm size. Niringire, Luvanda and Shitundu (2010) also used DEA approach and Generalized Least Squares (GLS) technique to measure technical efficiency among the East African manufacturing industries (Tanzania and Uganda only) and revealed a negative linkage between enterprise size and the level of technical efficiency in these two countries.

By adopting an SFA model and Cobb-Douglas functional form, Soderbom and Teal (2004) found that ownership structure does not explain the observed dispersion in firm-level efficiency among Ghanaian manufacturing firms. In Indonesia, where a similar model was used, it was concluded that domestic owned industries were less technically efficient when compared with foreign-owned industries (Suyanto and Salim, 2011). Their presence is associated with negative spillovers but with positive spillovers to domestic suppliers. In addition, using DEA, foreign ownership had a positive effect on firm efficiency in Ghana (Faruq and Yi (2010). Besides, Goedhuys and Sleuwaegen (2003) also investigated the causes of technical inefficiency of manufacturing enterprises in Côte d'Ivoire; and observed that there is a greater presence of foreign firms that outweigh domestic firms on scales of technical efficiency. This is because domestic firms are more resource-constrained to scale up and less actively involved in technological development and production activities (Goedhuys & Sleuwaegen, 2003).

In principle, the older the firm, the more efficient it is expected to be. This is due to learning-by-doing, where older firms often have immense experience gained from past production operations (Barasa et al., 2019). Additionally, Thornton and Thompson (2001) found that producers in wartime shipbuilding can upgrade their productivity over time by learning from rivals. In contrast, Deraniyagala (2001) using cross-section survey data, illustrated that firm age affects technical efficiency negatively among textile factories and agrarian machinery industries in Sri Lankan. This was attributed to the use of obsolete and out-dated capital equipment coupled with inefficient production practises among the firms considered. Furthermore, Lundvall and Battese (2000) estimated SFA model on technical efficiency and found out that the firm's age has less influence on the technical efficiency of manufacturing enterprises in Kenya. This illustrates that age of the enterprise has a negative impact to the technical efficiency for old and small firms but positively for young and large firms in Kenya. Similar evidence is also documented by Cheruiyot (2017) for Kenyan manufacturing firms; Ajibefun and Daramola (2003) for microenterprises in Nigeria and Tingum and Ofeh (2017) for manufacturing enterprises in Cameroon; where most of the older firms established before the country gained independence in 1960 still heaving to depend on the out-dated competences and technologies.

Foreign technology use is predicted to improve technical efficiency. Considered a substitute for R&D, foreign technology adoption is seen as a way in which firms can avoid the huge costs associated with undertaking R&D. Foreign technology ensures that technological gaps between firms in a developing country and firms in a developed country are closed. By adopting foreign technology, it is expected that firms gain especially when the technology being adopted is effectively integrated into the production unit of the adopting firms and the existence of highly trained or the skilled manpower to operate it. Barasa et al. (2019) used SFA in technical efficiency estimation and found that foreign technology adoption negatively impacts technical efficiency in Kenya, Uganda and Tanzania. They argue that this is likely due to the fact that foreign technology is not only suitable for the prevailing socio-economic environment but also the countries' unwillingness to adopt foreign technology.

On export-orientation or status of firms, widespread literature suggests that enterprises that export more goods in developing countries enjoy a comparative market space than those that only concentrate on the domestic market. According to Grossman and Helpman (1991) and Krugman (1987), diversification of markets through liberalization of trade and an export-oriented policy increases firm-level efficiency. But there is narrow evidence that exporting can cause technical efficiency gains. Bigsten et al. (2000) analysed data using the stochastic production frontier on the manufacturing sector of selected countries (Cameroon, Zimbabwe, Ghana and Kenya) in SSA for the period ranging from 1992 to 1995 and investigated the effect of firm-level efficiency on exporting status among manufacturing firms. After controlling for unobserved heterogeneity using the dynamic correlated random-effects model, they show that by exporting, firms reap substantial efficiency gains not only in terms of growth but also in levels; a finding that is considered positive in terms of the learning-by-doing hypothesis. Interestingly, the study also asserts that the observed efficiency from exporting is larger for the sample considered, compared to studies from other regions and attributes this to the nature of African markets which are relatively smaller. In addition, Fafchamps et al. (2004) measured the productivity of Moroccan industrial firms using panel and cross-sectional data. It was evidenced that young firms export more than old firms in three subsectors (such as garment, textile and leather) with further findings revealing that export status having a non negative effect on technical efficiency amongst firms in Morocco. In contrast, Munisamy, Fon, and Wong (2015) using a nonparametric approach and Tobit regression model measured the technical efficiency of Malaysian industries. They found out that export status negatively affects technical efficiency. Granér and Isaksson (2009) examined the linkage between exporting and firm efficiency of manufacturing enterprises in

Kenya. They found that non-exporters are more technically inefficient than exporters after controlling for self-selection into exporting of enterprises in Kenya.

The influence of R&D activity on technical efficiency has received less attention with few empirical studies existing in the SSA region. According to Biggs (1995), inefficiency among firms in the region is attributed to the absence of organized R&D and in instances where R&D is undertaken, it is often not well organized. Bigsten et al. (2010) assert that for SSA firms to bolster their efficiency levels, they need to adopt R&D. Therefore, several studies have specified a positive and significant association between the R&D and technical efficiency among firms (Sheu and Yang, 2005; Kumbhakar et al., 2012; Diaz-Mayans and Sánchez, 2013; and Kim, 2003). In contrast, Gumbau and Maudos (2002) have also indicated an inverse linkage between technical efficiency and R&D expenditure. Therefore, it has been established that enterprises are inter-connected; chains that employ R&D are more probably to outperform those that do not leverage on technology. Torii (1992) proposes that the excessiveness of R&D can be counter-productive. Moreover, a particular strand of R&D that works best for a given firm may unnecessarily provide similar results in another entity(Torii, 1992).

In a study of manufacturing countries targeting OECD members, Salas-Velasco (2018) used both SFA and DEA and found that manufacturers that have a higher propensity to innovate are more efficient. Similar evidence is found for Kenya, Uganda and Tanzania by Barasa et al. (2019) using SFA to show that innovation has a significant impact on the level of technical efficiency.

The formal status of a firm has been established to be associated with technical efficiency. In this view, La Porta and Sheifer (2014) established that in developing countries, an informal enterprise is generally technically inefficient compared to its formal counterparts. It is evidenced that informal enterprises are more likely to be technically inefficient and unlikely to take advantage of being formally registered enterprises in the manufacturing sector. However, Abdallah (2017) provides empirical evidence showing that in the manufacturing sector in Tanzania, informal SMEs grow faster than formal registered SME. This is due to the external factors (such as regulations and low level of enforcement of tax) and internal factors (such as the creation of new employment opportunities) all of which affect productive efficiency of formally registered enterprises negatively.

2.3 Overview of Literature

Industrialization plays a critical part in economic growth and development. Though, contextual literature suggests that the industrial sector is still struggling with cases of inefficiency. Many researchers have, therefore, aimed at unravelling the underlining factors of technical efficiency among manufacturing enterprises for both developed and developing economies (Caves & Barton, 1991; Battese & Coelli, 1995; Tybout, 2000). From the literature, different methods have been applied in an effort to respond to this pertinent problem. These methods include SFA approach and DEA approach. It is also evident that firm size, ownership structure, firm age, export status, the formal status, R&D activity and foreign technology are expected to be the main factors influencing technical efficiency in the current study. However, these factors vary with respect to their importance in determining technical efficiency from one study to another and their importance varies depending on the sector under consideration. The sub-sectors that have attracted the attention of the different researchers according to the literature include food, wood, metals, textile, garment and leather. Evidence suggests that some factors of technical efficiency are statistically significant in affecting some sub-sectors. Others are less systematic and insignificant in developing countries (Battese & Lundvall, 1999). This study expands the literature on the determinants of technical efficiency mainly in Rwanda's manufacturing enterprises by using the SFA method and cross-sectional data. The results provide the basis for suitable policy implications for enhancing productivity among Rwandese manufacturing enterprises.

CHAPTER THREE
RESEARCH METHODOLOGY

3.0 Introduction

To meet study objectives, this section presents the methodological approach adopted. More specifically, the following sections explain the stochastic frontier and inefficiency model, specification of the empirical model, variables measurement and description that used for the estimation strategy and finally the data type and source.

3.1 The Stochastic Frontier and Inefficiency Model

Following Battese and Coelli (1995) and Lundvall and Battese (2000), this study adopts the parametric approach. Therefore, there are three reasons why this method is popular; first founded on a well-specified functional form; second, on SFA production function which is suitable for hypothesis testing because it yields a parameter that avoids measurement error estimates by making a distinction between inefficiency and noise (Aigner et al., 1977 & Meeusen and van Den Broeck, 1977). In addition, the SFA allows the adoption of classical estimation methods such as Likelihood Ratio (LR) and the Maximum Likelihood (ML) Estimation (Cornwell & Schmidt, 2008).

Consider the production frontier function of the i^{th} firm:

$$y_i = f(x_i, \beta) \qquad (3.1.1)$$

Where y_i is the potential output for the i^{th} firm (with $i = 1,2, \ldots, n$, that can be achieved in a technically efficient case and x_i, represents the number of inputs available to enable efficient production.

Consequently, it is assumed that any observed output can either be on or below the production function. This suggests that expression for a parametric production frontier function with a cross-sectional firm-level is given as:

$$y_i = f(x_i, \beta).TE_i \qquad (3.1.2)$$

Where $f(.)$ represents the production frontier with vector inputs (x_i). Van Den Broeck and Meeusen (1977) demonstrated that the production frontier has to be deterministic and dependent not only on the number of inputs but also on a technological factor, which is given as, β (vector of a parameter).

TE_i, which is presented as a ratio of actual output against the potential output, representing technical efficiency of a given producer i and is expressed as:

$$TE_i = \frac{y_i}{f(x_i, \beta)} \quad (3.1.3)$$

Earlier firm efficiency estimations were inherently non-deterministic frontier functions until Farrell (1957) formulated a deterministic component that is specified in the following equation:

$$y_i = f(x_i, \beta). \exp(-u_i) \qquad u_i \geq 0 \quad (3.1.4)$$

Where u_i, denotes technical inefficiency for each and every expected output, and it is subject to $\forall u_i \ (u_i \geq 0), \ni TE_i \leq 1$.

Additionally, following Battese and Coelli (1995), the theoretical contribution that the maximum potential output for a given firm i that produces using a set of inputs is given by the following model specification:

$$y_i = exp(x_i \, \beta + v_i - u_i) \quad (3.1.5)$$

In equation (3.1.5), v_i denotes a random error as the first error component which accounts for the random disturbances. It is, therefore, likely to have both zero and symmetric mean $v_i \sim N(0, \sigma_v^2)$ in the production process with random factors and independently distributed of the u_i. However, as mentioned in equation (3.1.4), u_i denotes a technical inefficiency as a second error element that is also likely to be independently distributed. Thus, a truncated normal distribution is adopted in the model specification for the inefficiency term in a one-step approach (Stevenson, 1980). This is because the two-steps approach can lead to severely biased results and $v_i \sim N^+(0, \sigma_u^2)$ (Wang & Schmidt, 2002).

Aigner et al. (1977) and Battese and Coelli (1988, 1992) proposed a set of explanatory variables $(z)_i$ and an unknown vector of coefficients (α) to describe the inefficiency level for a firm with the assumption that $u_i \sim N^+(0, \sigma_{ui}^2)$. Accordingly, the technical inefficiency effect model underestimation is analysed as:

$$u_i = \alpha z_i + w_i \quad (3.1.6)$$

Where w_i represents the variable (randomly) which is stated by the normal distribution through the truncation form with both zero and variance σ^2 mean. This implies that the truncation is specified as $-z_i\alpha$ with an assumption that; u_i is a non-negative truncation of the $N(\alpha z_i, \sigma^2)$ distribution.

The assumption above that v_i and u_i are independently distributed for the i^{th} firm, the stochastic frontier model that can capture the effect of technical efficiency is defined by as:

$$TE_i = \frac{y_i}{f(x_i, \beta)} = \exp(-u_i) = \exp(-z_i\alpha - w_i) \qquad (3.1.7)$$

Where TE_i represents a fully technically efficient firm in the production process and ranges between (0, 1).

3.2 Empirical Model Specification

Following Battese and Coelli (1995), this research project adopts a stochastic frontier model to measure and analyse factors that contribute to the technical efficiency of manufacturing enterprises in Rwanda. In this stochastic frontier model, estimates considered as explanatory variables are enterprise age, enterprise size, ownership structure, export status, the formal status of a given firm, R&D activity, foreign technology adopted from foreign workers and the enterprise location. Thus a Cobb-Douglas production function in the log-log form is specified in the following equation:

$$\ln(Y_i) = \beta_0 + \beta_1 \ln(K_i) + \beta_2 \ln(L_i) + v_i - u_i \qquad (3.2.1)$$

Therefore, the inefficiency effects model to be estimated in this study is stated as:

$$u_i = \alpha_0 + \alpha_1 \ln(A)_i + \alpha_2(S)_i + \alpha_3(O)_i + \alpha_4(E)_i + \alpha_5(F)_i + \alpha_6(R)_i + \alpha_7(T)_i + \alpha_8(Lo)_i + w_i \qquad (3.2.2)$$

Where *ln* stands for the natural logarithm function and i indicates a given firm under consideration (with $i = 1; \dots; 14{,}013$);

$\boldsymbol{Y_i}$ represents the output or annual turnover of manufacturing enterprises in Rwanda;

$\boldsymbol{K_i}$ represents physical capital inputs and used as a proxy of the total value of employed capital of both fixed and current assets, and $\boldsymbol{L_i}$ represents labour inputs;

A represents enterprise age. It is predicted to be absolutely correlated with technical efficiency of manufacturing enterprises owing to learning by doing arising from immense experience gained (Barasa et al., 2019; Lundvall & Battese, 2000).

S represents enterprise size. The 2017 Establishment Census has grouped enterprises in accordance with the number of workers in four categories: Micro, Small, Medium and Large enterprises. It is, therefore, predicted to positively influence technical efficiency of manufacturing firms (Diaz & Sánchez, 2007; Niringire et al., 2010);

O represents the ownership structure. Foreign ownership is likely to take a positive relationship with efficiency than domestic ownership among manufacturing firms in SSA (Goedhuys & Sleuwaegen, 2003; Faruq & Yi, 2010; Suyanto & Salim, 2011).

E is the export status. According to Granér and Isaksson (2009), non-exporting enterprises are more inefficient than exporting enterprises. Export status is expected to have a positive association with technical efficiency (Bigsten et al., 2000; Munisamy et al., 2015).

F represents the formal status of a firm. Formally registered enterprises are less inefficient than informal enterprise (La Porta & Sheifer, 2014). It is positively expected to be related to technical efficiency.

R represents R&D variable. It is expected to be have a positive effect on technical efficiency (Kumbhakar et al., 2012).

T represents foreign technology adoption**.** The Rwanda Enterprise Census (2017) reports this variable as an enterprise foreign workers who are perceived as an important role for bringing foreign technological catch up in the industry sector. It is positively projected to be associated with technical efficiency (Barasa et al., 2019) and ***Lo*** represents enterprise location in the manufacturing sector in Rwanda.

Additionally, the α**s** are coefficients indicating shares of each of the independent variables in the above model.

3.3 Variables Description and Measurement

The description of the variables in the study is shown in Table 2 below.

Table 2: List of variables, their description and measurement

Variable		Measurement
Production Frontier		
Output (Y)		REC reported output as annual turnover over a fiscal year in RWF (i.e. 2016). It measured as the final output of all supplies that are made within a twelve-month period on the level of trading activities.
Capital (K)		Measured as the sum of the employed capital (in net terms value of RWF) of fixed assets plus current assets minus current liabilities within a defined period (i.e. buildings, the value of land, vehicles, equipment and machinery etc...)
Labour (L)		Captured as the total employees engaged in production at the fiscal year-end. This refers to both paid and unpaid workers.
Independent variables		
Age (A)		Captured as the time difference between when the survey was conducted and when a given enterprise began its operations
Size (S)		Captured as the enterprise's size. As per the International Standard Industrial Classification (ISIC, Rev.4) and REC, this variable is classified in four categories: Micro (1∼3 workers), small (4∼30 workers), Medium (31∼100 workers) and Large (100 and plus workers) as adapted by the NISR in 2012.
Ownership (O)	Domestic ownership (DO)	Measured as a dummy variable, which takes 1 if an enterprise is domestic-owned and 0 otherwise.
	Foreign ownership (FO)	Measured as a dummy variable, which takes 1 if an enterprise is foreign-owned and 0 otherwise.
	Joint ownership (JO)	Measured as a dummy variable taking value 1 if an enterprise is joint-owned and 0 otherwise.
Exporting status (E)		Measured as the export orientation of the firm which can either be indirect or direct exports. It is a dummy taking value 1 if an enterprise is an indirect or direct exporter, and 0 otherwise.
Formal status (F)		Captures the enterprise's formally registered or not and is a dummy that takes the value 1 if an enterprise is established into the formal sector, and 0 otherwise
R&D activity (R)		Measured as a dummy variable that takes value 1 if a firm spends on formal R&D activities through Rwanda Development Board (RDB) and 0 otherwise.
Foreign technology (T)		Measured as foreign technology adoption from foreign workers in the production unit. It is also captured as a dummy taking value 1 if an enterprise reported that it has at least a foreign worker, and 0 otherwise.
Location (Lo)		Measured as a dummy variables taking value 1 if a firm is located in Kigali city, Eastern, Southern, Northern or Western provinces of Rwanda, and 0 for otherwise.

Note: *The above variables were measured as per the enterprise's responses in Rwanda Enterprise Census 2017and referenced as rwa-nisr-rec-2017-VO.1*

3.4 Data Type and Source

The study employs cross-sectional data sourced from the Rwanda Enterprise Census 2017. This Enterprise census carried out by NISR in a period of 2017/2018 for the whole country. This survey involved 14,013 enterprises in the Rwandan manufacturing sector. In addition, the country’s Enterprise census which gathers an extensive collection of quantitative and qualitative information related to the business environment in productivity of Rwandese enterprises also incorporated in this study.

CHAPTER FOUR
PRESENTATION AND DISCUSSION OF RESULTS

4.0 Introduction

This chapter presents and discusses the results of the study. Thus, the main aim was to investigate the technical efficiency among manufacturing enterprises in Rwanda. To achieve this, the study used a stochastic frontier model whereas the truncated normal distribution for the inefficiency term was employed. Section 4.1 presents descriptive statistics of variables, section 4.2 correlation analysis, and section 4.3 econometric results.

4.1 Descriptive Statistics

This analysis is important to realize the features of the data on the response variable and the predictor variables of interest. The sample comprised of 14,013 manufacturing enterprises (excluding branches and sub-branches establishments of the head office-enterprises) which covers the thirty districts of Rwanda. According to Table 3, the majority of 99.64% of the manufacturing enterprises in Rwanda are single unit establishment.

Table 3: Manufacturing Enterprise types in Rwanda

Enterprise type	Frequency	Percentage	Cumulative
Head office	50	0.36	0.36
Single unit establishment	13,963	99.64	100.00
Total	14,013	100	

Source: NISR, REC Data 2017

The characteristics of the outcome variable and predictor variables ranging from the size of the sample, the standard deviation, the mean as well as the respective maximum and minimum values are shown in Table 4.

Thus, Table 4 provides the summary figures used for production frontier and essential determinants influencing the technical efficiency of manufacturing enterprises. It is observed that the majority of manufacturing enterprises in Rwanda are domestic-owned firms with about 98.5 % (no jointly with foreigners). Therefore, only 8.1% of the enterprises registered or invested in R&D activities through the Rwanda Development Board in collaboration with the National Industrial and Research Development Agency (NIRDA). Only 2.2% of manufacturing enterprises adopted foreign technology through enterprises foreign workers.

Similarly, only 0.9% of manufacturing enterprises in Rwanda had a transaction of selling produced goods with a foreign country or abroad and half of them are small size enterprises.

Referring to the Rwanda SMEs development policy (2010) and ISIC (Rev.4), manufacturing enterprises in Rwanda have been classified as micro, SME and large enterprises; and the enterprise's size has been grouped according to the number of workers. Therefore, about 87.2% of the manufacturing enterprises in Rwanda are micro-sized enterprises meaning that they have between one and three workers. By contrary, only 11.6%, 0.8% and 0.4% are small, medium and large size enterprises respectively. All enterprises in Rwanda are supposed to register with concerned administrative entities such as Sector, District, Social Security Board, Rwanda Development Board, Rwanda Governance Board, Rwanda Cooperative Agency, Private Sector Federation and Rwanda Revenue Authority. However, only 7.3 % of manufacturing enterprises were formally registered firms in Rwanda by 2017. On the other hand, informal manufacturing enterprises are predominant in Rwanda. About, 92.7 % of business-oriented enterprises were in the informal sector.

About the location of manufacturing enterprises in Rwanda, Eastern province has the highest proportion of manufacturing enterprises with 22 %; followed by the Southern province (21.8%), Western province (20%), and Kigali city with 19.7%. While the last being the Northern province with only 16.2% of all manufacturing industries.

Table 4: Summary Statistics for Enterprises in the Manufacturing Sector in Rwanda

Variable	Observation	Mean	Std. Dev.	Min	Max
Enterprise_Output	14,013	3,079,662	6,730,252	0.000	5.00e+07
Enterprise_Capital	14,013	3,981,143	9,815,337	0.000	7.50e+07
No. of production workers	14,013	4.357	51.618	1.000	3511.000
Enterprise_Age	14,013	3.717	6.116	0.000	110.000
Enterprise_Size	14,013	1.146	0.407	1.000	(100+)
Small_Size (4~30)	14,013	0.116	0.321	0.000	1.000
Medium_Size (31~100)	14,013	0.008	0.091	0.000	1.000
Large_Size (100+)	14,013	0.004	0.063	0.000	1.000
D_Domestic_ownership	14,013	0.982	0.132	0.000	1.000
D_Foreign_ownership	14,013	0.016	0.124	0.000	1.000
D_Joint_ownership	14,013	0.002	0.048	0.000	1.000
D_Export Status	14,013	0.009	0.096	0.000	1.000
D_Formal Status	14,013	0.073	0.261	0.000	1.000
D_R&D activity	14,013	0.081	0.274	0.000	1.000
D_Foreign Technology	14,013	0.022	0.148	0.000	1.000
*Location dummies					
D_Kigali city	14,013	0.197	0.398	0.000	1.000
D_South province	14,013	0.218	0.413	0.000	1.000
D_West province	14,013	0.200	0.400	0.000	1.000
D_North province	14,013	0.162	0.369	0.000	1.000
D_East province	14,013	0.220	0.414	0.000	1.000
*Summary statistics of stochastic production frontier estimates in logarithmic form					
ln(Output)	9,728	13.854	1.962	11.918	17.727
ln(Capital)	13,990	13.592	1.708	12.429	18.133
ln(Labour)	14,013	0.456	0.825	0.000	8.163

Source: Author's computation from REC Data, 2017

Furthermore, as illustrated in Table 5, about 87.05 % of manufacturing enterprises are micro size industries and about 12.95 % of these enterprises have four and more workers. By comparing the formal and informal sector, 90.88 % of informal enterprises and 38.86 % of formal enterprises are micro-enterprises. On the other hand, 8.83 % of informal and 47.77 % of the formal sector are small enterprises and overall 13.37 % of the formal sector has more than 30 workers, while only 0.3 % of the informal sector has more than 30 workers in the sector.

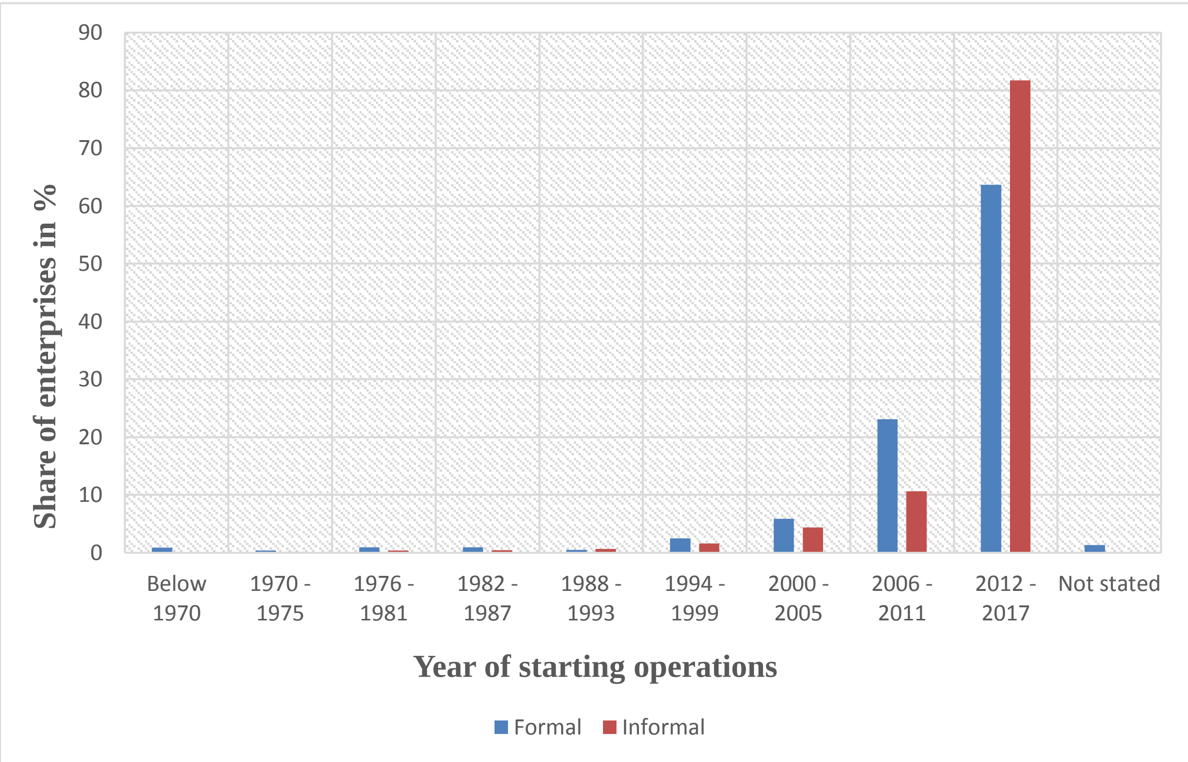
Table 5: Distribution of Manufacturing Enterprises into the Formal and Informal sector by Size in Rwanda

Enterprise_Size	Count			Percentage		
	Total	Formal	Informal	Total	Formal	Informal
Micro (1-3)	12,199	401	11,798	87.05	38.86	90.88
Small (4-30)	1,639	493	1,146	11.70	47.77	8.83
Medium (31-100)	118	83	35	0.84	8.04	0.27
Large (100+)	57	55	2	0.41	5.33	0.02
Total	14,013	1,032	12,981	100	100	100

Source: Author's computation from REC Data, 2017

Figure 4 illustrates the comparative time trend of the year of starting operations for both formal and informal manufacturing enterprises. It reveals that over than 80% of enumerated manufacturing enterprises have started operations in Rwanda between 2012 and 2017. By comparing the formal and informal manufacturing enterprises, 64.53 % of formal enterprises have started operating in Rwanda, while 81.72 % of the informal enterprises also started during the same period.

Figure 4: Distribution of Formal and Informal Manufacturing Enterprises according to year of starting operations in Rwanda



Source: Author, using REC Data, 2017

4.2 Correlation Analysis

Table 6 presents the pairwise correlation matrix. The pairwise correlation coefficients indicate that correlation between most of the variables are low and, therefore, multicollinearity was not an inherent problem in the estimated model.

Table 6: Pairwise Correlation Matrix

	Output	Capital	Labour	Age	Size	Domestic_ ownership	Foreign_ 0wnership	Joint_ ownership	Export_ Status	Formal_ Status	R&D_ activity	Foreign_ Tech
Output	1											
Capital	0.7835	1										
Labour	0.2489	0.2666	1									
Age	0.2291	0.1295	0.1072	1								
Size	0.4824	0.5145	0.3132	0.1222	1							
Domestic_ ownership	-0.2075	-0.2482	-0.1607	-0.0386	-0.1827	1						
Foreign_ ownership	0.1410	0.1792	0.0941	0.0176	0.1276	-0.9308	1					
Joint_ ownership	0.2077	0.2215	0.1995	0.0607	0.1741	-0.3598	-0.0061	1				
Export_Status	0.3821	0.4202	0.264	0.0862	0.3314	-0.2319	0.1489	0.2544	1			
Formal_Status	0.4699	0.4987	0.1626	0.1066	0.4516	-0.1535	0.1059	0.1498	0.2893	1		
R&D_activity	0.3645	0.3926	0.1365	0.0787	0.3503	-0.1402	0.0970	0.1358	0.2376	0.4019	1	
Foreign_Tech	0.2647	0.2795	0.1277	0.0362	0.2212	-0.7538	0.7255	0.2104	0.2385	0.1555	0.1418	1

Source: Author's computation from REC Data, 2017

4.3 Empirical Results

The regression results for the SFA model estimated are reported. This study adopts a stochastic frontier model to estimate the technical efficiency and analyse factors influencing technical efficiency of the Rwandan manufacturing enterprises as proposed by Battese and Coelli (1995) (see equations 3.2.1 & 3.2.2).

4.3.1 Estimation of Technical efficiency among manufacturing enterprises in Rwanda

Since the first objective of the study was to estimate technical efficiency among manufacturing enterprises in Rwanda; following Jondrow et al. (1982) and Battese and Coelli (1988) estimates of the technical efficiency via $E[\exp(-u_i) e]$, the distribution of T.E is shown in Figure 5 below. The statistics indicate that the estimated mean technical efficiency among 9,719 manufacturing enterprises is 0.52257 which is about 52.25% and the estimated standard deviation is 0.14843 (see Table 7). The results are consistent for the estimated stochastic frontier model in Table 8. This implies that on average, a typical enterprise in the manufacturing sector in Rwanda operates at 47.75% below its maximum potential output level[3].

Furthermore, according to the GoR (2014), it has been observed that the mean of industrial capacity utilization at the national level is estimated at 50% of the total productive capacity. This is due to the challenges that face some subsectors (textiles and clothing; wood, paper and printing; non-metallic minerals; furniture and export crops processing) mainly such as limited and stagnant of market demand, scarcity of raw materials and the lack of appropriate technology that result into technically inefficient. Food processing; beverages and tobacco are dominating the manufacturing sector by operating at a higher output level (70%) of the total manufacturing output than other subsectors (GoR, 2014).

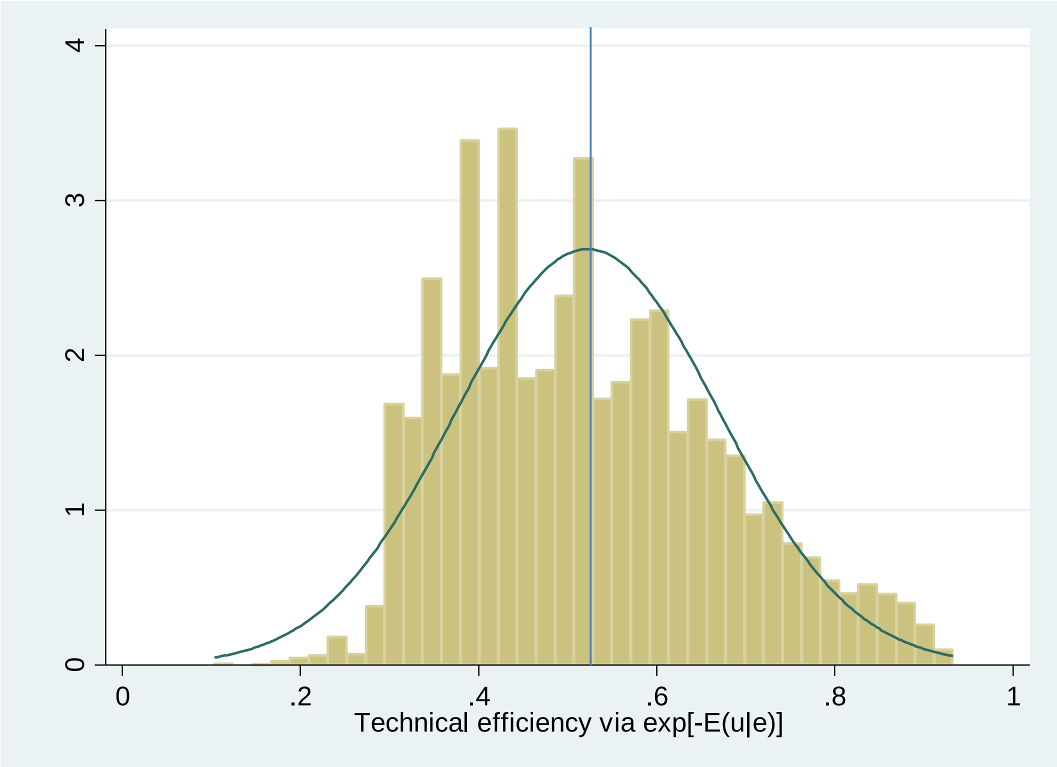
Table 7: Technical efficiency estimates of manufacturing enterprises in Rwanda

Variable	Obs	Mean	Std. Dev.	Min.	Max.	Var.	Skew.	Kurt.
Technical efficiency score	9,719	0.5225	0.1484	0.1032	0.9330	0.0220	0.4596	2.5537

Source: Author’s computation from REC Data, 2017

[3] **Note**: Efficiency scores close to 1 indicate more technically efficient firms. In contrast, scores close to 0 indicate less technically efficient firms.

Figure 5: Distribution of Technical efficiency levels among Manufacturing Enterprises in Rwanda



Source: Author, using REC Data, 2017

4.3.2 Factors influencing the Technical efficiency of manufacturing enterprises in Rwanda

Given the second objective of this study, the estimated parameters of stochastic frontier and the inefficiency effects models respectively arising from Equations (3.2.1) and (3.2.2) are presented and discussed in this section.

Table 8 below displays the results of the SFA estimates and the determinants of inefficiency among 9,719 manufacturing enterprises in Rwanda.

Table 8: Maximum-Likelihood regression estimates of the SFA

SFA Results	SF Model				
Variables	**Coeff.**	**Std. Error**	**z**	**P-value**	**Sign.**
Frontier					
ln(Capital)	0.589945	0.010189	57.90	0.000	***
ln(Labour)	0.272840	0.051109	5.34	0.000	***
Constant	6.317850	0.223831	28.23	0.000	***
Determinants of inefficiency [Mu]					
Age(log)	-0.177710	0.027396	-6.49	0.000	***
Small_Size	-0.143793	0.156950	-0.92	0.360	
Medium_Size	0.655585	0.288283	2.27	0.023	**
Large_Size	1.310119	0.386425	3.39	0.001	***
Domestic_ownership	-0.496265	0.959484	-0.52	0.605	
Foreign _ownership	0.901853	0.973320	0.93	0.354	
Joint_ownership	0.250000	(Omitted)	-	-	
Export Status	-0.045200	0.337131	-0.13	0.893	
Formal Status	-0.618500	0.245073	-2.52	0.012	**
R&D activity	-0.289778	0.099556	-2.91	0.004	***
Foreign Technology	0.053086	0.202069	0.26	0.793	
Enterprise location^					
Kigali city	-0.533821	0.082449	-6.47	0.000	***
Southern province	0.038511	0.049966	0.77	0.441	
Western province	-0.354742	0.060438	-5.87	0.000	***
Northern province	-0.219934	0.061212	-3.59	0.000	***
Eastern province	0.250000	(Omitted)	-	-	
Constant	0.622991	0.976697	0.64	0.524	
Usigma	-2.235757	0.613269	-3.65	0.000	***
Vsigma	0.770961	0.027690	27.84	0.000	***
Sigma_ui	0.326973	0.100261	3.26	0.001	***
Sigma_vi	1.470321	0.020357	72.23	0.000	***
Number of Observations	9719		Robust standard errors:		
Log likelihood	-1.77E+04		*** p<0.01, ** p<0.05, * p<0.1		
Wald chi2(2)	3685.76				
Prob > chi2	0.0000				

Source: Author's computation from REC Data, 2017

The results show that the overall model estimated is fit. This is evidenced by a strong statistically significant p-value of 0.0000. In addition, the production frontier coefficients of all inputs are positively and statistically significant at the 1% level. However, as noted earlier that most of the surveyed industries face the challenge of the limited working capital to invest in full production capacity in order to supply both national and international markets in Rwanda (GoR, 2014).

Given the interpretation of the coefficients on the determinants of inefficiency effect model by Belotti et al. (2012), a negative sign indicates a reduction in the enterprise inefficiency. This implies that a negative sign on the coefficient is reported to have a positive impact on technical efficiency. On other hand, a positive sign indicates an increase in the enterprise inefficiency, which implies that a positive sign on the coefficient reflects a negative impact on technical efficiency. It is, therefore, observed from SFA results that the standard deviations of the technical inefficiency component (sigma_u_i) are positively and statistically significant at 1% level in the estimated model.

About the independent variables, the SFA results show that the coefficient for the firm age is negative and statistically significant at 1% level. Indicating that the enterprise's age is positively and statistically significant on technical efficiency in the Rwandan manufacturing sector; due to the gained experience. The older the firm becomes, the less inefficient that firm becomes in Rwanda. This confirms the empirical findings that the older the firm, the more efficient it is expected to be in developing countries (Thornton & Thompson, 2001; Barasa et al., 2019). However, the results are in contrast with those of Tingum and Ofeh (2017); Ajibefun and Daramola (2003); Deraniyagala (2001) and Lundvall and Battese (2000) on technical inefficiency among manufacturing firms, in Kenya, Sri Lankan, Nigeria and Cameroon respectively. The authors found that the firm age has a less systematic influence or negative effect on technical efficiency.

With regard to the enterprise's size, which is estimated based on the number of employees per establishment; the coefficient of the small size is negative and statistically insignificant while those for medium and large sizes are positive and statistically significant for estimated model. These results are in line with a study by Diaz and Sánchez (2007) who found that the majority of small firms in Spain are less technically inefficient than large firms. The results are however in contrast with Battese and Lundvall (2000). It is, therefore, noted that the old equipment, power shortage and insufficient working capital are major constraints face medium enterprises in Rwanda, while some large enterprises are significantly constrained by lack of sufficient raw materials, power shortage and poor road facilities since they are still marked with relative inefficiencies (GoR, 2014).

The coefficient for domestic ownership is negative and statistically insignificant in contrast with foreign ownership and joint ownership. This indicates that domestic ownership is positively associated with technical efficiency. Therefore, to be a domestic-owned enterprise is associated with a reduction in technical inefficiency than to be either a foreign-owned or jointly-owned enterprise in the manufacturing sector in Rwanda. The results are in line with a study by Soderbom and Teal (2004) who found that technical inefficiency was lower with domestic-owned enterprises than foreign-owned enterprises in Ghana. The results are, however, in contrast with a study by Goedhuys and Sleuwaegen (2003) and Suyanto and Salim (2011) in Côte d'Ivoire and Indonesia respectively.

The coefficient of the enterprise's export status is negative and statistically insignificant for the estimated model. This denotes that the enterprise's export (either direct or indirect) has a statistically insignificant association with technical efficiency. This could be due to the capacity underutilization of the national export. It is only estimated at 57.27% of the total productive capacity especially the export of crop processing (i.e. Pyrethrum, Coffee and Tea), mining and quarrying sectors (GoR, 2014). Therefore, the results are in line with a study by Fafchamps et al., (2004) who found that young firms export more than old firms in Morocco. Granér and Isaksson (2009) also found that non-exporters are more technically inefficient than exporters among manufacturing industries in Kenya. Accordingly, exporting effects positively technical efficiency in African manufacturing sector (Bigsten et al., 2000).

The coefficient of formal status is negative and statistically significant for the estimated model. The results shows that formally registered enterprises are less inefficient than unregistered enterprises. Thus, to be a formally registered enterprise has a positive and significant effect on technical efficiency in Rwanda. La Porta and Sheifer (2014) establish that in developing countries, informal enterprises are generally more technically inefficient than formal enterprises.

The coefficient of R&D activity is negative and statistically significant. We predicted a negative association between R&D activities and technical inefficiency when an enterprise spends worth on formal R&D activities with the use of innovation, technological development and applied research. Therefore, the study shows that R&D activity has a positive and statistically significant effect on technical efficiency. These findings are consistent with those of Sheu and Yang (2005) of technical inefficiency in Taiwan's Manufacturing Industries. The results are, however, in contrast with a study by Barasa et al., (2019). According to Biggs (1995), inefficiency among firms in the developing countries is credited to their absence of organized R&D and in instances where R&D activity is undertaken; it is often not well organized.

Foreign technology’s coefficient is positive and statistically insignificant. The study, therefore, shows that foreign technology brought about by foreign workers has a negative and insignificant effect on technical efficiency in Rwanda. The findings are in line with those of Barasa et al. (2019) who found that foreign technology increases technical inefficiency among manufacturing firms in SSA, particularly in Kenya, Uganda and Tanzania.

The coefficients of enterprise location dummies such as Kigali city, Western province and Northern Province are negatively and statistically significant at 1% level while the coefficient of Southern province is positively and insignificant associated with technical inefficiency among manufacturing enterprises in Rwanda. The results show that firms located in Kigali city, Western and Northern provinces are more technically efficient compared with those located in the Southern and Eastern provinces of Rwanda.

CHAPTER FIVE
SUMMARY, CONCLUSION AND POLICY IMPLICATIONS

5.0 Introduction

This chapter provides a summary of the findings, conclusions, policy implications and the areas to which this study can extend. Section 5.1 provides a summary of the study, sections 5.2 and 5.3 respectively provide the conclusion and policy implications, while 5.4 provides areas of future research to which this study can be extended.

5.1 Summary

Rwanda has the aim of transforming into a knowledge-based middle-income country by 2020. However, the share of manufacturing value-added to GDP growth in Rwanda has declined since 2000. This study investigated the technical efficiency levels and factors of technical efficiency of Rwandese manufacturing enterprises using cross-section firm-level data. The study estimated a Cobb-Douglas production function using an SFA technique.

The study displays that the estimated mean of technical efficiency is 52.25 %. Regarding the production frontier, the results indicate that the coefficients of all inputs are positive and statistically significant at the 1% level. About the factors that influence the technical efficiency of manufacturing enterprises in Rwanda, the results also show that the coefficients of the enterprise's age, formal status and R&D activity are positively and statistically significant. This implies that, these factors are important determinants of technical efficiency in Rwanda. The coefficients of domestic ownership and the enterprise's export status are positive but statistically insignificant. This implies that domestic ownership and enterprise's export status are not important determinants of technical efficiency in Rwanda. On the other hand, the coefficient of foreign technology adoption is negatively and statistically insignificant with technical efficiency. Furthermore, about the enterprise's size, the coefficient of small enterprises is positive and statistically insignificant while medium and large enterprises are a negative but statistically significant association with technical efficiency among manufacturing enterprises in Rwanda.

The study also shows that location in Kigali city, Western province and Northern Province positively influence technical efficiency in Rwanda. The importance of the area of location enterprise in influencing technical efficiency is supported by significant coefficients at 1% level of significance.

5.2 Conclusion

Low levels of technical efficiency is a major concern for the GoR and other stakeholders both local and international; because the incorporated policies are yet to be fulfilled. With average technical efficiency of 52.25%, a typical manufacturing enterprise in Rwanda operates at 47.75 % below its maximum potential output level.

Manufacturing in many developing economies has been widely perceived as one of the economic drivers of transformation from low to high productive activities. In Rwanda, the sector is, however, still facing major obstacles in all sizes (micro, small, medium and large) and subsectors of manufacturing enterprises such as lack of sufficient of raw materials; limited and stagnant of market demand; lack of sufficient, reliable and affordable electricity; inappropriate technology; insufficient working capital and old equipment. The capacity underutilization or inefficiency allocation of resources, therefore, has been ranked as the most significant obstacle to the industrial technical efficiency among manufacturing enterprises in Rwanda.

In this study, therefore, it has been observed that the older the firm becomes, the less inefficient that firm becomes in Rwanda. The results show that formally registered enterprises are less inefficient than unregistered enterprises. Thus, to be a formally registered enterprise has a positive effect on technical efficiency in the manufacturing sector in Rwanda. Due to the use of innovation, technological development and applied research, the study shows that the enterprises that spend worth on formal R&D activities are more technically efficient than those that do not spend on formal R&D activities in the Rwandese manufacturing sector. However, foreign technology brought about by foreign workers is negatively associated with technical efficiency. In addition, to be a domestic-owned enterprise is associated with reduction in technical inefficiency than to be either a foreign-owned or jointly-owned enterprise; and to be either a direct or indirect exporter enterprise is more technically inefficient than to be a non-exporter enterprise in the manufacturing sector in Rwanda.

Micro and small sizes enterprises have a positive effect on technical efficiency than those medium and large sizes in the Rwandan manufacturing sector. Therefore, the firms located in Kigali city, Western province and Northern Province are also more technically efficient compared with those located in the Southern and Eastern provinces of Rwanda.

5.3 Policy Implications

The study established the positive and significant coefficients of enterprise's age, formal status, R&D activity and enterprise location (only Kigali city, Western and Northern provinces). These variables are key in determining technical efficiency among the manufacturing enterprises in Rwanda. Therefore, the GoR should provide a conducive environment for enterprises to progress from infancy to maturity. This is because mature enterprises as represented in the research are associated with increased technical efficiency. Secondly, there is a need for enterprises to progress from informal to formal in the manufacturing sector. This is because as the research findings suggest, there is a positive attribute associated with formality thus leading to technical efficiency. The GoR and other stakeholders should sensitize enterprises in the manufacturing sector on the need to become formal. Thirdly, enterprises should consider adopting R&D activities. This is associated with improved technical efficiency since it results in innovation and improvement through technical skills. Since investment in R&D may be expensive, there is need for the enterprises to have a joint investment in R&D activities. Lastly, enterprises located in Kigali city, Western and Northern provinces are seen to be technically efficient than those located in Southern and Eastern provinces. Technical efficiency in Kigali city, Western and Northern regions could be attributed by good infrastructure. This, therefore, implies that GoR should invest in infrastructure across the country so as to increase technical efficiency among manufacturing enterprises in Rwanda.

The study established the negative and significant coefficients of medium and large manufacturing enterprises. This may be a pointer that the size of the enterprises in the manufacturing sector in Rwanda increases challenges in organization management hence cropping in. There is a need, therefore, for the GoR and other stakeholders to invest in training managers of enterprises in the manufacturing sector through organization behaviour and practices. This will equip them with skills to overcome challenges associated with large enterprises.

5.4 Areas for future research

This study estimated the technical efficiency levels and analysed the main determinants that influence technical efficiency among the manufacturing enterprises in Rwanda. The study can be extended by using different data like panel data to investigate the determinants of technical efficiency in the manufacturing sector. The same investigation can be extended to other sectors of Rwandan economy; for instance service sector, agricultural sector and mining sectors which have received considerably less attention from researchers.

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