Measuring technical efficiency in Zimbabwe's manufacturing sector: a two-stage DEA Tobit approach

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ABSTRACT

This paper measures and explains efficiency of firms in Zimbabwe's manufacturing sector. The paper uses a panel of 166 firms from 6 subsectors of the manufacturing sector in the financial year 2014. The Data envelopment analysis program is used to measure efficiency and identify its determinants. Exporting, labour quality, size and firm age were found to enhance productivity. Efficiency was found to significantly vary with location with firms in Bulawayo being more efficient. This paper found no evidence of a relationship between foreign ownership and manufacturing productivity in Zimbabwe. By identifying factors that affect efficiency as well as measuring their impact on manufacturing efficiency this paper answers the bigger policy question: how to reindustrialise Zimbabwe following two decades of economic recession. Zimbabwe's manufacturing sector exhibits strong backward and forward linkages with other sectors of the economy. These interlinkages make manufacturing sector productivity growth relevant to the resuscitation and growth of the economy.

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1. INTRODUCTION AND BACKGROUND

1.1. Introduction

Zimbabwe has since 2000 undergone economic and political transitions that have led to a general economic decline and deindustrialisation. Characteristics of Zimbabwe's deindustrialisation include a recurrent negative trade account and decreased contribution of the manufacturing sector to GDP and employment. The Zimbabwean economy, which is agro-based, has especially been worsened by manufacturing sector decline owing to the strong interlinkages between the manufacturing sector and the agricultural sector as well as other important sectors such as mining. The interlinkages are evidence of the critical role the manufacturing sector has in the resuscitation of the Zimbabwean economy. To be successful in this role, the sector must become more efficient.

This study explores factors that are important for improving manufacturing sector efficiency. It begins with an overview of the Zimbabwean economic and political landscape in the aftermath of 2000 and its contribution to the collapse of the manufacturing sector. The background also gives a snapshot of the polices that have been adopted by the government since the financial collapse to revive the manufacturing sector. In the literature review section, factors that have been found to be important in determining efficiency are discussed. These factors include firm age, location, access to financing, exporting and labour quality. The methods section outlines how efficiency in Zimbabwe's manufacturing sector is measured in this paper. The section also outlines how determinants of efficiency are established and their impact measured. The policy recommendation section concludes the paper and discusses the economic relevance of the findings and how they can be used to effect efficiency increase in Zimbabwe's manufacturing sector.

1.2. Importance of the manufacturing sector to Zimbabwe's growth

An improvement in manufacturing sector capacity utilisation and growth is critical to the resuscitation of Zimbabwe's economy. Zimbabwe's manufacturing sector exhibits strong backward and forward linkages with other sectors of the economy. The sector has the potential to contribute substantially to GDP, export and employment growth. For example, the manufacturing sector absorbs 63% of Zimbabwe's agricultural output and supplies 50% of agricultural inputs as well as components to critical industries such as mining (CZI, 2010).

Empirical evidence suggests that a positive correlation exists between the level of manufacturing sector development and economic development (Szirmai, 2012). The positive relationship is a result of the relatively higher levels of productivity in the manufacturing sector than other traditional sectors such as agriculture and forestry. The view that the manufacturing sector is a driver of economic development is supported by the interlinkages exhibited by the manufacturing sector with other sectors. Usually rapid growth in the manufacturing sector translates to economy wide growth through positive spill-over effects to other sectors (Szirmai, 2012) and better opportunities for high investment return, productivity growth and scale efficiency (Cornwall and Cornwall, 1994). Zimbabwe could be different, but the obvious place to start such enquiry is with an analysis of the manufacturing sector's technical efficiency performance. Due to data constraints, this is a single country study at a single point in time, which means that it is not possible to comment on absolute or relative growth, but critical indicators of productivity can be identified within the group of manufacturing firms for which data are available.

1.3. Collapse of the manufacturing sector in Zimbabwe

Zimbabwe inherited at independence one of the most robust and structurally developed economies in Africa (Brett, 2005). Soon after independence, Zimbabwe's growth trajectory changed as macro-economic fundamentals such as inflation, employment, and investment environment began to deteriorate. Zimbabwe's economic turmoil resulted from several years of uncontrolled government spending and budget deficits (Koech, 2012). Koech (2012) also blames the land reallocation programme of 2000 which led to reduction in commercial farming output by 50% for deepening the emerging crisis in the Zimbabwean agro-based economy. The agro-processing industry in Zimbabwe accounts for 60% of total manufacturing output and 30% of manufacturing employment. The manufacturing sector absorbs 63% of Zimbabwe's agricultural output and supplies 50% of agricultural inputs(CZI, 2010). Therefore, the collapse of the agricultural sector contributed to Zimbabwe's deindustrialisation. Deindustrialisation accelerated the collapse of the Zimbabwean economy due to interlinkages of the manufacturing sector with the rest of the economy. At its peak in the 1990's, Zimbabwe's manufacturing sector contributed 24 % to GDP, 37% to export income while directly employing 15% of the total workforce (CZI, 2009). Today the manufacturing sector accounts for only about 10% of GDP and 7% of total employment due to closure and relocation of firms and low industrial capacity utilisation (World Bank, 2016).

1.4. Factors that contributed to industrial sector collapse in Zimbabwe, 2000 - 2015

In the crisis period of 2000 to 2015, the political landscape in Zimbabwe was highly volatile and perceived as risky by investors. Existing investors exited, while potential investors looked for less risky alternative investment destinations. The land appropriation policy compromised property rights and security of investments in Zimbabwe. The Indigenisation Act of 2009 strengthened the notion that the risk of expropriation was high. As a result, foreign direct investment (FDI) reduced denying firms the much-needed finance to retool, upscale and update production methods and technologies.

The economic recession that hit Zimbabwe was coupled with a hyper inflationary period which reduced domestic savings and available funds. The lack of confidence in the banking system also worsened liquidity challenges. As a result, the cost of capital is very high in Zimbabwe which limits industrial progress. The policy environment and the recession itself also repelled FDI. Due to low investment firms were not able to recapitalise and upgrade to new technologies. More than 60% of large firms are operating equipment that is more than 20 years old, which raises the cost of production relative to regional and global competitors (CZI, 2017) . The shortage of foreign currency adds to viability challenges faced by the manufacturing sector in Zimbabwe. Half of manufacturing firms in Zimbabwe identify forex challenges as a major constraint to the supply of raw materials (CZI, 2017).

Zimbabwes economic crisis was characterised by hyper inflation which eroded domestic savings and funds available within the banking system. This resulted in chronic cash shortages that threatened the viability of businesses . In 2009 the Zimbabwean governemnt adopted a multi currency regime in order to contain the runway inflation . The US dollar was adopted as the the main currency. The strong USD however made Zimbabwe’s exports to be uncompetitive. the introduction of the US dollar also encouraged capital flight and externalisation of funds. This worsened the cash crisis in the country. The poor performance of exports due to the strong US dollar coupled with capital flight and externalisation of funds led to an adverse balance of payment position (RBZ, 2016). In 2015 the USD started disappearing from the formal banking system leading to a shortage of hard currency. The shortage was prompted by the public and businesses hoarding the US dollar which was now being considered a a store of value or asset as opposed to a medium of exchage. The high appetite by the public to keep cash outside the banking system worsened the cash crisis. The ease at which the US dollar could be extenalised also excebated the cash crisis. .In order to put an end to the cash crisis , the governemnt of zimbabwe intoduced a surrogate currency backed by a $200m bond facility from the Africa Export-Import Bank. Again , black market speculation quickly eroded the bond note value, leading a shortage that the central bank tried to offset by creating electronic notes (Aljazeera, 2019)

Due to the economic crisis, the government has failed to invest in the expansion and maintenance of public infrastructure and utilities such as roads, electricity and water. This contributes to low productivity in the economy as electricity is an important input in Zimbabwe's industrial sector. Zimbabwe relies on imports to make up for electricity deficits. However, due to financial constraints that prevents it from settling bills, Zimbabwe's power company often resorts to power cuts which affects productivity (AfDB, 2009). Bulk transport services are also important to industrial economies due to their ability to transport bulk materials at relatively cheap costs. The national railways of Zimbabwe (NRZ), the major bulk transport services provider in the country, suffered in the economic crisis as well (AfDB, 2009). Zimbabwe's railway is dilapidated, obsolete and inadequate. As a resulted the industrial sector is turning to bulk road transport which is expensive and has less capacity in comparison to a functional rail system.

The high cost of production in Zimbabwe has led to an uncontrollable influx of cheap imports into the country. Weak border controls exacerbate the problem. The existing tariff framework also promotes deindustrialisation and dumping of goods in Zimbabwe (ICAZ, 2012). For example, imported goods such as medical drugs are duty and VAT free, yet imported raw materials for the manufacture of the same goods locally attract up to 40% import duty and 15% VAT. As a result, domestic firms are faced with low demand and low profitability due to competition from imports. The viability challenges resulting from low demand are exacerbated by low levels of disposable income, high rates of emigration and unemployment. The negative effects of land expropriation on agriculture further undermined the manufacturing sector's performance.

1.5. Manufacturing sector recovery policies since 2009

In 2009, Zimbabwe adopted the United States dollar as its functional currency to put a halt to the runaway inflation which was an important feature of the economic crisis. In acknowledgement of the important role of the manufacturing sector in economic recovery, the government has launched several policies aimed at resuscitating the sector to enhance its output, productivity and competitiveness. These policies include the short-term emergency recovery programme of 2009 (STERP 1) which sought to increase manufacturing capacity utilisation from 10% to over 60% by September 2009. STERP 1 was followed by STERP 2 of 2010, which was adopted to reinforce STERP 1, still with the aim of increasing capacity utilisation to over 60%. In 2011 a Medium-Term Plan outlining the country's collective economic policies to 2015 was adopted. The policy sought to achieve manufacturing driven economic growth through an increase in the sector's capacity utilisation to 80% by 2015. In October 2011 a US 40 million revolving fund called the Distressed Industries and Marginalised Areas Fund (DIMAF) was established with the objective of resuscitating struggling or bankrupt firms especially those located in Bulawayo. In November of 2011, the Government committed to increasing manufacturing's share of GDP from 15% to 30% by 2016 in the 2012-2016 Industrial Development Policy. Part of the plan was to increase manufacturing exports to 50% of export value by 2016. Again, capacity utilization was prioritised, and this time the target was 80% by 2016. Two years later (2013) the government released an economic blueprint called the Zimbabwe Agenda for Sustainable Socio-Economic Transformation to promote growth in the manufacturing sector. The growth targets were as follows; 1.5% in 2013, 3.2% in 2014, 6.5 % in 2015, 7.5% in 2016, 8.4% in 2017 and 9.5% in 2018. Plans to achieve these p targets included provision of lines of credit, upskilling of the workforce, import substitution, reduction in imported raw materials tariffs, improved electricity and water supply and promotion of beneficiation of products to harness maximum export value.

1.6. Research problem and significance of the study

Despite the government's many, ambitious policies to revive the manufacturing sector, capacity utilisation has remained very low as shown in Figure 1. This data was obtained from the Confederation of Zimbabwean industries (CZI) (www.czi.co.zw) who define capacity utilisation as the ratio of actual output to installed equipment capacity. Capacity utilisation has averaged 37% between the years 2005 and 2017 and has largely remained below 50% during the last decade. Regressing capacity utilisation on the year to calculate growth rate produced an annual increase in capacity utilisation of 1.5%, a figure which is significant at $p \leq 0.10$. However, it is largely the result of the global financial crisis of 2008 when Zimbabwe' manufacturing sector plummeted to less than a third of its typical capacity utilisation during the period 2005 to 2017. The regression of capacity utilisation on the years (2009 - 2017) post the global financial crisis produces a lower annual increase in capacity utilisation of 0.12%, a figure which is significant at $p \leq 0.15$. The Zimbabwean manufacturing sector was greatly affected by the global financial crisis. During the crisis, exports to major export destinations such as the European Union (EU), the United States of America (USA) and South Africa dropped significantly. For example, exports to South Africa dropped by 71.9%. Exports to the EU dropped by 40%. Exports to the USA dropped by 90%. The global financial crisis thus led to further deepening of the crisis in the already troubled manufacturing sector (ICAZ, 2009)

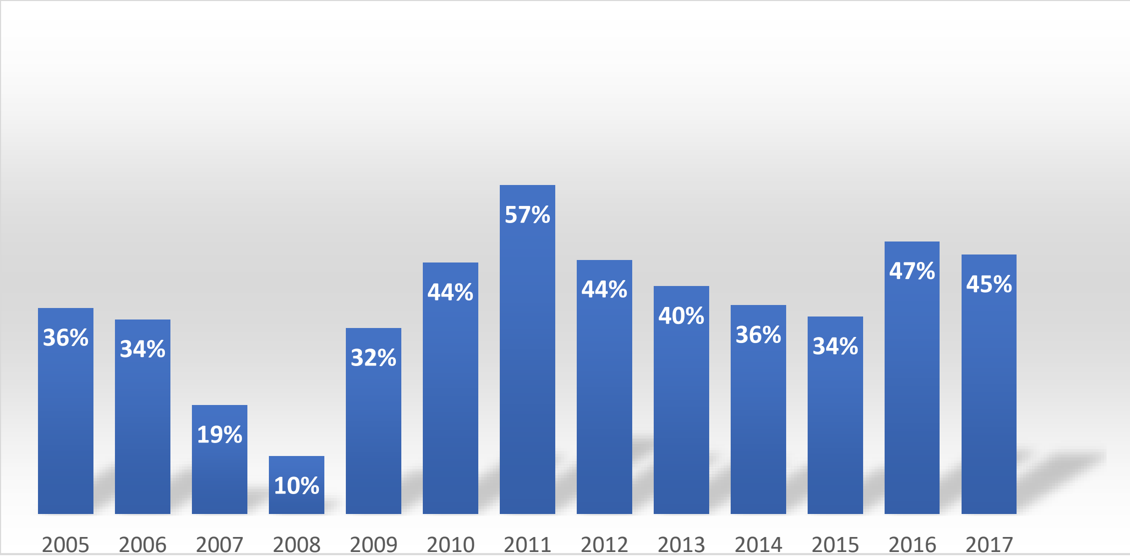

Figure 1: manufacturing sector capacity utilisation, Zimbabwe (Source: Confederation of Zimbabwe Industries)

The objective of this study is to understand the determinants of technical efficiency in Zimbabwe's manufacturing sector as a way of answering the bigger question which has occupied the government over the last decade, namely, how to reindustrialise the country. The question is designed to provide the basis for understanding how levels of technical efficiency compare across firms, subsectors and geopolitical zones of the country thereby informing policy making of factors that might improve capacity utilisation and growth.

The paper will contribute to the firm efficiency literature in Zimbabwe's manufacturing sector as well as in the South African Development Community generally, and will develop a clear picture of the technical efficiency in the Zimbabwean manufacturing sector by answering the following questions:

i. How do levels of technical efficiency compare across firms, subsectors and geopolitical zones of the country?

ii. What is the impact of firm characteristics such as firm age, size and location on technical efficiency?

These questions are relevant to Zimbabwe's economy as they provide an insight into policies and plans required to increase the level of technical efficiency and capacity utilisation in Zimbabwe's manufacturing sector.

In this study the non-parametric data envelopment analysis (DEA) method will be applied to data collected in a survey of registered manufacturing firms in Zimbabwe. The study was carried out by the University of Cape Town (UCT) in 2015. It covers 196 firms in six manufacturing sub sectors, namely rubber and plastics, textiles, wearing apparel and leather, wood, food, beverages and tobacco, chemical, petroleum and coal, and metal, machinery and equipment. The DEA method is a tried and tested empirical method of total factor productivity analysis that is strong on analysing the role of economies of scale in inefficiency. Most studies focusing on technical efficiency in Africa's manufacturing sector make use of the DEA method combined with a tobit model or categorical comparisons using ANOVA (see Kapya et al., 2018 for a local application of this approach).

2. LITERATURE REVIEW

2.1. Manufacturing sector productivity and its determinants

Total factor productivity remains important for improving living standards of poor economies (Naudé and Szirmai, 2012). Therefore, many studies attempt to identify the difference between efficient and inefficient firms. In literature, the consensus is that ownership forms, export participation, cumulative market and production experience in the firm (age/ date of establishment) location and size matter most. These factors are discussed below.

2.1.1. Impact of exporting on efficiency

Several studies of manufacturing sectors show that exporting is positively correlated with efficiency (Bigsten et al., 2004; Marin and Voigtländer, 2013). The increase in efficiency stems from interaction with foreign clients and competitors. Through this interaction exporting firms have the advantage of learning, imitating and adopting foreign knowledge. Firms also get to know worldwide best practices and global production technologies and complement these with local knowledge (Biesebroeck, 2005). In a study of Chilean, Colombian, and Mexican manufacturing firms, Marin and Voigtländer (2013) used plant level marginal costs as a measure of efficiency. They showed that the marginal cost of production drops significantly after export market entry due to efficiency gains. Bigsten et al. (2000) studied four manufacturing sub-sectors of Cameroon, Ghana, Kenya and Zimbabwe covering the period 1992-95. The study's findings showed that an additional year in the export market raised a firm's efficiency by 10%. Bigsten et al. (2004) reiterate the importance of exporting by African manufacturing firms by pointing out that because Africa's domestic market is small, manufacturing firms will only thrive it they can break into the export market. This of course is most likely in industries where the region has a competitive advantage, such as in labour-intensive industries which include agriculture (Antwi & Ehizuelen, 2013). There are exceptions in the literature too. For example, Brada et al. (1997) found no link between efficiency and exports in manufacturing in Hungary or Czechoslovakia. They argue that exporting will only lead to efficiency gains if the export destination is relatively more efficient than the domestic market as this acts as an incentive for the exporting firm to adopt efficient production methodologies in order to be more competitive.

Other studies produced mixed results on the impact of exporting on firm efficiency. For example, Charoenrat and Harvie (2014) studying the nine subsectors of Thai manufacturing (Food, Beverages, Crude materials, Chemicals, Manufactured goods, Machinery and other) showed that only the chemicals and crude material sectors' export activities were positively correlated to technical efficiency. The chemicals sector, which benefitted the most from exporting was found to have relatively higher levels of foreign ownership. In the African context, Eifert et al. (2005) shows that foreign owned firms tend to export more than their domestic owned counterparts.

Although most studies show that exporting leads efficiency improvements, Melitz (2013) showed that the direction of causality between exporting and efficiency can run from productivity to export entry. Firms that are more efficient may enter the export market as they possess a competitive advantage.

2.1.2 Impact of foreign ownership on efficiency

There is an empirical link between foreign shareholding and productivity. The higher productivity stems from the transfer of global knowledge and technology to domestic firms in such a way as to improve productivity. Haddad and Harrison (1993) observed that firms with foreign shareholding have higher export market participation rates. Export orientation leads to improved production induced by competing on a global level. Firms with foreign ownership tend to pay higher wages and attract highly skilled and productive employees. In addition, foreign firms are likely to be cushioned from domestic economic turmoil's that reduce efficiency. Firms with foreign shareholding may have access to low cost or readily available credit and foreign currency from their foreign parent companies which is not available to locally owned firms (Makochekanwa, 2017). Evidence from Parinduri and Riyanto's (2014) study shows that banks with foreign ownership where the most efficient in Indonesia's banking sector. The strategic transfer of bank shares from domestic to foreign investors was found to improve a bank's efficiency. In Slovenia, a 1% increase in foreign shareholding is associated with a 3.9% increase in profitability (Smith et al., 1997).

Chhibber and Majumdar's (1999) identified the conditions under which foreign ownership has a positive effect on firm efficiency. These conditions are significant foreign ownership share and property rights that allow foreign owners to influence decisions and drive the strategic direction of the business. In a study of Turkey's emerging markets, Gurbuz and Aybars (2010) found that where domestic ownership formed most of the shareholding, additional foreign investment had no impact on profitability. Foreign shareholding above a certain threshold was also found to have no impact on profitability. Domestic ownership in optimal levels is required to understand the unique local business conditions and to leverage on domestic market relationships. These findings show that balance must be struck between foreign and domestic shareholding.

Gurbuz and Aybars (2010) also pointed to a possible bidirectional relationship between business performance and foreign ownership. Efficient firms are likely to attract foreign investment while foreign investment is likely to improve efficiency.

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2.1.3 Impact of firm size on efficiency

Empirical evidence suggests that as a firm increases its size, its efficiency increases due to economies of scale. An increase in firm size allows for specialization of labour and technology, and therefore increased productivity. This leads to lower per-unit costs due to existence of fixed costs. The link between larger size and greater efficiency was demonstrated by Önder, Deliktas et al. (2003) for the Turkish manufacturing sector, Brada et al. (1997) for Czechoslovakia and Hungary, Margono and Sharma (2006) for the Indonesian manufacturing sector, as well as Lundvall and Battese (2000) for Kenya..

In other studies, technical efficiency is shown to have a negative correlation with size (Fernandes 2006; Etim and Okon 2013). The findings suggest that as firms grow large, diseconomies of scale set in, perhaps because large firms have more employees and more complicated processes which are more difficult to monitor and coordinate. This leads to principal agent problems as it is complex to ensure that management objectives are aligned to shareholders objectives and interests.

Other studies show that there is no relationship between efficiency and size. One such study is by Page (1984) on the Indian soap, shoes, machine tools and printing firms. While a positive relationship between technical efficiency and firm size was observed in the machinery tools subsector no evidence of a relationship between technical efficiency and firm size was found in other sectors. This means that there is not a priori expectation about the relationship between efficiency and firm size in the current study.

According to Biesebroeck (2005) as firms grow the direction of causality between firm size and efficiency becomes bidirectional. Large firms benefit from economies of scale and have better access to resources such as labour and financial resources which helps them grow faster in size and efficiency

2.1.4 Impact of firm age on efficiency

Findings on the relationship between efficiency and firm age are mixed too. Margono and Sharma (2006) could not find a link between the two in Indonesian manufacturing, while Charoenrat and Harvie (2014) reported a single exception in their sample of Thai manufacturing.

Arguments supporting that efficiency increases with firm age base the argument on the learning by doing hypothesis where firms become more experienced and acquire more knowledge as they continue operations such that older firms run more efficient factories and take more appropriate risks. Critics of the learning by doing hypothesis suggest that as a firm ages, efficiency decreases because older firms likely possess older, less efficient machinery compared to new firms entering the market with newer efficient production technologies (Charoenrat and Harvie 2014) . The fast pace of innovation entail that production technologies change more quickly than a firm can replace its machinery hence increasing the probability of old firms owning old equipment. The magnitude of the effect is probably a function of the type of product produced. For example, in highly sophisticated chemical production processes there might be a greater advantage to modern machinery than in basic agro-processing such as grain milling. Brada et al (1997) explained it slightly differently; they argued that older firms seem to be more efficient than younger firms because inefficient firms do not survive.

In Lundvall and Battese (2000) the age effect was a function of firm size. These authors found no correlation between efficiency and age for firms of a given size, but as soon as they controlled for size there was an effect.

Lundvall and Battese (2000) argued that efficiency can be improved by size but that it takes time for a firm to grow large, and therefore they concluded that firm age is the effect rather than the cause of efficiency growth.

2.1.5 Impact of location on efficiency

In the literature, regional differences in productivity are common. According to Charoenrat and Harvie (2014) the location of a firm influences its proximity or access to financing, transport services, markets, infrastructure, technology, information networks and qualified labour, factors important in driving efficiency. Location also has an impact on key supply chain efficiency indicators such as inventory lead time, flexibility to demand changes and quality (Bhatnagara & Sohalb, 2005). Naudé and Matthee (2010) studying the South African manufacturing sector showed that location affects transport costs and therefore efficiency and profitability of exporting firms. As a result, 80% of exporting firms were found to be located within 100 km of a port. Fedderke and Wollnik (2007) studying South African industries show that the location of resource intense industries was tied to locations of resource supplies in order to improve operational efficiency factors such as the cost, reliability and speed of freight. Önder et al. (2003) utilised the stochastic frontier method to determine the impact of location specific factors on efficiency in the different provinces of Turkey's manufacturing sector. The location specific factors that were studied are market size and the degree of industrial agglomeration. Market size which was proxied by population density was found to have a positive effect on efficiency. The larger the market, the higher the demand and scope for economies of scale. Locations that have a higher concentration of firms were also found to impact efficiency positively. Regional agglomeration increases the scope of positive externalities such as interactions between firms and ability to share infrastructural development costs. Kapya et al. (2018) studying the Zambian manufacturing sector found that firms located in a remote region of the country – the Western province were relatively less efficient as the cost of doing business far away from the central hub was high. These studies show that the choice of a firm's location is a key decision factor as it affects the performance of a firm.

2.1.6 Skilled labour and efficiency

Skilled employees add value to a firm through the application of their skills to improve current production, human resources and financial processes. These improvements are instrumental in maintaining efficiency and competitiveness of the firm. Ottersten and Mellander's (1999) findings on the Swedish labour market showed that in the long run, a unit spent on employee training yields cost reductions up to 25 times the training expenditure. Kwack (2010) emphasizes the importance of skilled labour by noting that current technological innovations are skilled biased such that only firms that employ skilled labour can take advantage of the efficiency gains associated with technological change . Jaffry et al. (2010) shows that while the productivity of skilled labour has increased, the productivity of unskilled labour has not changed since the 1970's which implies that the expected effect of labour skill on firm productivity could be a function of the proportion of skilled labour employed in the firm.

There is a possible bidirectional relationship between technical efficiency and access to skilled labour. Efficient firms are likely to attract skilled labour as there more profitable and thus can hire, retain and remunerate skilled labour.

2.1.7 Access to credit and efficiency

In literature, there is a consensus that access to financing increases the productivity of firms and the economy at large. Measures of access to financing include the degree of financial leverage, whether a firm has access to an overdraft facility, whether a firm is listed on the stock exchange and the ratio of total interest payments to total capital among other measures. Mok et al. 2007 utilised a two stage DEA method to analyse the impact of financial leverage (total liabilities/total assets) on the performance of foreign owned toy manufacturing firms in China. The study showed that a 1% increase in leverage increased technical efficiency by 0.078%.

The study provides evidence that well-developed financial markets have a positive impact on efficiency and profitability. The problem of information asymmetry in financial markets however remains a major barrier to provision of financing. According to Peachey and Roe (2004) in the absence of information to weigh risk associated with lending, firm size and age are used to form perceptions or opinions on the risk associated with lending. New and small firms usually have little or no previous business track record of profitability. These firms usually have inadequate or no collateral. These characteristics help form the perception that new and small firms are high risk borrowers leading to poor access to financing. Perhaps this explains as the premature collapse of SMEs. Amornkitvikai and Harvie (2010) studying Thai listed manufacturing enterprises also found a positive relationship between leverage and efficiency. Other authors who found a positive relationship between leverage and efficiency include Kim (2003).

A possible bidirectional relationship between technical efficiency and access to financing exists . Efficient firms are likely to obtain financing as there are likely to be considered to have a have low default by financial institutions .

3. DATA AND METHODS

3.1 Data

This dataset derives from a survey of registered manufacturing firms in Zimbabwe. The study was carried out by the University of Cape Town (UCT) in 2015. The UCT survey followed up on earlier surveys carried out by the Regional Program on Enterprise Development (RPED) on Zimbabwe's manufacturing in 1993, 1994 and 1995. The pooled sample of the earlier waves contains 203 observations, but these data were not available for analysis in this study. In 2015 only 78 of the original participants could be found, and only 39 of those were still in business. A further 156 new firms were recruited to bring the 2015 sample size to a n = 195, to give a similar sized sample as the one obtained in the earlier wave. The 2015 survey covered firms in six sub-sectors, namely rubber and plastics, textiles, wearing apparel and leather, wood products including furniture, food, beverages and tobacco, chemical, petroleum and coal and metal, machinery and equipment. The data is for the 2014 financial year.

Table 1: Composition of the sample by sector and business outcome in the 2015 survey (n=195)

	Complete and still in production	*Incomplete responses presumably still in business*	*Shut down*
Food beverages tobacco	20	4	2
Textiles apparel leather	35	11	0
Wood products, furniture	21	7	1
Chemicals, petroleum, coal	19	4	1
Rubber, plastics	38	6	5
Metal, machinery equipment	33	5	3
Full sample	166	28	12

Data inspection revealed several serious problems with the 2015 data. Firstly, twelve firms (mainly in rubber and plastics) reported zero revenue, which was taken as evidence that they had ceased trading. One very large outlier (firm 3010), in metal, machinery and equipment, was removed to improve the overall fit of the model since data envelopment analysis does not have the ability to content with measurement error.

A further 29 observations miss data on one or more critical inputs. In 61% of cases, capital was the culprit rather than labour, material or energy (defined as fuel + electricity), and this high non-response rate is partly due to the way in which capital was measured. In the literature capital is proxied in several ways which include using insurance values, second-hand values, depreciation values and book values. In the sample under study capital is measured as a book value, which could be zero for firms with old equipment that are still in business, and we know that more than 60% of large firms in Zimbabwe have operating equipment that is more than 20 years old (CZI 2017). The high cost of capital in Zimbabwe, the difficulty of getting loans and the high price of US dollars explains why firms continue with outdated machinery. The problem with measuring capital as a book value in a DEA model is that firms with old equipment will enter a lower capital input that will make them look more efficient that firms which use modern equipment that still reflects a residual book value. See below.

The treatment of missing data is always a difficult decision, and in this case the choice is between ignoring old machinery (i.e. deleting observations with missing capital data) and a regression approach in which capital data for firms with new machinery is used to estimate capital values for firms with old machinery. Obviously, both are flawed, and if measurement error is too large the unintended effect could be failure to fit a frontier, which would imply zero inefficiency. This is highly unlikely in Zimbabwean manufacturing. In the end it was decided that the most cautious approach would be to restrict the productivity analysis to firms with complete information simply because there was no reliable way to quantify the contribution to output from old machinery. Kapya et al. (2018) made a similar argument. Resultantly energy (fuel + electricity) was used as a proxy for capital. Fuel and electricity are the main sources of energy for powering machinery in the manufacturing sector in Zimbabwe. Energy usage thus measures well the extent of capital usage in the production process. This measure of capital makes it possible to measure the contribution of machinery that has a book value of zero to production.

The remaining pooled sample of n=166 observations to which the efficiency analysis is applied, contains 12% firms from the food, beverages and tobacco sector, 21% that produce textiles, wearing apparel and leather, and 13% from wood and wood products. In other words, more than a third of the manufacturing firms included in this efficiency analysis are involved in agro processing. Firms in chemicals, coal and petroleum represent 11% of the sample, rubber and plastics account for 23% and metal, machinery and equipment firms account for 20% of firms. In this study the analysis works on pooled data as opposed to each subsector of manufacturing separately.

3.2 Methods

Technical efficiency is defined as the ratio of total weighted output to total weighted input (Hosseinian et al., 2012). In production economics productivity analysis involving technical efficiency, has become the norm. The approach can be parametric or non-parametric.

Parametric efficiency analysis, in the form of stochastic frontier analysis (SFA), can either just fit trends for technical progress and efficiency gains as in Battese and Coelli (1992) or fit a frontier and explain deviations from it as in Battese and Coelli, (1995). Both models are more suited to panel data than to a simple cross section and decompose the error term into the typical mis-measurement error and an inefficiency term.

In the non-parametric approach, executed by means of linear programming is called data envelopment analysis (DEA). In DEA the full deviation of each observation from a piece-wise linear production possibilities frontier is interpreted as the inefficiency term (Mardani.et al., 2017). The DEA method either assumes constant or variable returns to scale. The constant returns to scale production function assumes that an increase in inputs results in the same proportional increase in output, in other words that in any dimension the production is a 45°line from the origin. This assumption is appropriate when business units under consideration all operate at an optimal scale (Mok et al., 2007). The variable returns to scale production function assumes that a change in inputs does not result in a proportional change in the outputs. Effectively it bends the 45° line inwards towards the observations at each end to envelop the observations more snugly. The result is an increase in technical efficiency and the assumption is appropriate when business units may not perform optimally due to such reasons as imperfect competition (Mok et al., 2007).

In Battese and Coelli (1995) the process of determining efficiency is parametric, i.e. by means of econometric modelling, and the model jointly fits the frontier and explains deviations from it. In DEA the frontier finding process is non-parametric and there is no automatic explanation of observed differences in efficiency. Such analysis takes place in a second stage, which usually involves t-tests, analysis of variance tests (ANOVAS), simple Spearman correlations or tobit models (Conradie and Piesse, 2015; Galloway et al., 2018; Zhou et al., 2017).

This paper will employ a two-stage method that combines DEA with a Tobit regression to study efficiency and its determinants in Zimbabwe's manufacturing sector. The two stage DEA method first obtains efficiency scores through DEA analysis. In the second stage, the efficiency scores are regressed on factors that affect efficiency. Regression methods used in the second stage include ordinary least squares regression, Tobit regression, or maximum likelihood estimation (Zhou et al., 2017). The Tobit model which is a limited dependent variable model is the appropriate and unbiased regression method for corner solutions like efficiency scores which have a minimum value zero and a maximum value one. Unlike the SFA method, the

DEA method does not impose apriori assumptions about the shape of the production function or the distribution of errors (Cullinane, Wang et al., 2005). The main disadvantage of the DEA method is that unlike the SFA method, measurement and random errors influence the DEA efficiency score. The DEA is also non-econometric in nature and does not allow for hypothesis testing (Cullinane et al., 2005).

3.3. Measuring efficiency with DEA

The DEA model can calculate efficiencies assuming a constant or variable return to scale production function. The constant returns to scale model assumes that an increase in inputs results in a proportional increase in output. The variable returns to scale model allows a unit change in input to result in a more or less than proportional increase in output. DEA models can either be output oriented or input oriented. The objective of the output-oriented model is to maximise output subject to the production possibility curve while that of the input-oriented model is to minimise input subject to production output. The Zimbabwean manufacturing sector is affected by capacity underutilisation and as such firms are faced with an output maximisation problem. The output-oriented DEA model is relevant to Zimbabwe's context and will be employed in this paper.

The output-oriented DEA model can be as expressed as an optimisation problem as shown in (1) – (5) (Cullinane, et al., 2006).

$$MAX\ \Phi \quad (1)$$

$$Subject\ to$$

$$\Phi {y'}_k - Y'\lambda \leq 0 \quad (2)$$

$$X'\lambda - {x'}_k \leq 0 \quad (3)$$

$$e\lambda' = 1 \quad (4)$$

Where Φ is the efficiency score of the firm under study , $X_k = (x_{1K}, x_{2k} \dots \dots \dots \dots., x_{mk} \epsilon R_+^N$) is an input matrix for decision making units under study,$Y_k = y_{1k}, y_{2k}, \dots \dots \dots \dots .. y_{mk} \epsilon R_+^N$) is a positive vector of output for firms under study, $\lambda = (\lambda_1, \lambda_2, \dots \dots \dots \dots \dots, \lambda_k) \epsilon R_+^K$ is a non-negative matrix forming a linear combination of k decision units under study , e = (1, 1, 1…, k) represents a k dimensional matrix of ones and mk is the unique (number) identifier of each firm under observation. The inputs that are used to compute technical efficiency are capital, labour and materials. The output variable used is the firm's annual turnover. In order to correct for the problem of missing data for the capital variable, energy cost is used as a proxy for capital. Machinery in Zimbabwe's manufacturing sector is mainly powered by electricity and diesel during power cuts. The sum of electricity and fuel costs is therefore a good a proxy for capital usage. Labour is measured as the labour head count while materials is measured as the monetary value of raw materials used in the production process.

The technical efficiency of the unit under study TE_{nk} is given in Equation (5) as

$$Technical\ Efficiency\ TE_k = 1/U_K \quad (5)$$

Equation 6 is a computation of scale efficiency for the Kth firm where U_{CCR-k} is the technical efficiency score under constant returns to scale assumptions and U_{BCC-k} is the technical efficiency score under variable returns to scale assumptions

$$Scale\ efficiency\ SE_k = U_{CCR-k} / U_{BCC-k} \quad (6)$$

Where SE_k = 1 indicate scale efficiency while SE_k < 1 indicates scale inefficiency.

3.4. Technical inefficiency effect -Tobit Regression

In empirical studies factors that have been shown to have an impact on firm efficiency include firm size, age, location, access to skilled labour, access to financing, and exporting activities of a firm.In this paper the effect of firm size, age, location, access to skilled labour, access to financing and exporting activities on firm efficiency is determined in the second stage tobit regression . The choice of variables used in the second stage tobit regression is informed by literature. In literature firm age is associated with a positive effect on technical efficiency. Older firms are well established and possess vast knowledge on markets, production methods and research (Harvie & Amornkitvikai, 2010). Location is also shown to have an impact on firm efficiency. Location determines market size, access to infrastructure, access to markets and proximity to raw materials (Önder et al., 2003). Exporting leads to improved firm efficiency as it enables business units to interact with foreign clients and competitors. The interaction benefits firms as they learn, imitate and adopt world best practises (Harvie & Amornkitvikai, 2010). Access to skilled labour and financing is also shown to affect firm performance. Access to financing allows firms to fund research and technologies that improve the efficiency of operations (Mok et al., 2007). Skilled labour allows firms to benefit from knowledge and research that human resources possess for the improvement of operational and cost efficiency (Ottersten & Mellander, 1999). The effect of these firm specific characteristics on efficiency is found by regressing the characteristics of the firm on the technical efficiency score. The thinking behind the second stage tobit model is firm performance is determined by a combination of environmental, technological and human capital factors that makes one management team more efficient than the rest. Often selection of explanatory variables is limited by data availability, especially in datasets collected for other purposes such as the one being analysed in this case. In the empirical literature, the consensus is that ownership forms, export participation, cumulative market and production experience of the firm (age/ date of establishment), location, quality of the human resource and size matter most.

The exogenous factors that affect technical efficiency that have been identified as relevant to Zimbabwe's context are age of the firm, location relative to Bulawayo, export status, scale efficiency and foreign ownership. The choice of these variables has also been informed by literature and data availability. Table 2 provides a summary of the key findings in literature on the impact of these exogenous factors on efficiency.

The Tobit regression in this study that relates the impact of exogenous factors on efficiency in the Zimbabwean manufacturing sector is expressed as

$$TE_k = \beta_0 + \beta_1\, firm\ age + \beta_2\, scale\ \ efficiency\ score + \beta_3 Skilled\ labour\ ratio$$
$$+ D_1\ Large + D_2\ Bulawayo + D_3\ Exporting$$
$$+ D_4 Foreign\ sharehoding + D_5\ Overdraft\ facility$$

Where

TE_k is the pure technical efficiency score for firm k.

Size is a dummy variable that takes the value 1 when the firm size is large and 0 otherwise. Large firms are defined as firm with 100+ employees.

Location is a dummy variable that takes the value one when a firm is in Bulawayo and 0 for other locations

Exporting is a dummy variable that takes the value 1 when a firm is engaged in export and 0 when a firm does not export. The amount exported is not taken into consideration.

Age of the firm denotes the age of the firm in 2015

Scale efficiency is the scale efficiency score produced by DEA. Overall technical efficiency decomposes into scale efficiency and pure technical efficiency

Skilled labour ratio refers to the ration of total labour that is skilled

Overdraft facility is a dummy variable that takes the value 1 when the firm has an existing overdraft facility and 0 when the firm does not have an overdraft facility

Table 2: Determinants of efficiency and impact -developing country's manufacturing sector

			Correlates of pure technical efficiency						
Citation	Country, period, industry, number of firms (N) and periods observed (T)	Method	Age	Size	Location	Foreign ownership	Skilled labour	Exporting	Firm size proxy
Lundvall and Battese (2000)	Kenya, 1993-1995, food, wood, textile, metal, N=276, T=3	Translog Stochastic frontier	(+), for textiles and insignificant effects on other sectors	(+)					Value of intermediate inputs
Charoenrat and Harvie (2014)	Thailand 1997 and 2007, Food, Beverages, Crude materials, Chemicals, Machinery and other=22685(1997), N=56441(2007),	Stochastic frontier	Mixed results	Mixed results	Significant	(+) for all but significantly (-) for machinery	(+)	Mixed results	Number of employees
Margono and Sharma (2006)	Indonesia ,1993-2000, food, textiles, chemicals, metal, N=,733, T=8,	Time variant Stochastic frontier	Mixed results	(+)	Mixed results across subsectors				
Aggrey et al. (2010)	Kenya, Uganda, Tanzania ,2002-2003 agro-processing, N=403, T=1	Data envelopment Analysis	Mixed and insignificant	Mixed results but significantly (-) for Tanzania	Significant for Tanzania only	(+) for all but significantly for Kenya only		(+) for all but significantly for Tanzania only	

In the literature, the findings on the impact of size on efficiency are mixed. For example, Lundvall and Battese (2000); Brada et al. (1997) and Margono and Sharma (2006) showed that firm size was positively correlated to technical efficiency. Fernandes (2006) and Etim and Okon (2013) on the other hand showed that larger firms were inefficient compared to their smaller counter parts . Page (1984) found no relationship between firm size and efficiciency. Due to the mixed nature of results in literature on the impact of firm size on efficiency , there is not a priori expectation about the relationship between efficiency and firm size in the current study.

Bulawayo developed into an industrial city due to its strategic location as a gateway to South Africa, Botswana, Zambia and Namibia. During the colonial era, Bulawayo became an important economic link between these countries. The arrival of the railway in Bulawayo in 1897 promoted the growth of mining, agriculture and manufacturing industries. Bulawayo also developed as the main transshipment point for goods to and from South Africa. Supporting infrastructure which included a coal fired power station (1957) was developed to promote the emerging industrial city's development. Zimbabwe's rail network company, NRZ is also headquartered in Bulawayo. Firms located in Bulawayo are expected to have higher efficiency due to robust supporting infrastructure in Bulawayo that was developed to support Bulawayo's status as an industrial city. The coefficient associated with Bulawayo is expected to be positive.

The age of the firm is expected to have a positive effect on efficiency in support of the "learning by doing" hypothesis where firms become better and more efficient with more experience in the market. The competing hypothesis that older firms are less efficient due to older equipment is not expected to apply to Zimbabwe's manufacturing sector. The sector is mainly agro-based. Most processes in this sector are basic and require basic technology. New firms do not have the advantage of entering the market with newer advanced technology. In addition, the scarcity of capital in Zimbabwe leads to slow adoption of technology. Technology across firms is to a greater extent uniform. On the margin, experience rather than technology is a much more important differentiator of performance. Firms in Zimbabwe are also expected to improve their efficiency by exporting. Competition and innovation in the global market requires that firms innovate and become efficient in order to stay competitive. Exporting also enhances efficiency through improving access to foreign currency required to import raw materials, equipment and machinery. Firms in Zimbabwe are heavily reliant on imported raw materials, equipment and machinery. Often, forex shortages translate to production stoppages. Forex shortages in the country are crippling the economy and the impact is more pronounced for firms that do not earn forex revenue. The coefficient of exporting is thus expected to be positive. The coefficient of foreign ownership is expected to be positive too since foreign ownership is associated with access to international markets, finance, technology and knowledge. Access to financing is also expected to enhance efficiency.

4. RESULTS ANALYSIS AND DISCUSSION

Technical efficiency is defined as the ratio of total weighted output to total weighted input (Hosseinian et al., 2012). In this paper the DEA programme was used to calculate efficiency scores of firms. The DEA methodology takes observed input and output to form a production possibility curve against which individual units are compared to determine their efficiency scores (Mardani., et al 2017). The mean technical efficiency for Zimbabwe's manufacturing sector is 55% with a median efficiency of 56%. Textiles, wearing apparel and leather and metal, machinery and equipment perform better than average, while wood and furniture and chemicals petroleum and coal perform significantly worse than the average. See Table 3.

More than a fifth of firms in the sample produced technical efficiency scores of more than 90%. Using the proportion of firms in each sector that are more than 90% efficient as a measure of success indicates that the textile, wearing apparel and leather industry is the strongest in the country. 55% of firms in this sector were more than 90% efficient. The only other sector that comes close to it was the rubber and plastics industry where one in five firms in the sample were found to be more than 90% efficient. Line 2 in Table 3, which records the number of firms in each sector that were less than 50% technical efficient, reveals that not all textile, wearing apparel and leather firms are equally successful, in fact 37% of firms in that sector have a technical efficiency score of less than 50%. If a score of less than 50% is taken as a measure of failure, the industries with the highest failure rates are wood and furniture and chemicals, petroleum and coal. In the wood and furniture sector, more than three quarters of firms are less than 50%. In chemicals, petroleum and coal the corresponding figure is 63%.

Table 3: Technical and scale efficiency by manufacturing subsector

Technical and scale efficiency measure	*Food beverages tobacco N=20*	*Textiles apparel leather N=35*	*Wood furniture N=21*	*Chemicals petroleum coal N=19*	*Rubber plastics N=38*	*Metal machinery equipment N=33*	*All industry N=166*
Number of firms more than 90% technically efficient	20%	57%	10%	5%	21%	3%	22%
Number of firms that are less than 50% technically efficient	45%	37%	8%	63%	32%	2%	44%
Number of firms experiencing constant returns to scale	0%	3%	5%	5%	3%		2%
Number of firms experiencing decreasing returns to scale	100%	94%	90%	90%	97%	97%	95%
Number of firms experiencing increasing returns to scale	0%	3%	5%	5%		3%	2%
Mean technical efficiency score	56%	66%	43%	45%	51%	63%	56%
Mean scale efficiency score	3%	10%	19%	5%	7%	12%	7%

Scale inefficiency is a much more significant problem in Zimbabwean manufacturing than technical efficiency. The results show that only 2.5% of firms in the sample are the right size, while the vast majority are too large. With industry-wide scale efficiency of just 7%, the overall technical efficiency (pure technical efficiency x scale efficiency) drops to below 5%. The wood and furniture sector achieved the highest scale efficiency score, but even there, only one firm is scale efficient.

An ANOVA test shows that technical efficiency varies significantly across sectors with ρ value ≤ 5%. As explained above, the textile sector has a clear technical efficiency advantage over other sectors. An ANOVA test with ρ ≥10%, however show that no single sector has a scale efficiency advantage over another.

4.1. Potential explanations of Technical Efficiency

The Tobit regression model results are presented in Table 4. These results give an insight into why levels of efficiency may vary across firms. It shows that a firm's scale efficiency, age, size and labour quality enhance pure technical efficiency.

Table 4: Results of a tobit model explaining pure technical efficiency in Zimbabwe's manufacturing industry

Variable	*Coefficient*	*Standard error*	*Significance*
Scale efficiency score	0.2209	0.1015	**
Firm age	0.0044	0.0010	***
D overdraft	-0.0402	0.5061	
D exporting	0.1049	0.0497	**
D large	0.3088	0.0532	***
% skilled labour in workforce	0.1854	0.0924	**
D foreign ownership	-0.0955	0.0753	
D Bulawayo location	0.1250	0.0470	***
Constant	0.1387	0.0779	*
McFadden's R-squared	0.8240		

*** $\rho \leq 0.001$, **$\rho \leq 0.05$, *$\rho \leq 0.10$, † $\rho \leq 0.15$

These results are in line with expectations. The model also shows that firms in Bulawayo are more efficient than firms located elsewhere in the country. Given Bulawayo's longstanding position as Zimbabwe's industrial heartland this finding was as expected. Against expectations, the model shows that foreign ownership and access to an overdraft facility do not explain variations in the levels of efficiency. The pseudo R-squared value is 0.8240. The value is significant and shows that the model is a good fit.

4.2.Firm size and technical efficiency

As explained in chapter 2, the common variables that are used to determine firm size in literature are turnover, annual costs, number of employees, wages and net assets value. In this study the number of employees served as proxy for firm size. Out of the 166 firms in the sample, 56 firms were classified as small, 69 as medium and 41 as large. The legal cut-offs that apply in Zimbabwe are small firms of less than 20 employees, medium firms of 20 to 100 workers and large firms of more than 100 workers. In the rest of sub-Saharan African, the cut off for the small category is usually 50 workers, while the cut-off for medium sized firms is usually a hundred workers. The only exception is South Africa where medium sized firms are defined as those employing 51-200 workers.

Efficiency scores for the Zimbabwean manufacturing show that the mean technical efficiency for large firms is 80% compared to 55% for medium firms and 37% for smaller firms. Table 5 shows that efficiency increases consistently with firm size across all sectors. The difference in technical efficiency across firm size groups is statistically significant at $p \leq 0.01$ according to the F-statistic produced by a single variable analysis of variance test (ANOVA).

The size coefficient is 0.3088 with a t-value of 5.18. The result shows that large firms in Zimbabwe are 36% ($e^{0.3088} - 1$) more efficient. The results reflect the advantage that large firms have in accessing resources. For example, the average skills ratio in large firms is 75%

compared to 71 % in medium firms and 65% in small firms. Also, 42% of large firms have an overdraft facility compared to 20% of medium firms and 13% of small firms.

Table 5: Mean technical efficiency scores by sector and firm size

	Large	*Medium*	*Small*
Food beverages tobacco	75	38	
Textiles apparel leather	93	59	46
Wood products, furniture	74	42	33
Chemicals, petroleum, coal	66	48	30
Rubber, plastics	75	67	33
Metal, machinery equipment	78	66	46
% firms with an overdraft facility	42	20	13

One of the most important difference between small and large firms is how easy it is for them to finance new expansions or refurbishments. Table 5 also reveals that twice as many large firms have access to an overdraft facility than does medium-sized firms. Small firms are even worse off. These findings support Biesebroeck's (2005) empirical results which show that large firms are more efficient and grow faster in size because they have better access to financial compared to their smaller counterparts.

4.3.Firm age and technical efficiency

The average age of the firms in the sample is 36 years. The oldest firm is 111 years old, the median age of the firms is 33.5 years, and the minimum age is 1 year. An ANOVA test with $\rho \geq 0.01$ shows a significant association between firm size and age. Large firms tend to be older while smaller sized firms tend to be younger. The average age for large firms is 48 years compared to 36 years for medium firms and 27 years for small firms. From this observation, it can be concluded that SMES in Zimbabwe have a relatively low survival rate and the majority go bankrupt within the first few years of doing business.

The age coefficient in the second stage tobit regression is 0.0044 and is significant with a t-value of 4.48. This shows that older firms are more efficient. A one unit increase in the firm's age is associated with a 0.44 % increase in technical efficiency. An ANOVA test to determine if efficiency varies with a firms age group, at $\rho \leq 0.01$ shows that the more mature a firm is, the more efficient it becomes. The test results summarised in Table 6 show that firms that are 21+ years are 61% efficient on average compared to 56% for firms that are between the ages 11-20, and 35% for firms that are 0-10 years old. While the first decade is vitally important for firms to become competent, there is not much more to be gained after the second decade of existence.

Table 6: Mean technical efficiency by firm age

	Entry firms 1-10 years	*Mature firms 11-20 years*	*Old firms 20+ years*
Mean technical efficiency score	35	56	61

These finding are consistent with the learning by doing hypothesis where an increase in experience over time leads to improved efficiency. Critics of the learning by doing hypothesis however suggest that as a firm ages, efficiency decreases because equipment becomes older and less efficient over time (Charoenrat and Harvie 2014) . The Zimbabwean CZI (2017) manufacturing survey shows that older firms in Zimbabwe operate antiquated equipment. 60% of large firms are operating equipment that is more than 20 years old, compared to 36% for medium sized firms and 31% for small firms. Evident however from the efficiency scores is that positive effect of experience offsets the negative effect of old equipment and outdated technology. Despite possessing older machinery, older firms are more efficient as there are well established in the market and their operators are more experienced. Older firms possess vast knowledge of the markets and production technologies obtained from experience spanning many years. Older firms are thus able to put into use knowledge obtained over years to improve their operations leading to increased efficiency levels. Lundvall and Battese (2000) argued that efficiency can be improved by size but that it takes time for a firm to grow large, and therefore they concluded that firm age is the effect rather than the cause of efficiency growth. The results of an ANOVA test to determine if efficiency varies between age groups showed that large firms tend to be mature and small firms less mature perhaps in support of Lundvall and Battese's (2000) finding that size is an indicator of age.

4.4.Firm location and efficiency

In the Tobit regression to determine the impact of location on efficiency, Bulawayo is used as a reference point because of the city's historical status as industrial growth point. The coefficient associated with the Bulawayo dummy variable is significant and positive in line with expectations. The result shows that firms located in the Bulawayo area are on average 13 % more technically efficient than firms located elsewhere in Zimbabwe. The difference in technical efficiency across different provinces of the country is statistically significant at $p \leq 0.05$ according to the F-statistic produced by a single variable analysis of variance test. Firms located in Bulawayo have a clear technical efficiency advantage with a mean technical efficiency score of 65%. The results confirm the *a priori* expectation that firms in Bulawayo are more efficient as they have access to well-developed support infrastructure. Bulawayo was designed as an industrial city with robust supporting infrastructure such as a power station, water, railway. Harare on the other hand was developed as an administrative city.

Table 7: Mean technical efficiency score (%) by location

	Bulawayo N=45	*Harare N=103*	*Mutare N=10*	*Midlands N=8*
Mean technical efficiency	65	53	41	57
Distance from Bulawayo	0 km	443 km	579km	166km

A study by Arimah (2003) aimed at measuring and explaining the provision of infrastructure in African cities rated Bulawayo as having the best infrastructure compared to 75 other African cities in the sample which included Harare. The rating is a weighted index of water connections, sewerage connections and wastewater treatment, collection and disposal of solid waste, electricity connections and telephone connections. The strategic location of Bulawayo close to

South Africa, Botswana, Zambia, Mozambique and Namibia also enhances the city's manufacturing competitiveness as these countries are major export destinations for Zimbabwean products. These countries are also sources of critical inputs such as spare parts, equipment and raw materials. World Integrated Trade Solution (2018) shows that in in 2018 South Africa was a destination for 51.48% of Zimbabwe's exports. In addition, 52.66% of total capital goods imported and 27% of raw materials imported were from South Africa. Bulawayo's location means it is close to markets as well as input suppliers.

Patterns in the data as shown in Table 7 reveal that being located close to Bulawayo causes an efficiency advantage. These results confirm that regional disparities in the availability of support facilities such as quality labour, industry infrastructure, information networks, access to financing, transport services and markets determine variations in efficiency across locations (Badunenko et al. 2008; Charoenrat & Harvie 2014).

4.5.Foreign ownership and technical efficiency

In this study 12% of firms in the sample have foreign ownership. Table 8 shows how foreign ownership varies across sectors. The metals subsector has the highest ratio of exporting firms. 18% of firms in this sector have a foreign ownership element. The textiles subsector on the other hand has the least ratio of firms with foreign ownership. Only 5.7% of firms in this sector have an element of foreign ownership.

Table 8: Distribution of foreign ownership across subsectors

Sector	*Food beverages tobacco N=20*	*Textiles apparel leather N=35*	*Wood furniture N=21*	*Chemicals petroleum coal N=19*	*Rubber plastics N=38*	*Metal machinery equipment N=33*
Number of firms with foreign ownership	3	2	2	3	3	6
% of firms with foreign ownership	15%	5.7%	9.5%	15.8%	7.9%	18%

In the Zimbabwean manufacturing sector, the coefficient that relates foreign ownership and efficiency is negative and insignificant. The coefficient -0.0955 and the t-value is 1.27 This result contrary to most findings and expectations, shows that presence of foreign ownership has no impact on efficiency in Zimbabwe's manufacturing. This means that there are no efficiency gains associated with foreign ownership.in Zimbabwe's manufacturing sector. Chhibber and Majumdar (1999) offer a plausible explanation as to why foreign ownership may fail to yield efficiency gains by suggesting that there are conditions under which foreign ownership has a positive effect on firm efficiency. These conditions are; significant foreign ownership share and property rights that allow foreign owners to influence decisions and drive the strategic direction of the business. In the Zimbabwean scenario, the Indigenization Act of 2000 which has since been repealed, required that foreign shareholding be limited to 49% of issued capital. This together with the poor record in the rule of law and property rights enforcement has kept foreign investment low. As a result, indigenous shareholders are the majority owners and drive the strategic direction of most Zimbabwean companies. Perhaps this explains why foreign ownership has little or no impact on efficiency. Further research is required in this area to understand why foreign ownership has no impact on efficiency and whether this can be used as a motivation for the Zimbabwean government to seek to promote the indigenisation of businesses in Zimbabwe. Previous indigenisation policies include the land reform program of 2000 and the indigenisation act of 2009.

4.6.Exporting and Technical efficiency

Countries that take part in international trade will benefit more by specializing in the production of goods in which they have absolute advantage or relative advantage. Absolute advantage means that a country can produce goods at a lower cost than any other country. This allows a country to export goods at a lower price. Even without absolute advantage, a country can benefit from exporting if it has relative advantage. Relative advantage means that a country can produce goods at a lower opportunity cost as compared to other countries. Absolute and relative advantage therefore determine a country's competitiveness in the export market. The main sources of absolute and relative advantage include, factor endowment and production technology employed (Voinescu & Moisou ,2015). Zimbabwe's comparative advantage lies in agriculture. The country is endowed with climatic conditions and land that is suitable for agriculture. Given the importance of agriculture in GDP, one would have expected the food, beverages and tobacco industry to be more prominent, but only 15% of manufacturing firms in this sector exports part of their output, on average just 3% of what is produced in the sector. Clearly most of Zimbabwe's agricultural commodities leave the country in an unprocessed state.

Table 9 presents the detail of Zimbabwe's manufacturing' export profile. The most important exporting sectors, both as a head count and according to the percentage of total production that is exported are wood products and furniture (which was previously shown to be amongst the most inefficient sectors in manufacturing) and metal, machinery and equipment (where firms are predominantly too big for current economic conditions).

Table 9: Export activity by sector

	% firms that export	*% of revenue from exports*
Food beverages tobacco	15	3
Textiles apparel leather	23	3
Wood products, furniture	33	10
Chemicals, petroleum, coal	11	2
Rubber, plastics	18	4
Metal, machinery, equipment	30	16

An ANOVA test to determine if export activity varies with firm size with $\rho \leq 0.05$ shows that export activity increases with firm size. 31 % of large firms are engaged in export activities compared to 24 % of medium firms and 13% of small firms. The Tobit coefficient associated with exporting is 0.1049. The coefficient is positive and is significant at the 5% confidence level. The result confirms *a priori* expectations that exporting increases firm efficiency. The results show that firms engaged in exporting are 11% more efficient than firms that do not. The mean technical efficiency score for domestic firms was 53% compared to 64% for exporting firms. These results support Bigsten, et al's. (2000) findings which show that exporting increases firm efficiency in Zimbabwe's manufacturing sector.

4.7.Labour Quality

Findings in Zimbabwe's manufacturing sector support findings in literature that a larger proportion of skilled employees improve firm efficiency. The regression coefficient associated with skilled labour is 0.1853. The coefficient is significant at the 5% level and suggests that firm efficiency increases with labour quality. The Tobit result indicates that a 1% increase in the labour quality increases firm efficiency by 0.19%. In this study labour quality is measured as the proportion of skilled labour to total labour employed by the firm.

Table 10: Proportion skilled workers per industrial subsector

	% skilled labour in the workforce
Food beverages tobacco	55
Textiles apparel leather	77
Wood products, furniture	72
Chemicals, petroleum, coal	69
Rubber, plastics	66
Metal, machinery equipment	70

Table 10 provides a summary of average labour quality per firm across sectors. At $p > 0.05$, there is a statistically significant difference in labour quality across sectors. The food, beverages and tobacco sectors have the lowest labour quality ratio. The food, beverages and tobacco sector is a primary sector that requires little specialised skill for production. An ANOVA test at $p > 10\%$ shows that the skills ration increases with firm size. The skilled labour ratio increases with firm size with the skill ratio being 65% for Small firms ,71% for medium firms and 76% for large firms. This entails that large firms are better positioned to attract, remunerate and retain skilled employees.

4.8.Economies of scale

Table 3 presents the scale efficiency scores per subsector. The table shows that the mean scale efficiency in Zimbabwe manufacturing sector is exceptionally low at 7% .The DEA returns to scale as shown in table 3 reveal that 95% of firms are experiencing diseconomies of scale (too small), 2 % are experiencing economies of scale (too large) and 2% are experiencing constant returns of scale (right sized). Table 11 shows a breakdown of scale efficiency by region and sector.

Table 11: Percentage scale efficiency by sector and region

	Zimbabwe	*Harare*	*Bulawayo*	*Mutare*	*Midlands*	*All locations*
Food beverages tobacco	3	0	0	8	22	3
Textiles apparel leather	9	9	5	86		9
Wood products, furniture	15	14	100	2		15
Chemicals, petroleum, coal	5	3	8			5
Rubber, plastics	9	9	12	2	3	9
Metal, machinery equipment	12	7	26		3	12
All industries	7%	7	14	12	5	7

These results are largely explained by the recession that the Zimbabwean economy is facing. Most firms have huge net book values and number of employees relative to capacity being utilised and current demand. The challenge of capacity underutilization is more pronounced for large firms owing to a relatively wide gap between capacity and current demand. As a result, scale efficiency is lower for larger firms. The scale efficiency of large firms is 1% compared to 5 % for medium sized firms and 22 % for small firms. The difference in scale efficiency across firm size groups is statistically significant at $p \leq 0.01$ according to the F-statistic produced by a single variable analysis of variance test (ANOVA). The ANOVA test shows that scale efficiency decreases with an increase in firm size. A comparison of scale efficiency on a regional level shows that Bulawayo has the highest average scale efficiency of 14% followed by Mutare with a scale efficiency of 12%. Harare's scale efficiency is 7% while Midlands records the lowest scale efficiency of 5%. A comparison of scale efficiency across regions shows that the wood subsector has the highest scale efficiency of 15% followed by the metal subsector with a scale efficiency of 12%. The food sector records the lowest scale efficiency of 3%. ANOVA tests to determine if scale efficiency varies significantly across subsectors and regions at $p \leq 0.10$ show that there exists in Zimbabwe's manufacturing industry, non-significant sectorial and regional differences in the levels of scale efficiency.

The coefficient associated with scale efficiency in the second stage tobit regression is 0. 2209 The coefficient is significant at p>5%. The coeffect suggests that scale efficiency has a positive impact on technical efficiency. A 1% increase in scale efficiency is associated with a 0.23 % increase in technical efficiency.

4.9.Access to finance

In the Zimbabwean manufacturing sector, the coefficient associated with having an overdraft facility is positive though insignificant. The coefficient is - 0. 0422 with a t-value of 0.79. The negative sign is unexpected as it suggests that access to financing reduces efficiency. The insignificance of the coefficient is also perplexing as it suggests that an overdraft has no significant impact on technical efficiency. The result which suggest that the performance of firms with an overdraft facility and firms without an overdraft facility is not different is contrary to most findings and expectation which show that access to finance has a positive impact on efficiency. A probable explanation is due to liquidity challenges in Zimbabwe, having an overdraft facility does not translate to cashflow as financial institutions are constrained too. Also, since financial institutions extend credit against future expected cash inflow, low demand in the economy translates to poor cash-flow. This limits ability to make use of available credit facilities. Again, due to illiquidity of the economy access to an overdraft facility probably does not measure well access to financing.

5. POLICY IMPLICATION AND RECOMMENDATIONS

This result of this study can be used to contribute to evidence-based policy making for economic planners as well as entrepreneurs of Zimbabwe's manufacturing sector.

5.1.Exporting

This study has shown that exporting firms are more efficient compared to their non-exporting counterparts in Zimbabwe. From an economic planning view, the study points out to the importance of having national export promotion programmes to help business enterprises achieve superior returns in export markets. Economic planners need to assess the needs of the manufacturing sector in order to understand the barriers to export market entry. This is critical to evaluating the effectiveness of current export promotion programs as well as in coming up with new programs. Export promotion policies to consider include those that increase the price competitiveness of export goods. In the current financial environment in Zimbabwe, production costs are very high, mainly due to old equipment. Policies that reduce the cost of capital in Zimbabwe are required for re-tooling and capitalising of the industry in order to enhance cost and export competitiveness. In a survey of manufacturing firms, 63% of companies indicated that they pay duty on capital expenditures like purchase of equipment and replacement parts (CZI, 2017). Import duty relief on capaital expenditure can accelerate re-capitalization efforts. Industrial companies rely on imported raw materials. In order to enhance cost competitiveness of export goods, exemption of import and VAT must be considered for raw material for the manufacture of export goods. Policies that reduce delays in the flow of exports across borders are also instrumental in achieving industrial efficiency. A study carried out by Edwards & Kirk (2014) shows that trade facilitation delays such as border delays increase the cost of export and therefore impede export activity in Zimbabwe. Other efforts to consider include those that reduce information asymmetry. They should be close communication between the manufacturing sector and export promotion agencies. Close communication is necessary to increase knowledge about export-promotion programmes available to firms. Communication also allows the private sector to make recommendations to improve the efficiency of export market polices. For export promotion programmes to be effective the government must improve the ease of doing business and increase the overall competitiveness of the economy. Overall competitiveness of the economy can be achieved through investments in new and improved infrastructure like roads , railway infrastructure and power stations .Overall competitiveness of the country can also be improved through more secure property rights , improved ease of doing business, better quality control and research to support innovations.

5.2.Firm size, age and access to financing

In this study firm age was found to have a positive impact on efficiency. This implies that firm survival is key to driving efficiency gains in the manufacturing sector. A study by Makochekanwa (2017) identifies exporting, reliable electricity and access to foreign currency as key to preventing the premature collapse of firms especially during economic melt downs. SME policies need to focus on export incentives to provide SMES with alternative markets that cushion them from economic downturns in the local economy. Access to forex is also important in enhancing the survival and competitiveness of firms in Zimbabwe. The scarcity of foreign currency has resulted in the mushrooming of foreign currency black markets where forex is sold at an exorbitant premium to the official exchange rate. The shortage of forex in the formal market prompts businesses to buy forex at uncompetitive rates from the black market. This results in very high costs of doing business that affects the viability of firms and competitiveness of firms. Access to foreign exchange also enhances survival as it allows firms to purchase equipment, spare parts and raw materials that are needed to run efficient operations. In the current economic environment in Zimbabwe where forex is very scarce policies that allow exporting firms to retain a great potion of their export earnings in foreign currency can be expected to improve efficiency of operations.

Evidence that shows that firm size has a positive impact on efficiency in Zimbabwe's manufacturing sector has policy implications for both business managers as well as Zimbabwe's policy makers. For business managers, the results suggest that managers need to have explicit and sound growth strategies. Managers should pay attention to strategies that impact increase growth such as exporting. Zimbabwe's policy planners also need to ensure that the economic, regulatory and legal, political, financial, trade environment is conducive and promotes firm size growth. Polices that ensure that firms have access to financial resources such as cheap loans and enough forex to pursue new growth opportunities can be expected to increase efficiency. According to the World Bank (2018) the high risk of adverse selection and moral hazard resulting from information asymmetry is a barrier to SMES accessing finance. Information asymmetry therefore stands in the way of small firms pursuing growth strategies. In developing economies due to lack of ''hard'' information to assess credit worthiness of firms ,soft information related to firm size is used to access credit risk at the disadvantage of small firms (World Bank, 2018). Credit reporting in Zimbabwe must be considered in order to increase information access and bank lending to small firms. Credit reporting helps banks to objectively evaluate credit worthiness through assessment of such characteristics as the borrower's characteristics, past behaviour, repayment history and current debt exposure (World Bank, 2018).

5.3.Foreign ownership

There are no apparent efficiency gains associated with foreign ownership. This entails local investment promotion should be given equal or greater priority as programmes to attract foreign investment. Investment incentives and policies should be geared towards promoting local investment in the industrial sector. Indigenisation policies in Zimbabwe when correctly implemented have the potential to improve efficiency in Zimbabwe's industrial sector. The land reform (agricultural indigenisation) in Zimbabwe is an example of a potentially good indigenisation policy that otherwise failed resulting in the collapse of the agricultural sector. The failure can be attributed to lack of capacity (financing and knowledge) by beneficiaries to effectively take over and run the businesses. The model of expropriation without compensation resulted in corrupt officials hoarding land they did not have to pay for. As a result, the country is sitting with large tracts of idle land. Indigenisation models should ensure beneficiaries pay for the benefit of owning resources to reduce the incidence of moral hazard, adverse selection and corruption in allocation of benefits. In order to be effective indigenisation policies should ensure that beneficiaries of the programmes have the skill required to run the business. Target beneficiaries can include indigenous people with experience working with or for businesses in the same industry. The government can also train target beneficiaries to run the businesses. Indigenisation programs also need to ensure beneficiaries have access to financing required to takeover and run the enterprises. Given that Zimbabwe is failing to attract enough FDI to revive the manufacturing industry, domestic investment therefore provides good alternative investment funding strategy. Domestic investment vehicles that the government can establish or promote to channel local investment into industry include sovereign wealth funds, equity funds and industrial development corporations (Weiss & Clara, 2016).

5.4.Location

This study found firms located in Bulawayo to be the most efficient in the country. The finding in show that Bulawayo is key to industrial revival. In the past, Bulawayo was the country's industrial hub contributing about 25 % to GDP in the 1990's. It is important that Bulawayo recaptures this position as Zimbabwe's industrial city given the city's proven potential to contribute to economic development. Bulawayo's special industrial zone status must be geared towards incentivizing firms to set up in Bulawayo. Incentives to consider include tax exemptions. Tax incentives should also be given to new manufacturing projects that use new and unused or abandoned manufacturing assets in Bulawayo (Deloitte, 2017). Many factories in Bulawayo are being used as churches due to abandonment.

5.5. Labour quality

Labour quality was found to enhance efficiency. Economic planners need to assess the human resource needs of the manufacturing sector in order inform education policies and curricula to be geared towards meeting the needs of the industry. Apprenticeship and technical high schools should be considered in order to produce industry oriented and ready graduates. The government can also enact policies to incentivise employee training in companies or simply pay schoolteachers more so that they can do a better job. Policies that make expenditure on relevant employee training and education tax deductible can be expected to increase efficiency in the industry. The finding also entails that management in the industrial sector must invest in continuous improvement of employees through training and education.

In response to Zimbabwe's economic crisis many Zimbabweans have left the country in search of better opportunities. According to UNDP (2006) over 3 million Zimbabweans the majority of whom are skilled professionals have left the country in search of greener pastures. The major push factors that have motivated the mass exodus of skilled labour in Zimbabwe include poor working conditions , low salaries , low job satisfaction and a hostile political environment (Shumba and Mawere ,2012) The mass exodus of Zimbabwe's skilled labour limits the ability of the country to deliver on its development goals . Given the important role that skilled labour has in enhancing efficiency, the government needs to enact policies to attract and retain skilled labour. Policies to attract and retain labour should address working conditions such as remuneration. In Zimbabwe, the government is the largest employer. Civil servants in Zimbabwe are one of the lowest paid in Africa with an average salary of less than 5000 US per annum. Remuneration in Zimbabwe is thus uncompetitive and lends itself to brain drain.

Therefore, the starting point for the government will be to pay civil servants' competitive salaries that compare well to neighbouring countries such as Botswana, Namibia and South Africa. These countries are the main destinations of emigrant labour in Zimbabwe

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APPENDICES

Appendix 1: Data used in the DEA and Tobit models

Firm ID	technical	scale	age	over draft	export	large	skilled	Foreign ownership	bulawayo
1	0.007	0.116	27	0	0	0	1	0	0
2	0.014	0.038	29	0	0	0	1	0	0
3	0.021	0.166	9	1	0	0	1	0	0
4	0.027	0.045	28	1	1	0	1	0	0
5	0.036	0.382	10	0	0	0	0	0	1
6	1.000	0.099	35	0	0	0	1	0	1
7	0.048	0.064	7	1	0	0		0	1
8	0.057	0.857	14	0	0	0	1	0	0
9	0.064	0.944	27	0	0	0	1	0	0
10	0.069	0.058	16	0	0	0	0	0	0
11	0.074	0.018	1	1	0	0	0	1	0
12	0.253	0.553	4	0	0	0	1	0	0
13	0.088	0.038	24	0	0	0	1	0	0
14	0.099	0.163	1	0	0	0	1	0	0
15	1.000	1.000	54	0	0	0	1	0	1
16	0.106	0.013	1	0	0	0	1	0	0
17	0.115	0.020	27	1	0	0	1	0	0

18	0.128	0.193	19	0	0	0	1	0	0
19	0.132	0.071	22		0	0	1	0	0
20	0.135	0.023	4	0	0	0	1	0	0
21	1.000	0.380	52	0	0	0	1	0	1
22	0.153	0.046	29	0	0	0	1	0	0
23	0.159	0.058	5	0	0	0	1	0	0
24	0.171	0.301	66	0	0	0	1	0	0
25	0.173	0.047	25	1	0	0	0	0	0
26	0.184	0.210	37	0	0	0	0	0	0
27	0.187	0.064	12	0	0	0	1	0	0
28	0.192	0.026	28	0	0	0	1	0	0
29	0.203	0.088	24	0	0	0	1	0	0
30	0.206	0.053	18	0	0	0	0	0	0
31	0.206	0.019	4	0	1	0	1	0	1
32	0.226	0.076	24	0	0	0	1	0	1
33	0.231	0.094	26	0	0	0	1	0	1
34	0.243	0.969	42	0	0	0	0	0	1
35	0.239	0.023	10	0	1	0	0	0	0
36	0.244	0.020	14	0	0	0	1	0	0
37	0.264	0.327	18	0	0	0	1	0	0
38	0.263	0.070	45	0	1	0	1	0	0
39	0.259	0.022	45	0	0	0	0	0	0
40	0.272	0.027	28	0	0	0	0	0	0
41	0.287	0.097	0	0	0	0	1	0	0
42	1.000	0.600	13	0	0	0	1	0	0
43	0.301	0.096	54	0	0	0	1	0	1
44	0.308	0.077	34	0	0	0	1	0	0
45	0.278	0.006	54	0	0	0	1	0	0
46	0.280	0.008	51	0	0	0	1	0	0
47	0.283	0.003	79	0	0	0	0	1	0
48	0.315	0.023	10	0	0	0	1	0	0
49	0.295	0.005	35	0	0	0	0	0	0
50	0.324	0.010	18	0	0	0	1	0	0
51	0.363	0.241	2	0	0	0	1	0	0
52	0.334	0.008	17	1	0	0	0	0	0
53	0.377	0.215		0	0	0	1	1	0
54	0.376	0.067	11	0	0	0	1	0	0
55	0.370	0.017	1	0	0	0	1	0	0
56	0.356	0.013	18	0	0	0	1	0	1
57	0.366	0.019	16	0	0	0	1	0	1
58	0.358	0.009	18	1	0	0	1	0	1
59	0.358	0.007	47	1	0	0	1	1	1

60	0.361	0.005	25	0	0	0	1	0	0
61	0.396	0.009	20	0	1	0	1	0	0
62	0.384	0.014	16	0	0	0	1	0	0
63	0.416	0.014	34	0	0	0	1	0	0
64	0.421	0.022	4	0	1	0	1	0	0
65	0.439	0.036	9	0	0	0	1	0	0
66	0.459	0.069	60	1	1	0	1	0	0
67	0.410	0.005	2	0	1	0	0	0	0
68	0.410	0.004	16	0	1	0	1	0	0
69	0.454	0.022	21	0	0	0	1	0	0
70	0.449	0.008	9	1	1	0	1	0	0
71	0.467	0.013	13	0	0	0	1	0	0
72	0.434	0.004	44	0	0	0	0	1	0
73	0.485	0.028	32	0	0	0	1	0	0
74	0.446	0.003	52	1	0	0		0	0
75	0.476	0.017	33	0	0	0	0	0	0
76	0.528	0.060	56	0	0	0	1	0	0
77	0.464	0.002		1	0	1	1	1	1
78	0.514	0.025	35	0	1	0	1	0	1
79	0.503	0.012	60	1	0	0	1	0	1
80	0.486	0.010	9	0	0	0	1	0	0
81	0.555	0.043	76		1	0	1	1	0
82	0.528	0.019	60	0	1	0	1	0	0
83	0.500	0.003	54	1	0	0	0	0	0
84	0.569	0.036	39	1	0	0	1	0	0
85	0.544	0.010	14		1	0		0	0
86	0.518	0.010	59	1	0	0	0	0	1
87	0.574	0.022	66	0	0	0	1	0	1
88	0.537	0.011	13	0	0	0	1	0	1
89	0.616	0.058	69	0	0	0	1	0	1
90	0.609	0.036	21	0	0	0	1	0	1
91	0.610	0.032	69	0	0	0	1	0	0
92	0.617	0.031	62	0	1	0	1	1	0
93	0.560	0.004	16	0	1	0	1	0	0
94	0.598	0.012	29	0	0	0	1	0	0
95	0.572	0.006	28	1	0	0	1	0	0
96	0.668	0.072	17	0	0	0	1	0	0
97	0.584	0.003	32	0	1	0	1	0	0
98	0.678	0.061	18	1	0	0	1	0	0
99	0.644	0.021	11	0	1	0	1	0	1
100	0.681	0.037	42	0	1	0	1	0	1
101	0.695	0.047	78	0	0	0	1	0	1

102	0.728	0.704	51		0	0	1	0	1
103	0.730	0.175	69	0	0	0	1	0	1
104	0.743	0.833	32	0	0	0	0	0	1
105	0.756	0.532	43	0	0	0	1	0	1
106	0.711	0.029	35	0	1	0	1	0	0
107	0.739	0.053	55	0	0	0		0	0
108	0.651	0.001	21	1	0	1	1	0	0
109	0.657	0.000	28	1	0	1		0	0
110	0.663	0.001	85	1	0	1		0	0
111	0.669	0.001	56	1	1	1	0	0	0
112	0.675	0.003	4	0	0	1	1	0	0
113	0.681	0.001	101	1	0	1	1	0	1
114	0.687	0.001	88	1	1	1	0	0	0
115	0.714	0.014	15	1	0	1	1	0	0
116	0.699	0.003	40	0	0	1	1	0	1
117	0.780	0.028	64	1	1	1	1	0	0
118	0.711	0.002	20	0	0	1	0	0	0
119	0.717	0.001	44	0	1	1	1	1	0
120	0.723	0.005	62	0	0	1	1	0	0
121	0.729	0.001	55	0	0	1	1	1	0
122	0.735	0.005	46	0	0	1	1	0	1
123	0.741	0.003	44	1	0	1	1	0	0
124	0.747	0.001	45	0	1	1	1	1	0
125	0.753	0.002	11	0	0	1	1	0	1
126	0.759	0.003	45	0	0	1	1	1	0
127	0.765	0.002	42	0	1	1	1	1	0
128	0.771	0.000	71	0	1	1	1	1	0
129	0.777	0.003	50		0	1	1	0	0
130	0.783	0.001	43	1	0	1	1	0	0
131	0.789	0.001	61	0	0	1	1	0	1
132	0.932	0.139	58	0	0	1	1	0	1
133	0.801	0.000	13		0	1		1	0
134	0.807	0.000	52		1	1	1	1	0
135	1.000	1.000	1	0	0	0	1	0	0
136	0.934	0.049	42	0	0	0	0	0	1
137	0.937	0.025	28	0	1	0	1	0	1
138	0.956	0.056	50	0	0	0	1	0	1
139	0.986	0.186	111	0	0	0	1	0	0
140	1.000	1.000	16	0	0	0	1	0	0
141	0.993	0.076	46	1	0	0	1	0	1
142	0.969	0.039	17	0	0	0	1	0	1

143	1.000	0.108	49		1	0	0	0	0
144	0.867	0.005	20	1	0	0	1	0	0
145	0.963	0.024	30	0	1	0	1	0	0
146	0.909	0.011	84	0	0	0	1	0	1
147	0.979	0.024	64	0	0	0	1	0	0
148	0.948	0.012	62	0	0	0	1	0	0
149	1.000	0.031	52	0	0	0		0	0
150	0.904	0.001	3		0	0	1	1	0
151	1.000	0.028	55	0	1	0	1	0	0
152	0.916	0.000	67	0	0	1	1	0	0
153	0.922	0.001	57	0	0	1	1	1	0
154	0.928	0.006	33	0	1	0	1	0	0
155	0.934	0.001	40	0	0	1	1	0	0
156	0.940	0.004	40	0	0	1	1	0	0
157	0.946	0.009	57	0	1	1	1	0	0
158	0.952	0.003	47	1	1	1	1	1	0
159	0.958	0.006	56	1	0	1	1	0	0
160	0.965	0.011	56	1	1	1	1	0	0
161	0.970	0.006	42	1	0	1	1	0	0
162	0.976	0.006	34	0	0	1	1	0	0
163	0.987	0.009	34	0	0	1	1	0	1
164	1.000	0.012	75	0	1	1	1	0	1
165	0.994	0.008	48	1	0	1	1	0	1
166	1.000	0.012	63	0	0	0	1	0	1

Appendix 2: A copy of the Stata output

```
2 . tobit vrste scale age q7a_3_overdraft q3b_11b_export large skilled q3a_4b_prifo

  Refining starting values:

  Grid node 0:   log likelihood = -10.430412

  Fitting full model:

  Iteration 0:   log likelihood = -10.430412
  Iteration 1:   log likelihood = -9.7989254
  Iteration 2:   log likelihood = -9.7952369
  Iteration 3:   log likelihood = -9.7952355
  Iteration 4:   log likelihood = -9.7952355

  Tobit regression                                  Number of obs     =        149
                                                       Uncensored     =        140
  Limits: lower = 0                                    Left-censored  =          0
          upper = 1                                    Right-censored =          9

                                                    LR chi2(8)        =      79.53
                                                    Prob > chi2       =     0.0000
  Log likelihood = -9.7952355                       Pseudo R2         =     0.8024

  ----------------------------------------------------------------------------------
            vrste |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
  ----------------+-----------------------------------------------------------------
            scale |   .2208802   .1014967     2.18   0.031     .0202281    .4215322
              age |   .0043724    .000975     4.48   0.000      .002445    .0062999
  q7a_3_overdraft |  -.0402293   .0506069    -0.79   0.428    -.1402757    .0598171
   q3b_11b_export |   .1049147   .0497161     2.11   0.037     .0066293    .2032001
            large |   .3087895   .0531821     5.81   0.000     .2036522    .4139268
          skilled |     .18535   .0924129     2.01   0.047     .0026561     .368044
   q3a_4b_prifore |  -.0955293     .07527    -1.27   0.206    -.2443329    .0532744
        bulawayo |   .1250243   .0470076     2.66   0.009     .0320935    .2179552
            _cons |    .138729   .0779003     1.78   0.077    -.0152745    .2927325
  ----------------+-----------------------------------------------------------------
     var(e.vrste) |   .0578306   .0070227                       .045488    .0735221
  ----------------------------------------------------------------------------------
```