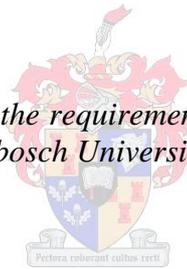


Technical and allocative efficiency in determining organizational forms in agriculture: a case study of corporate farming

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Declaration

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Abstract:

The optimal farm size and organizational form of agriculture is a widely discussed topic with little consensus as to which organizational form would be optimal under certain circumstances. There is often confusion as to what constitutes a corporate farm as well as a family farm, with the size of the farm often used as a distinguishing factor. This should however not be the case as there are many extremely large farms that are owner-operated within South Africa. The distinguishing factor should rather revolve around the management structures of these farms. It is these management structures that would seem to limit the metamorphosis of owner-operated farms into large corporate structures.

This thesis uses an analysis of both technical and allocative efficiency in determining the organizational form chosen within agriculture. It is shown in the thesis that farm size determines or improves the technical efficiency and this is brought about by the farms ability to stay abreast with the technological times by having “economies of size” to their advantage. The evolution of farm size would therefore seem to be driven by this need to obtain “economies of size” so as to be able to earn comparable wages to off-farm activities. The attainment of this technical efficiency however does not seem to be linked to the organizational structure of the farm; it is rather dependant of the size of the farm.

While the size of the farm is an important factor in achieving technical efficiency it is not as important in determining allocative efficiency, with various studies arguing that larger farms are less allocatively efficient than smaller farms. This reduced allocative efficiency seems to stem from various transaction costs and principle agent issues within the corporate setting that are not prevalent in the owner-operated farms. This is because in the owner-operated settings the family are the residual claimants to profit, which suggests that they do not have the incentive to shirk. The opposite is true for the corporate setting where the model is fraught with moral hazard and other issues of the principle-agent nature, which would seem to raise the transaction costs of this organizational form, and this has negative implications for the allocative efficiency with which these farms operate at.

This thesis therefore uses data obtained from such a corporate farm, where the owners of the farms are kept on as farm managers and the company makes all the production decisions. This thesis argues that it is these agency issues and transaction costs that hamper this organizational form while it is shown that the technical efficiency for these farms are high suggesting that economies of size are important in determining the technical efficiency of these farms.

Opsomming:

Die optimale plaasgrootte en organisasievorm in die landbou is 'n onderwerp wat al baie aandag in die literatuur ontvang het, maar waar daar min ooreenstemming is oor watter organisasievorm optimaal sal wees onder spesifieke omstandighede. Met die grootte van die plaas wat dikwels as 'n onderskeidende faktor gebruik word, is daar dikwels verwarring oor wat 'n korporatiewe plaas sowel as 'n familie plaas uitmaak. Dit hoort egter nie die geval te wees nie, want daar is baie groot plase wat as alleen-eienaar bedryf word in Suid-Afrika (m.a.w. familie-plase met gehuurde arbeid). Die onderskeidende faktor moet eerder die bestuur strukture van hierdie plase wees. Dit is hierdie bestuur strukture wat die metamorfose vanaf eienaar-bedryfde plase na (groot) korporatiewe strukture beperk.

In hierdie tesis word 'n ontleding van beide tegniese en allokatiewe doeltreffendheid gebruik in die ontleding van die optimale organisasievorm in die landbou. Die tesis bewys dat die plaas se grootte die tegniese doeltreffendheid bepaal of verhoog, vanweë die groter plase se beter vermoë om op hoogte te bly met tegnologiese ontwikkeling deur die "ekonomieë van grootte" tot hul voordeel te gebruik. Plaasgroottes pas aan by die geleentheidskoste van die eienaar-bestuurder en tegniese doeltreffendheid is nie afhanklik van die organisasiestruktuur van die plaas nie, maar is eerder afhanklik van die grootte van die plaas.

Terwyl die grootte van die plaas 'n belangrike faktor in die bereiking van tegniese doeltreffendheid is, is dit nie so belangrik in die bepaling van allokatiewe doeltreffendheid nie. Verskeie studies wys daarop dat groter plase minder allokatief doeltreffend is as kleiner plase, hoofsaaklik as gevolg van verskeie transaksiekoste voordele van klein plase. Maar daar is ook prinsipaal-agent kwessies in die korporatiewe omgewing wat nie algemeen by eienaar-bedryfde plase voorkom nie. Dit is omdat in die geval van die eienaar-bedryfde instellings die familie aanspraak het op die residuele wins, en dus 'n aansporing het om opdragte uit te voer. By korporatiewe plase is daar egter prinsipaal-agent probleme wat gepaard gaan met morele risiko ('moral hazard'). Dus het familieplase 'n koste voordeel oor korporatiewe plase.

Hierdie tesis gebruik dan data wat verkry is uit 'n korporatiewe boerdery onderneming, waar die eienaars van die plase die plaasbestuurders is en die maatskappy al die produksie besluite maak. Die tesis wys dat dit hierdie agentskap kwessies en transaksie koste is wat die organisasievorme belemmer terwyl dit blyk dat die tegniese doeltreffendheid vir dié plase hoog is wat daarop dui dat die ekonomie van grootte belangrik is in die bepaling van die tegniese doeltreffendheid van hierdie plase.

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Chapter 1: Introduction

Within the micro-economic theory of the firm there are two price considerations that firms face which govern their decisions about what to produce and how to produce it. These are the prices of the inputs and the prices of the outputs - determined by the market. These decisions are said to be made by the producer under profit maximizing and cost minimizing assumptions (Leibenstein, 1977). If the firm does not produce the level of output aimed for, or could have produced the level of output using less of the given inputs then there is a situation in which there is waste (Stigler, 1976). Waste would seem to be unavoidable in agriculture because of the difficulty in the optimal choice of inputs, *ex ante*, given the uncertainty about the season to come, *ex post*. Waste in agriculture can therefore either arise because the decisions of the producer could be flawed (allocative inefficiency), or the technique of producing these outputs could be flawed (technical inefficiency) (Stigler, 1976).

In the case of technical inefficiency this waste could present itself in the form of how well the inputs are used to produce outputs given the level of output produced and inputs used in producing this output such that excess levels of inputs applied would result in a low level of technical efficiency and subsequently wastage of inputs. Allocative inefficiency, on the other hand, would have an impact on the level of wastage via the incorrect proportions of inputs being chosen to produce outputs given the input prices and quantities used in producing the output. Although these types of waste are unavoidable in agriculture, the magnitude of these wastes however can be controlled for.

This level of waste would seem to be at the centre of the argument favouring the smaller family owned farm, especially with reference to allocative inefficiency. Numerous studies have found that family owned farms are more allocatively efficient than corporate farms while the converse is true for technical efficiency (Bojnec & Latruffe, 2013) (Liefert, 2005). Liefert (2005) argues that this is as a result of the higher flexibility of family owned farms in altering output levels as well as the input mixes in response to changes of both input and output prices (Liefert, 2005). This ability allows the farmers to react quicker to signals from the market and thus maintain profitability in an ever changing environment. It is because of this superior allocative efficiency that agriculture globally is based on a family farm model (Lipton, 2009). However, the advantage that flows from superior allocative efficiency alone does not explain the increase in the size of farms that is observed globally as soon as agricultural production starts to increase. This increase in farm size is better explained by a host of factors such as, amongst others, the opportunity costs of the farmers generated by off farm incomes, an aspect that will be further discussed later on in the thesis.

1.1 South African agriculture and farming organization

This trend of increasing farm size has also been prevalent in South African agriculture and according to Liebenberg (2012) the “*total farmed area grew from 77.6 million hectares in 1918 to a peak of 91.8 million hectares in 1960, declining steadily to 82.2 million hectares in 1996, where it has more or less stabilized since*” (Liebenberg, 2012, p. 29) . While the land

area used for farming purposes since 1996 has stayed at a relatively constant level the same cannot be said for the total number of farmers in South Africa. The total number of farmers according to Liebenberg (2012) has been “*declining at an average rate of 1.23 percent per year, so that by 2007 the number of farmers had dropped to about a third of the number that prevailed in 1953* (Liebenberg, 2012, p. 29).” This suggests then that the average farm has increased in size (ha) and a significant number of farmers have exited the industry.

This increase in farm size in South Africa could be explained by the well-functioning labour market that got encouraged. This is largely because of the opportunity cost that talented management faced. There were thus two ways of enticing this talented management to either remain on the farm or to start farming. The first was to corporatize farming, as was done on a large scale by the mining houses before mineral rights were separated from the ownership of land and they therefore did not need to own large tracts of land. The second was to either hire and exploit the abundant supply of labour or alternatively employ better labour management techniques suggesting that these farmers were good Human Resource’s managers, which is a largely neglected in the literature, or there was a combination between the two.

This increase in farm size and subsequent exploitation or improved Human management however was driven by the opportunity costs of the farm managers such that on-farm incomes could be comparable to incomes generated from off farm activities. It could thus be argued that it is this opportunity cost together with the ability to exploit labour that has encouraged the increase in farm size within South Africa. Resulting in farms that are thus for the most part owner-operated and grew into commercial farmers. These commercial farms in South Africa are regarded as “family farms”, this is not to be confused with the “family farm” in the international literature which are likened to subsistence farms in South Africa.

Commercial owner-operated farms produce goods for the market using own and hired labour, while small scale or subsistence owner-operated farms only intermittently produce a small portion of goods for the market, using mostly family labour and some hired labour, especially at harvest time when the demand for labour is high. Furthermore, while most of the labour input on commercial owner-operated farms does not come directly from the family, most of the supervision and management input does. It is therefore assumed that all commercial family farms produce goods for the market, and they use both hired and own labour in production.

1.2 Introducing the factors limiting corporatization

Various reasons are given in the literature to explain the endurance of the family owner-operated farm model¹. The first of these is that as residual claimants to profits, family workers will be more likely to work harder than wage workers, and these wage workers often require costly supervision (Deininger & Byerlee, 2012). Secondly owner-operators supposedly have intimate knowledge of the local soil and climate conditions that could give them an advantage in making management decisions (Deininger & Byerlee, 2012). Thirdly there are random shocks (including weather shocks) that limit the ability for specialization of

¹ In this thesis the nomenclature of family owned farms is used throughout to refer only to commercial farms, while small-holder or subsistence farms are ignored further.

these farmers (Allen & Lueck, 1998). Lastly family owner-operated farms are said to have considerable flexibility in adjusting labour supply with the seasonality and variability found in agriculture by easily reallocating effort to other tasks both on and off the farm (Deininger & Byerlee, 2012).

Allen & Lueck (1998) argue that it is the nature of the farm which prevents the smaller egalitarian “family farm” from tending toward the larger corporate farm. They suggest it is as a result of their inability to specialize² in certain aspects of production because the production process is characterized by short annual cycles. The result for the farmer is that his or her management time³ has to be split up to such an extent that they do not have the luxury of any form of true specialization⁴. This would imply that it is because of these factors that when crop cycles are short the farms would tend to stay smaller “family owned farms” in terms of both area as well as turnover, and not grow into large corporate farms, Allen & Lueck (1998). It is for this reason that fruit farms have tended to become bigger in both area as well as turnover, and even take on the form of large corporate farms (Allen & Lueck, 1998).

This would seem rather counterintuitive because in co-operatives the resources are pooled, while companies are thought to possess the ability to access better sources of finance. Why then would the family farm be superior to these organizational forms? Allen & Lueck (1998) argue that there are often considerable moral hazards that arise because of the inability of the company to accurately monitor or punish any negative outcomes, for example in the production phase the farm manager could decide to apply inputs to generate maximum output to the detriment of profitability. Because of the difficulty in monitoring and or punishing such unfavourable outcomes, the manager could blame any negative outcomes on poor weather conditions.

The result for the corporation that hires these farmers/managers to perform the farming duties is thus increased transaction costs. Buduru & Brem (2007) argue that it is these transaction costs⁵ that are bound to have an influence on the choice of the organizational form (Buduru & Brem, 2007). Crops with short cycles and many stages between the cycles⁶ are thought to generate even bigger transaction costs because of the affinity for moral hazards to arise between the principle and agent, perpetuated by the negative effects that environmental shocks can have on the output. These incentives and possible moral hazards are explained by technical and allocative efficiency as explained below.

If the farm manager is given the correct incentives to produce based on the correct use of intermediate inputs and fixed factors of production, given specialist advice, one could assume

² Allen and Lueck (1998) argue that “seasonal parameters (cycles, stages, and so on) limit gains from specialization and cause timing problems between stages of production” (Allen & Lueck, 1998, p. 346)

³ Management time in this instance is limited, in a quantifiable value (x hours/ day and x days per year) such that the manager’s time then has to be shared between all tasks on the farm.

⁴ Specialization in this case would be defined as at least 80% of one’s time being devoted to one aspect of production.

⁵ Buduru and Brem (2007) define transaction costs in this setting as “*the amount of resources used to establish and maintain property rights over assets*” (Buduru & Brem, 2007).

⁶ Allen and Lueck (1998) argue that since “*most farmers control several stages of production, such as soil preparation, planting, cultivation, and harvest*” crops with short cycles therefore limit the possibility for specialization (Allen & Lueck, 1998, p. 347).

that some level of specialization in crop production⁷ has been achieved. This would indicate that the incentives for production are correct and the technical efficiency would thus be relatively high. But if the allocative efficiency is low then one could assume that there are either incentive issues or moral hazards present.

These are because of adverse selection in choosing farmers to join the corporate farming model of Farmsecure that result in post-contractual opportunism. This generates a moral hazard and results in the principle agent problem (Allen & Lueck, 1998). These moral hazards therefore generate transaction costs (Allen & Lueck, 2000) which are perpetuated by short crop cycles and stages (Allen & Lueck, 1998) and the off-farm wage rate (Deininger, 2011). It is these factors that seem to be working in favour of the smaller family owned and operated farm and against corporatization.

1.3 Introducing productive efficiency

Following the work of Koopmans (1951), Debreu (1951) and Shepard (1953), Farrell set out to explain and predict productive efficiency. Farrell suggests that there was generally a failure to predict productive efficiency because it was considered adequate to measure the productivity of labour and use this as a measure of efficiency (Farrell, 1957). The obvious problem with this measure was the fact that it ignored all other fixed factors of production and other intermediate inputs save labour. The aim of Farrell's paper was therefore to create a framework to analyse firms that did not succeed in the optimization problem and compare them to "best practice" efficient frontiers that he decomposed into technical and allocative components using distance functions. This would allow the evaluation of the efficiencies of the firms that failed to either minimize costs or maximize profits relative to an "industry" frontier production function. A more complete discussion of these ideas and means of measurement will take place in Chapter 4.

1.3.1 Technical efficiency

Technical efficiency measures are used to determine how efficiently the farm managed to use their available inputs in producing a given level of output (Grazhdaninova & Lerman, 2005). In other words, technical efficiency determines whether the farm achieves maximum output using a given bundle of factors of production. Koopmans defines technical efficiency as a situation in which it is impossible to produce more of any output without producing less of some other output or using more of some input (Koopmans, 1951). Technical efficiency can therefore be either output maximising if using an input orientation or input minimizing if using an input orientation. These various orientations and applications will be discussed in Chapter 4.

1.3.2 Allocative efficiency

While technical efficiency is concerned with how well the farm managed to use their inputs to produce outputs, allocative efficiency is a measure of the farms ability to obtain maximum profit given the existing market prices for inputs as well as outputs, i.e. allocative efficiency measures whether or not the inputs are used in the optimal proportions to generate the

⁷ Specialization in crop production in this instance refers to the "specialist management" that is supplied and applied by the farmer.

maximum output given the market prices for both the inputs and outputs. Allocative efficiency would therefore give an indication of the farmer's flexibility as well as ability to alter production with the signals from the market. It is expected that in a corporate setting where bureaucratic processes limit the ability and flexibility to quickly alter production following changes in the market place, and where moral hazards that result from imperfect information in seeking farmers for the model, allocative efficiency of these farms is reduced, thereby favouring owner-operated farms.

1.3.3 Economic efficiency

Economic or cost efficiency of a farm consists of the above two components. This would indicate that if one of these two forms or types of efficiency were low this would have a negative impact on economic efficiency as this is the same of allocative and technical efficiency. Therefore in order to obtain economic efficiency both the allocative and technical efficiencies need to be at unity and the lower these two scores are the lower the economic efficiency would be. In order to improve economic efficiency the factors decreasing or limiting either technical efficiency or allocative efficiency need to be identified and rectified.

1.4 Objectives and importance of the study

In a study performed by Van Zyl (1996) on the total factor productivity of South African grain farmers, the frontier showed an interesting trend. As farms get larger they begin converging on the efficiency frontier even though he found that the total factor productivity (TFP) for these larger farms was lower than for the smaller farms. If this phenomenon is true, this would suggest that improved access to the market would allow the modern day farmer to specialize in the management of their farm by being able to elicit help from a wide range of industry specialists. This would imply that since most production decisions are made *ex ante* with the elicited help of specialists the farms could then be technically efficient in that if they follow the advice given to them they will achieve *ceteris paribus*, maximum output and by definition revenue. It is proposed then that any deviations from the frontier should be as a result of factors that are beyond the control of the manager. These would not be measurement errors, but instead factors such as weather and other acts of God.

If the technical efficiency is high because of the ability to hire industry specialists from the market place, how does "economies of size" influence this ability and subsequently technical efficiency, as well as the possibility for specialization on these owner-operated farms? Can this be used as an explanation for the ever increasing size of farms within modern day agriculture?

It is argued that short annual crop cycles result in moral hazards between the parties involved on corporately-owned and managed farms who rely largely on hired management⁸, and this is what decreases the allocative efficiency of the farms. In the family farm organization on the

⁸ It is important to remember that both the owner-operated commercial farms as well as the corporate farms rely largely on hired labour. The distinction between the two organizational forms would thus seem to lie in the amount of hired management the two different organizational forms rely on and not the size of the farm. That is commercial owner-operated farms rely largely on own or family management, while corporate farms rely largely on hired management, and this hired management generates the largest moral hazards for the corporate farms.

other hand they use family contracts (Allen & Lueck, 1998), and one could therefore assume that the family farm is not faced with these moral hazards or utility constraints. This is because in South Africa these owner-operated commercial farms do not largely rely on hired management and since the family are the residual claimants to farm profit they are not thought to behave in an amoral or opportunistic fashion. Thus how can agency theory and transaction cost theory affect allocative efficiency, and how could this be used to explain the organizational form chosen in farming?

It will thus be argued that because smaller farms are technically inefficient but allocatively efficient, with economies of size these owner-operated farms do have the ability to improve their technical efficiency, while the corporate farm is hampered by allocative and economic inefficiency and it is hypothesized that it is because of this fact that farms are not corporatizing. The objective of this thesis is therefore to contribute to the literature by using efficiency or inefficiency as a determining factor for the predominance of the owner-operated organizational form within South African agriculture by studying both the allocative and technical efficiency of a corporate farm. It is suspected that the family owned farm in the corporate⁹ setting is technically efficient, but it is the allocative and subsequently economic efficiency or inefficiency that has an impact on the organizational form chosen in agriculture.

1.5 Data

The study is performed on a privately owned corporation entitled Farmsecure Grains (FG) which is a subsidiary of Farmsecure Holdings, whose main purpose was to carry out primary production of certain field crops. In the 2011/2012 production season Farmsecure Grains decided to go into a form of partnership with various farmers in order to carry out the production of these field crops. The partnership was designed such that the farmers would contribute their farming experience and knowledge as well as the land and equipment for which they would receive a management fee in the case of their management time and rent for their land and equipment. FG would supply and pay for all other intermediate inputs and do the marketing for the produce, keeping the proceeds from such sales. If the venture showed operating profits over a five year period these would be shared equally between FG and the specific farmer concerned. The decisions as to what would be produced and where, however, was to be made by FG and various industry specialists and the farmers were to carry out FG orders and production decisions. This will be further discussed in Chapter 3.

The data used in this thesis was thus gathered from FG in the form of management accounts for the 2011/2012 production season, which had detailed financial information on the production for the various farms. This was cross sectional data with 51 farms spread out in six different areas of the maize belt in South Africa, namely the North West Province, the Eastern, Southern and Western Free State, Mpumalanga and Northern KwaZulu-Natal.

⁹ It is important to note that since only limited data was available the comparison between the efficiency of the group of farms within the Farmsecure model and the wider industry was not possible: the farms could thus only be compared to one another.

1.6 Organization of the Thesis

The thesis is thus organised as follows: The current chapter, Chapter 1, gives a general background to the South African owner-operated farms, and gives background information on the reason for the favourability of this functional form within South Africa. Chapter 1 also briefly discussed the data that will be used as well as established the concept of efficiency developed by Farrell (1957). Lastly Chapter 1 established firstly the objectives of the study and secondly the importance of the study within the field of knowledge.

Chapter 2 gives a review of theories and approaches that have been used to study firstly different organizational forms concentrating on the owner-operated, partnership and corporate organizational forms. Chapter 2 therefore attempts to isolate different studies that were relevant to this thesis, by seeing what effect these transaction costs and agency issues have on productive efficiency.

Chapter 3 gives a background to the company's model explaining the various obligations and expectations of the parties involved which was drawn from the contracts used. It also discusses the various aggregations of the variables to generate the production function which is then used to determine the functional form that best fit the data. Chapter 3 therefore also serves as a preliminary analysis of the data used for the empirical analysis in Chapter 4.

Chapter 4 discusses the various theoretical underpinnings of each approach used to model the technical and allocative efficiency of the various farms. These efficiencies are determined using both the parametric and non-parametric approaches in order to better generate variables that correctly measure efficiency.

Chapter 5 discusses the implications for the owner-operated and corporate organizational forms using the efficiency scores obtained in Chapter 4. This chapter draws on the various theoretical underpinnings and discusses the impacts of these transaction costs and principle agent relationships on the efficiency scores, and argues that it is these scores that would have an influence on the organizational form chosen. Lastly Chapter 6 concludes the findings of the thesis and highlights possible issues within the study. It also offers ideas for future research.

Chapter 2: Literature Review

2 Farm Size and Efficiency

There is a wealth of literature about the advantages of the family owner-operated farms (Johnson & Ruttan, 1994), (Schultz, 1964) and (Van Zyl, 1996). In Schultz's (1964) landmark study, *Transforming Traditional Agriculture*, he argued that smaller¹⁰ family owned farms were more efficient than larger farms. Similarly Van Zyl (1996) in a study done on South African grain farming found that on average small farms had a higher level of total factor productivity and was thus more efficient than larger farms. It is this apparent inefficiency of larger farms that is often suggested as a reason for the existence of the Inverse Relationship¹¹ (Oya, 2012), (Griffin, Khan, & Ickowitz, 2002) and (Heltberg, 1998), between farm size and productivity within agriculture.

Sender & Johnston (2004) argue that higher productivity¹² and efficiency of the smaller family owned farms is in most cases solely based on the productivity of labour by comparing the opportunity cost of family labour versus hired labour as well as the transaction costs involved. However, this idea often ignores the other factors of production. In the most recent studies total factor productivity (TFP) differences are taken into account, suggesting that the real problem lies in the differences in the quality of all inputs, not only land. To thus assume from competitive market assumptions that all inputs are homogenous in quality is to perpetrate a tautology.

The flaw in the argument would seem rather obvious and a key argument against the existence of the Inverse Relationship is that it often ignores differences in the quality of all intermediate inputs. This is said to then generate bias in the statistical analysis, and subsequently findings and recommendations (Sender & Johnston, 2004). For example, one cannot compare a sheep farm in the middle of the arid Karoo's productivity to the productivity of a sugar cane farm on the sub-tropical KwaZulu-Natal Coastline.

Similarly one should not be able to compare a one hectare farm to a one-thousand hectare farm. This could perhaps be because on the one hectare farm more intensive and unsustainable pressure could be put onto the environment to produce; this would lead to land degradation and subsequently economic degradation as a consequence. Or stated in another way with the inclusion of externalities, the function is not correctly specified to make provision for all the variables. Another important consideration is that family labour does have an opportunity cost, as members of the family are also faced with the decision of on or off farm employment, what-ever that employment maybe be. To therefore assume zero

¹⁰ There is seldom any reference to what constitutes a smaller family owned farm. The World Bank suggests that a smaller family owner-operated farm, relying mainly on family labour, is less than five hectares in the developing world.

¹¹ The inverse relationship suggests that productivity and efficiency with which farms operate decline with the size of the farms. That is that smaller farms are more efficient than larger farms.

¹² Griffin et al. state that "*Given that labour is abundant (and hence has a low opportunity cost) and land and capital are scarce (and hence have relatively high opportunity costs), small farmers have a higher total productivity than large and hence utilize resources more efficiently*" (Griffin, Khan, & Ickowitz, 2002, p. 286).

opportunity cost for family labour is not completely correct. Added to these important considerations is the fact that the majority of the factors of production are ignored in the analysis of the superiority of the smaller farm. It would seem then that a statement vindicating the superiority of a “small farm” over a large farm on the grounds of productivity and efficiency is somewhat unfounded.

Contrary to the idea of an Inverse Relationship within agriculture, farm size has constantly been increasing in most countries across the world, and various authors cite different reasons for this phenomenon. Deininger & Byerlee (2012) suggest that the major factors contributing to increased farm size have been the development of new technology that makes it easier to supervise labour¹³; high capital requirements of land clearance and infrastructure; and greater emphasis on integrated supply chains and certification of produce. Fandel (2003) argues that increasing competitive pressure has led to a change in both size and structure of the family owner-operated farm, to such an extent that farm sizes have been increasing because of this pressure.

Within agricultural economics, “economies of size” imply that there are certain advantages that larger farms have over smaller farms (Hallam, 1991). This constitutes another important argument for the increasing size of farms. One of the benefits of “economies of size” would be the farm’s ability to lower its costs of production (Duffy, 2009). This could be brought about by spreading fixed costs, by bulk purchases, and by marketing power (Duffy, 2009), therefore lowering the farm’s transaction costs which would provide a cost advantage for larger operations. This term however is often confused with “economies of scale” which has a very similar but at the same time a very different meaning in that “economies of scale” measures what the effect of inputs on outputs is i.e. what happens to output if all inputs are increased by the same proportion (Hall & LeVeen, 1978).

Deininger (2011) suggests that an important factor for the increase in farm size is increasing wages in the non-agricultural sector. The idea then is that farmers would seek to earn an on-farm income comparable to what they might obtain in the off-farm sector (Deininger, 2011). The result is that there will be a substitution of capital for labour which is made possible by recent developments and innovations in biotechnology, information technology and more productive means of working with the soil (collectively termed agronomic technology)¹⁴. Therefore, the better farmers who have the willingness and the ability to generate on farm wages equal to or better than off-farm wages, would grow in size while farmers who are not willing or able to achieve the same would perhaps exit the industry. This argument would therefore seem to rely on the effects of opportunity costs for the farmers, a key argument for the Inverse Relationship, which exists only when these opportunity costs are zero.

Management has thus developed, with the use of certain technological tools, the ability to effectively manage larger areas because standardization and or monitoring of processes have

¹³ Deininger and Byerlee (2012, pg. 707) suggest that “*The ability to have machinery operations guided by GPS technology rather than driver’s skills makes close supervision of labour less relevant while information technology can generate data to help better supervise labour*”.

¹⁴ Factors like variable-rate Global Positioning Systems (GPS) technology and access to soil laboratories for example.

improved (Deininger & Byerlee, 2012). The irony of the argument however, is that these farms often have to be a certain size before they are able to take advantage of these technologies. Larger farms will therefore have the ability to exploit modern technologies, giving these farms an added advantage over smaller farms who because of their size do not have the ability to take advantage of these technologies (Balmann, 1999), and therefore exit the industry where they are able to earn higher wages (Deininger & Byerlee, 2012).

Balmann (1999) suggests that because of path dependence, farm size has a larger bearing on the evolution of farm size than off-farm wage rates and it might be that, perhaps the relationship between farm size and off-farm wage rates is coincidental rather than causal as suggested by (Deininger, 2011) and (Deininger & Byerlee, 2012). This is because as farms get larger they have the ability to take advantage of economies of size, and thus better employ lumpy inputs such as management and machinery which together with biotechnology constitutes a large portion of the “technology” aspect discussed throughout the literature. Although it is perhaps possible for smaller farmer’s to do the same, one would expect it less frequently and perhaps management and management ability in that sense would have a larger impact on farm growth than “economies of size” or technology.

Another advantage of the “economies of size” for larger farms, is the ability of farmers to access credit and finance, which would have an impact on the farmer’s ability to carry the farm through difficult times (Heltberg, 1998) and (Mondelli & Klein, 2013). This advantage arises from the lower transaction costs of providing formal credit to the farmer. Deininger (2011) argues that since the size of the loan is bigger, the unit cost of providing the credit has decreased and this reduces the credit bias against the farmer.

Morrison *et al.* (2004) suggest that as a result of increasing costs (both fixed and variable), there has been increasing pressure for smaller family farms to grow bigger, as their economic viability has been constantly decreasing. This concept of economies of size and the benefits it infers would then seem to be a rather crucial determinant of the evolution of farm size over time. The advantages that “economies of size” infer is firstly the ability for these farmers to reduce unit fixed costs by spreading them over a larger and more diversified business, and secondly, by obtaining discounts on bulk purchases with lower interest rates for credit, the variable costs could also be reduced. Both of these factors improve the profitability of these farms. Furthermore as access to finance is easier for larger farmers they often have the ability to invest in technology such that they are on the leading edge of the technological curve, furthering the production advantage the larger farmer has over the smaller farmer (Deininger & Byerlee, 2012).

Balmann (1999) and Bechuck & Roe’s (1999) theory of path dependence as an explanation for the ever growing farm size is rather appealing, because larger farms have the ability to take advantage of their size they will continue to grow larger while the smaller farms who perhaps cannot interact freely within the market because of transaction costs will stagnate or even continue to grow smaller, and eventually be forced to leave the industry. Deininger (2011) and Deininger & Byerlee (2012) argue that it is the level of income that the farmer is

able to obtain off the farm that would explain smaller farmers exiting¹⁵ the industry. The increase in farm size then seems to be a vicious cycle that is almost inevitable, unless there is state intervention that puts a stop to this process.

Balman (1999) on the other hand suggests that sunk costs in production would have an impact on increasing farm size and this would increase competition for land. He uses the German milk quota market as an example to illustrate his point and states that “*the paradox situation arises that dairy farms rent quotas for up to a price of 40% of the yielded milk price although at the actual milk price (even without considering costs of quotas) most dairy farms are hardly able to cover their full costs*” (Balman, 1999, p. 18). There is little doubt that farm owners have been acquiring more land. However there is uncertainty as to the evolution of the organizational form of the farm. Therefore, given these reasons for farm size increasing, why are commercial farms staying family owned and operated rather than corporately owned?

Perhaps the answer lies in the alignment of objectives and incentives in production of the individual who is actually managing the production process. Liefert (2005) suggested that, during the central planning of Russian agriculture, the objective of the farm managers was not profit maximization, but rather achieving mandated output targets. As this had a negative impact on efficiency, it was often found that the managers lobbied for low-output targets with high input allocations (Liefert, 2005). As such, there was an obvious moral hazard present in the model, in which case the agent (farmer) had the incentive to understate his abilities, and the level of effort he applied throughout the productive process, and the principle did not have the means of detecting such behaviour (Allen & Lueck, 2000) and (Liefert, 2005). The implication was a deterioration of the manager’s incentives to attain economic efficiency.

2.1 Organizational forms in agriculture

Within agriculture, organizational forms can vary from the smaller family owned and operated farm to a public corporation with many anonymous owners. Allen & Lueck (1998: 347) define the purest family farm as an organization where “*a single farmer owns the output and controls all farm assets, including all labour assets*”, i.e. most of the labour input is supplied by the family members. On the other hand, the corporation is defined as the case where “*many people own the farm and labour is provided by large groups of specialized fixed wage labour*” (Allen & Lueck, 1998, p. 347). While the increase in farm size over time is an often cited fact, the optimum size and organizational form is not¹⁶.

The organizational form of the farm and which organizational form under which circumstances is best is a widely discussed topic in agricultural economics. Various reasons and theories are offered to try and answer these questions. However there is not much consensus as to which the best organizational form within agriculture would be, with equally compelling arguments both for and against the various organizational forms. We will therefore first discuss the main organizational forms within agriculture that are pertinent to

¹⁵ They are able to obtain higher incomes outside of farming in the labour market.

¹⁶ “*This is a traditional question about the “optimal farm size” and “optimal farm structure”, which has a long history in agricultural economics, in general, and in transitional economics in particular*” (Fandel, 2003, p. 376).

this study, namely family owner-operated farms and Corporate Farms, while at the same time taking note of some of the theoretical reasoning for certain organizational forms to prevail under certain situations.

2.1.1 Family owner-operated farms

In the previous discussion it was established that larger farms will continue to grow in size, and smaller farms will continue to shrink, the reasons being the off-farm wage rate for the smaller family farm and economies of size for larger farms (Antle, 1999) and (Deininger & Byerlee, 2012). It is thought that this trend poses a threat to the perseverance of the smaller family farm (Hurtig, 2003). Perhaps the difficulty lies in the definition of the smaller family owned farm, which is often defined by the use of family labour or by size (Lipton, 2009). It should strictly speaking be defined by organizational structure i.e. if the farm is owner-operated irrespective of the size it should be termed a family farm, while if there are partners it should be called a partnership and so on. Various studies suggest that the superiority of the family owner-operated farm is as a result of the family being the residual claimants to profit: in that case they will be less likely to shirk and therefore require less supervision than hired workers, who do have the incentive and the opportunity, given the spatial dispersion of agricultural production, to shirk (Deininger, 2011), (Breimyer, 1962) and (Berry & Cline, 1979).

Since the average farm size in South Africa is high by international standards, one can safely assume that not all the work is done by the family members. Therefore if they use hired labour these workers too would have the ability to shirk. The only difference between the commercial and corporate farm then is the reliance on hired management thus the size of the transaction and by implication the cost that is relevant (James, Klein, & Sykuta, 2011). That is the hired manager's wage and attributes compared to the general employee would be higher since the manager has a scarcer skill and would therefore command a higher wage.

The family owner-operated farm should therefore rather be defined by who makes the management decisions which would be the farmer/family in this case, and not the labour as the majority of the labour is supplied by wage workers. The result is that in the owner-operated scenario, the farmer would make all these decisions, and avoid moral hazard in the management of the business (James, Klein, & Sykuta, 2011). Deininger (2011) argues that because agricultural production has few technical (dis) economies of scale, a farm can consist of many different enterprises, something that is in any case common in South Africa with its poor natural resources. Any production forms could co-exist within the farm. This means that larger family owner-operated farms have the ability to diversify their enterprises, which enables them to spread costs over a larger asset base and in doing so reducing per unit costs of production.

The reduction of these costs means that these family farms are able to take advantage of all the benefits of "economies of size" (Antle, 1999) (Hallam, 1991) and (Helfand & Levine, 2004). "Economies of size" however are present regardless of the organizational form of the farm (i.e. family-owned, corporate or a partnership) and the presence or absence of these economies of size is a function of the size of the farm and not the organizational form of the farm.

Since large farms can be owner-operated, where the owner of the farm is also the manager of the farm, in the corporate setting this is not generally the case i.e. the manager of the farm is not the owner. The difference that separates the owner-operated organizational form from the others therefore is that the family owner-operated farm does not seem to be impeded by the potential moral hazard of hired management. This is a rather appealing explanation of the advantage of the family owner-operated farm over other organizational forms of farms. As a result of the inability of the owner (principle) to monitor or detect amoral behaviour from the farm manager (agent), the result is a moral hazard between the owner and manager which increases the transaction costs of running the farm (Boland & Marsh, 2006) and (Larsén, 2007), i.e. farms will grow to the extent of the farmer's management ability as well as the farmer's desired utility (Stigler, 1976).

Allen & Lueck (1998) attribute this to the lack of specialization¹⁷ and argue that when there are a low number of cycles in the farming process¹⁸ the gains from specialization are severely limited. Therefore the costs of extending the farmer's duties to adjacent stages would be lowered as a result of the importance of the timing between stages. Various studies have shown that it is for this reason that the family owner-operated farm would be the superior organizational form in the production of annual field crops (Allen & Lueck, 2000), (Deininger & Byerlee, 2012) and (Latruffe L. , Balcombe, Davidova, & Zawalinska, 2005). Allen & Lueck (1998) suggest that this is as a result of the possible moral hazards that arise between the principle and the agent in the form of either random production shocks, or seasonal parameters (cycles, stages and tasks). It is these moral hazards that they argue would limit the gains from specialization as well as cause timing problems between the stages of production, and thus favours the owner-operated farm as one individual makes all the management decisions.

They also suggest that when there are a large number of cycles, with long stages between the cycles, the farm has the ability to specialize and the monitoring of the various stages becomes easier (Allen & Lueck, 1998). Deininger & Byerlee (2012) seem to confirm Allen & Lueck's (1998) argument and they conclude that when the focus is on a single enterprise such as a perennial crop or intensive livestock production, there exists the opportunity to perform repetitive tasks and therefore to specialize. This is made possible by the fact that contracts can be made more complete, because it is easier to monitor the various stages. This reduces the transaction costs from the moral hazard to such an extent that the corporate farm becomes the dominant organizational form within agriculture (Allen & Lueck, 2000).

2.1.2 Corporate farming

Allen & Lueck (1998) argue that farmers cannot specialize in any specific task in the production of crops with few cycles. Crop farming thus favours the owner-operated farm over the corporate farm as an organizational form. On the other hand, Deininger & Byerlee (2012) suggest that many land abundant countries are characterized by rising investment in large-

¹⁷ Specialization is used here to mean specialization in a certain aspect of the farm process, i.e. either in production, marketing, or financial management, etc.

¹⁸ Cycles in this instance refer to the establishment of crops and the production thereof i.e. perennial or annual crops and not commodity cycles. See Allen & Lueck (1998) for a full discussion on the effects of cycles and the impact it has on specialization in agriculture.

scale farming based on a non-family corporate model, while Lipton (2009) finds that there hasn't been much change in the agrarian structure of farming in land scarce developed countries.

Deininger & Byerlee (2012) provide examples of large corporate farms in developing and transition countries to make their point¹⁹. Three out of five of the largest corporate farms in Latin America produce commodities with long cycles. This is as predicted by Allen & Lueck (1998) where they suggested that in agricultural production characterized by many cycles with long stages between the cycles, the farm organization would tend towards corporate ownership.

Allen & Lueck (1998) thus suggest that the more important specialization²⁰ becomes on the farm, the more likely that a corporate or partnership form of ownership will be chosen. However on an irrigation farm the principle would be able to reduce the moral hazard between itself and the agent by having the ability to specialize in a task; the irrigation scheduling for arguments sake. The ability of the principle to mitigate some of the uncertainty would then improve the ability to monitor stages, such that amoral behaviour of the agent could now be detected. It is for this reason that Allen & Lueck (1998) suggest that irrigation farms would tend to corporatize or form partnerships.

However these massive grain farms that are heavily reliant on significant capital stocks are obviously the exception rather than the rule. These farms seem to have worked particularly well under certain instances; this however has not been the case to a large extent in Africa (Eicher & Baker, 1992). Deininger & Byerlee (2012) suggest that this is probably the result of poorly established property rights. However since this thesis is on South African commercial farming and the property rights are generally well established, it shall be assumed that South African commercial farming behaves in a similar fashion to developed countries in that regard.

Deininger & Byerlee (2012) argue that if a country has well defined property rights it allows easy contracting, and this encourages the formation of corporate companies to farm on a large scale. The advantages these organizational forms have is their ability to freely transact with the market; i.e. they will have the ability to hire specialist labour at lower costs, as well as lower the costs of production due to the size of the organization, enjoying all the advantages of "economies of size" as discussed above (Deininger & Byerlee, 2012). As a result of this ease of access to the market, it is suggested that there will be feedback between producers and consumers. It is because of this feedback that James *et al.* (2011) argue that a tipping point in agriculture has been reached which has encouraged contracts and organizational transformation within agriculture.

These contracts are thought to encourage organizational transformation within agriculture and come in the form of either a marketing contract or a production contract (Allen & Lueck, 2000) and (James, Klein, & Sykuta, 2011). Under a marketing contract the producer and

¹⁹ See Deininger and Byerlee (2012) page 702, table 1.

²⁰ There is a significant level of specialization required in irrigation, and it is a widely studied field within Soil Science.

buyer negotiate prices and quantities before production begins. The production process details, such as planting date etc. are managed by the manager/producer (James, Klein, & Sykuta, 2011). A production contract on the other hand is a more tightly co-ordinated agreement such that the producer has far less authority over the production process, and the production methods are specified in much more detail by the parent company (James, Klein, & Sykuta, 2011).

Again the difficulty would seem to lie in the definition of a corporate farm, and it is assumed to relate to organizational structure and direct involvement in primary production rather than size and indirect involvement. Therefore marketing contracts should not be viewed as corporate farming, as in this case the farmer apply his or her labour and management and is contracted by a company which has investments in either upstream (intermediate input companies) or downstream markets (processing, value adding).

An example would be a flour milling company giving out marketing contracts to farmers for wheat; the farmer has the choice of either taking the contract or trading in the open market, involving a certain amount of risk. If a farmer accepts the contract they are then obliged to meet the contract with consequences should the contract not be met. The company can only design the contract such that the quality and quantity of the product is delivered at the end of the season using price as a reward or punishment. The company however cannot control or contract too far into the future because of risk, so that the farmer can therefore change contracts year on year and, since the farmer has full control over production, one could assume that he is an autonomous unit. Therefore under a marketing contract, one could not call the flour mill a corporate farmer as the firm is not directly involved with primary agriculture, but relies heavily on primary agriculture's output (Allen & Lueck, 1998).

Under the production contract on the other hand there are generally two forms used by corporate entities: either the cash-rent contract or alternatively the crop-share contract (Allen & Lueck, 2000). Allen & Lueck (2000) suggest that in cash rent contracts the farmer has the incentive to over-use the land and produce unsustainably, while with crop-share contracts the farmer has the incentive and the opportunity to shirk, while having less of an incentive to over-use the land. Therefore in order to ensure that agents take actions that maximize ownership interests, owners would have to invest in measurement and monitoring costs, also called agency costs (Elliott & James, 2013).

Numerous studies in the former Eastern European countries have all found that in general corporate farms²¹ did not perform well compared to owner-operated farms e.g. (Balman, 1999) for Germany, (Mathijs & Vranken, 2000) for Bulgaria and Hungary, (Fandel, 2003) for Slovakia and (Hockmann & Svetlov, 2006) for Russia. Agency costs and moral hazards constitute one of the three main reasons offered, for the dominance of the owner-operated farm as the predominant organizational form within agriculture these will all be discussed later on in Chapter 2.

²¹ Corporate farming in this sense uses mainly production contracts where the corporate is physically involved with the production process. The farmer does not have much authority in the production process, and thus acts as a true "manager" or agent.

2.2 Commercial farming: The dominant form in grain farming

There are reoccurring arguments within the literature that attempt to explain the persistence of family farms, or commercial farms in the South African context, as the predominant organizational choice of agriculture. These are transaction cost considerations (James, Klein, & Sykuta, 2011), (Allen & Lueck, 2000) and (Boland & Marsh, 2006), principle agent issues that present themselves in the form of a moral hazard (Allen & Lueck, 1998), (Mondelli & Klein, 2013) and (Boland & Marsh, 2006), or asset specificity (Deininger & Byerlee, 2012), (Hockmann & Svetlov, 2006) and (Allen & Lueck, 2000). In the remainder of the chapter we will consider the various theoretical considerations that are suggested as reasons for the perseverance of the commercial family farm as the predominant organizational form in South Africa.

2.2.1 Transaction costs

The overriding theme in the transaction cost²² approach according to Allen & Lueck (2000) is that patterns of ownership and contracts are chosen to mitigate transaction costs, which result from attempts to establish and maintain property rights. These transaction costs are perpetuated in agriculture by factors such as Mother Nature and the uncertainty in production she brings (Allen & Lueck, 2000) and (James, Klein, & Sykuta, 2011). Transaction costs arise because of the difficulty in monitoring the outcome because of the complexity of the biological production process and the inputs it requires, and this makes it difficult to detect certain amoral behaviour (Allen & Lueck, 2000).

Allen & Lueck (2000) argue that because all the goods involved in agriculture are complex and contain many attributes, they create an opportunity for transaction costs to arise for almost every single attribute. A good example would be that of land. Because of the various attributes of land, it is difficult to record all these attributes to document all these attributes, and lastly and most importantly to negotiate and implement prices to be paid for the land (Boland & Marsh, 2006). As a result, transaction costs are generated.

This is especially true if any circumstances change between the trading partners, as each trading partner would have the incentive to try and claim certain rents that a specific asset might have accrued, but is perhaps not due to them (James, Klein, & Sykuta, 2011). The transaction costs would then arise as a result of the governance structure attempting to dictate how the various prices and shares of the asset accrual are discovered and shared between the partners (James, Klein, & Sykuta, 2011). These price discoveries therefore often involve contracts between the principle and agent, and the more complex these assets or goods are the more imperfect the contracts between the parties become, resulting in increased transaction costs between the two parties (Allen & Lueck, 2000).

The organizational form chosen seeks to minimize these transaction costs, and it is for this reason that Allen & Lueck (1998) suggest that these transaction costs or lack thereof favours the owner-operated farms because grain farms have short cycles and infrequent tasks and are

²² Allen and Lueck (2000) define transaction costs as “the costs of enforcing and maintaining property rights—regardless of whether a market exchange takes place or not, and include the deadweight losses that result from enforcing property rights” (Allen & Lueck, 2000, p. 647)

subject to random as well as weather shocks making the monitoring of these various stages and cycles difficult. The result is that the transaction costs of contracting this uncertainty in production increases (Allen & Lueck, 1998). The advantage of the owner-operated farm could then perhaps lie in the management i.e. since it is assumed that in the owner-operated farm all the management decisions are made by the family, and since they are the residual claimants of profit they would not be faced with the same incentives to shirk as hired management (Allen & Lueck, 1998). The owner-operated farm would therefore be superior in this instance because the transaction costs are lower.

Therefore when considering the transaction cost approach it would seem to be important to remember that all individuals would only choose contracts or organizational forms that maximize their own expected value within the relationship (Allen & Lueck, 2000) and (Roberts & Milgrom, 1992). This does not necessarily have to be in the form of monetary gain however; instead it is dependent on the utility of that individual involved (Stigler, 1976). That is in every pattern of ownership there are various incentives that result in certain parties gaining at the expense of others (Allen & Lueck, 2000). Both the landowners and managers would therefore seek to mitigate amoral behaviour by altering the incentives given the various constraints, and the organizational form and contract chosen will be the one that lowers or has the lowest transaction costs (Allen & Lueck, 2000).

2.2.2 Principle-Agent theory

In the previous section it was shown that uncertainty results in increased transaction costs as a result of the difficulty in accounting for uncertainty in the contracts (James, Klein, & Sykuta, 2011), (Boland & Marsh, 2006) and (Allen & Lueck, 2000). In agriculture and specifically grain production this uncertainty can be caused by the weather and random shocks which, according to Roberts & Milgrom (1992), means that there is the potential for post-contractual opportunism between the parties involved. That is the agent has the potential to exploit²³ the principle because their level of effort is hidden by the uncertainty from the principle and this therefore generates a moral hazard between the parties involved (Allen & Lueck, 2000).

It is therefore said that under certain conditions of incomplete information and uncertainty there are two types of agency problems that can arise, those are adverse selection and moral hazard (Boland & Marsh, 2006). Adverse selection according to Boland & Marsh (2006) is the condition where the agent has asymmetrical information, and this makes it difficult for the principle to accurately determine if the agent is performing the tasks for which he is being paid. Allen & Lueck (2000) argue that this is because of the uncertainty generated by the weather that the agent can take advantage of the principle in several different ways. One of these many ways is that the managers could under-supply effort and blame any negative results on random weather patterns while the principle has no means of determining the actual cause of the negative outcome (Allen & Lueck, 2000).

²³ Roberts and Milgrom (1992, pg. 42) take a negative view of people and suggest that “*People will be very sharp in discovering even subtle ways in which they can advance their interests and that they will fundamentally be amoral, ignoring rules, breaking agreements, and employing guile, manipulation, and deception if they see personal gain in doing so*”.

Therefore if individuals only choose contracts or organizational forms that maximize their own expected value, the moral hazard²⁴ arises when their interests differ from the decision maker's interests and they have the incentive not report complete and accurate information to the decision maker (Roberts & Milgrom, 1992). It is obvious that this would limit the ability of management to make good decisions. The moral hazard in this instance would therefore be an information problem that is created by the difficulty or costs associated with monitoring amoral behaviour or the enforcement of actions against amoral behaviour (Roberts & Milgrom, 1992).

According to Allen & Lueck (1998) however, the owner-operated farm is able to avoid these agency problems, because as residual claimants to profits the family members would not have the incentive to withhold information or falsely report effort levels. Allen & Lueck (1998) argue that it is because of these moral hazards together with the lack in ability to specialize that the owner-operated farm is favoured above the other organizational forms in crops with short cycles such as field crops.

In a study conducted by Larsen (2007) in which they used questionnaires to determine the levels of trust between collaborating farmers, they found that if there is a high level of trust between the collaborating farmers their incentives to shirk may be eliminated, and they offer this as a reason for the relatively simple nature of the contracts within agriculture. However Larsén (2007) study could have had a bias in the questionnaire such that the respondents could have falsely reported their answers as to whether or not they found moral hazards in their existing relationships.

If this was so instead of the simple contracts in agriculture being explained by the lack of moral hazard (Larsén, 2007), it could be that there is a significant moral hazard, because the impacts of the actions that have efficiency consequences are not freely observable (Allen & Lueck, 2000), (Allen & Lueck, 1998), (Boland & Marsh, 2006) and (James, Klein, & Sykuta, 2011). There is therefore no point in trying to specify the way in which the farmer should behave, as this would involve enormous transaction costs (Roberts & Milgrom, 1992).

The principle therefore has to find methods and means of mitigating these moral hazards and Allen & Lueck (1998) suggest that it is for this reason that firms engage in agricultural production at either the beginning with the supply of intermediate inputs or at the end of the production process, while the owner-operated farms engage in and dominate the primary production process of agriculture (Allen & Lueck, 1998). An example of these firms could be the mill that gives out a marketing contract to the farmer. Although the company has very little say about the production decisions, the company to a certain extent controls these production decisions by paying different prices for quality as well as quantity. This would therefore create an incentive for the farmers to produce good quality commodities with high yields. The Global G.A.P standards in the fruit industry present a further example. Agency theory therefore suggests that the organizational form that best serves to squelch the moral

²⁴ Roberts and Milgrom (1992) define a moral hazard as “*the form of post contractual opportunism that arises because actions that have efficiency consequences are not freely observable and so the person taking them may choose to pursue his or her private interests at the expense of others*” (Roberts & Milgrom, 1992).

hazard through incentives and contracts will be the predominant organizational form in the industry.

2.2.3 Property rights

According to Agency theory managers can behave in an opportunistic way because of contractual incompleteness and asymmetrical information (Roberts & Milgrom, 1992). This generates a moral hazard between the principle and the agent and is used to explain the dominance of the owner-operated farm. Boland & Marsh (2006) however argue that it is because of property rights that this moral hazard arises and this is thought to explain the persistence of the owner-operated farms.

Mondelli & Klein (2013) argue this is important because when assets are highly specific to a project or enterprise they will have a lower value for other purposes and this subjects bondholders to opportunistic behaviour by the owner-manager of the farm (Mondelli & Klein, 2013). Therefore if property rights are absent Deininger & Byerlee (2012) suggest that there will be significant social and environmental risks for the strategies that employ these highly specific assets in production.

For example if a company hires land and management from the farmer, should the contracts need to be renegotiated the farmer who owns the assets has more bargaining power than the company²⁵, and the more complex and unique the asset or activities are the more disputes in need of renegotiation there will be (Boland & Marsh, 2006) and (Allen & Lueck, 1998). However since a considerable amount of resources are needed to establish and maintain these property rights in the renegotiation process, transaction costs become a determining factor in the success of the organizational form chosen (Buduru & Brem, 2007), (Hockmann & Svetlov, 2006) and (Deininger & Byerlee, 2012).

One of the greatest advantages that the owner-operated farm has over a company hiring land and using production contracts is that since the owner-operated farm has fully functioning property rights and relies predominantly on family management they have the ability to minimize transaction costs and squelch moral hazard between themselves (Allen & Lueck, 2000). However Allen & Lueck (2000) suggest that when the role of nature is diminished or the extension of seasons is possible, such as using greenhouses or orchards, the ability of the principle to monitor amoral behaviour and enforce their own property rights increases, and this favours the large factory style corporate farms.

There are thus three predominant theories within the literature that try to provide some form of explanation for the dominance of owner-operated farms within the production of agricultural goods that are characterized by short cycles, with few distinct tasks (Allen & Lueck, 1998). These are transaction cost theory, principle-agent theory and lastly property rights theory. It could be, however that all three of these theories determine the functional form within agriculture. In other words, because of the difficulty in property rights there are various contracts that need to be written to monitor behaviour and these create the

²⁵ This is because the owner of the land is the residual claimant to profits.

opportunity for post contractual opportunism. It is important to note however that what is cause and what effect is not known.

2.3 Efficiency of organizational forms

Technical efficiency is described by Koopmans (1951) as a situation in which it is impossible to produce more of any output without producing less of some other outputs or using more of at least one input. If the inputs are used to produce the maximum output obtainable with those levels of inputs, the farm manager uses her/his inputs well to produce outputs. Allocative or price efficiency on the other hand is the measure of the firm's success in choosing an optimal set of inputs to produce the output (Farrell, 1957). Therefore efficiency, both allocative and technical, seems to hang on the management ability of the farmers.

If the farmer does not have the management ability to know what the right amounts and in what combinations the inputs need to be used to generate the maximum amount of output given certain production constraints, one would not expect these farms to be producing outputs efficiently. These production constraints are generated by weather shocks as well as random shocks and while the owner-operated farms lack the ability to specialize, for the corporate farm there is a significant moral hazard that develops due to the fact that this management ability of the agent or manager in this case is unobservable (Allen & Lueck, 1998). Sarris *et al.* (1999) seem to confirm Allen & Lueck's (1998) argument and find that family run and owned farms are the most technically efficient followed by co-operatives and lastly by companies. In the next section, the effects of organizational form on both technical and allocative efficiency will be considered.

2.3.1 Technical efficiency

The impact of the organizational form on the efficiency of these farms is of considerable importance to this thesis, as inefficiency can have a drastic impact on both the profitability as well as the long term viability of any corporate farm. Contrary to the literature in support of the Inverse Relationship (Berry & Cline, 1979), there have been numerous authors who have found that there is a positive relationship between farm size and technical efficiency (Bojnec & Latruffe, 2013), (Deininger & Byerlee, 2012) and (Latruffe L. , Balcombe, Davidova, & Zawalinska, 2004). Helfand & Levine (2004) found that there is a U-shaped curve for economic efficiency with decreasing efficiency up to about 500 hectares, and then increasing efficiency up to 10-20 thousand hectares. It would seem then that these large farms do have the ability to be technically efficient.

According to Deininger & Byerlee (2012) and Bojnec & Latruffe (2013), these high technical efficiency scores are attributed to preferential access to services such as credit and extension services. This improved access to credit and extension, according to Bojnec & Latruffe (2013) results in the farmer's ability to employ capital intensive production techniques and suggest that this affinity for capital intensive production coupled with the ability to employ external factors such as rented land and labour add greatly to the technical efficiency of these large farms.

This can be expected because larger farms have better access to machinery and other technology, helping them to more timeously attend to the various tasks on the farms. It could

also be coupled to the fact that larger farms have better access to the various markets and have the advantage of being able to afford transport, as well as solicit the skills of various industry specialists such as agronomists in this scenario. While larger farms are more technically efficient than smaller farms the organizational structure of these farms is not often discussed in the literature.

With regards to the technical efficiency of the organizational form of the farm Fandel (2003) found that for farms in Slovakia, owner-operated farms were more technically efficient than agricultural co-operatives in crop and crop and dairy production. Similarly, Mathijs & Vranken (2000) in an empirical study performed in Hungary and Bulgaria, found that on average owner-operated farms were more efficient than co-operatives who were in turn less efficient than corporations or companies. These findings were similar to the predictions made by Allen & Lueck (1998): due to the potential for moral hazard the owner-operated farm would be the predominant form in the production of field crops with a low number of cycles and other production processes that limit the ability of the farmer to specialize in any certain aspect of his farm. Contrary to these findings however, Skold & Popov (1992) found that the technical efficiency scores for collective and state farms in the Stavropol region of Russia were high, and they concluded that eliminating inefficiencies in production would not increase the outputs of these farms.

In line with the predictions of Allen & Lueck (1998) however, Fandel (2003), Latruffe *et al* (2004) and Deininger & Byerlee (2012) all found that on average co-operatives and corporations were more efficient in livestock production. Allen & Lueck (1998) argue that because livestock production has many production cycles the ability to specialize increases and the moral hazard can be avoided as a result of the ability to better monitor the various stages in production. It is as a result of this ability to specialize that the technical efficiency of these farms would be improved; however the allocative efficiency of these farms is also of utmost importance, and will be considered next.

2.3.2 Allocative efficiency

According to Bojnec & Latruffe (2013), the second component of economic efficiency is that of allocative efficiency which, contrary to technical efficiency and very much in line with the Inverse Relationship, has a negative relationship with size. That is small farms are less technically efficient but more allocatively efficient and profitable than larger farms. The overall effect on economic efficiency however is positive, which would suggest that large farms are more economically efficient than smaller farms (Bojnec & Latruffe, 2013).

Within economic theory the production-allocation decisions are a set of constrained optimization problems, i.e. producers will optimize their objectives to certain constraints that are imposed by the production technology (Cherchye & Van Puyenbroeck, 2007). This is of course assuming that the farmers are profit maximizing and secondly that they have no incentive to not use resources inefficiently, i.e. they are guided by a set of prices within the market place and do not have any incentive to shirk. Liefert (2005) therefore argues that the raising of the allocative efficiency of input use requires flexibility of the managers in altering output levels as well as the input mixes in response to changes of both input and output prices.

For the corporate farm it could be that these assumptions are not applicable, and this would result in the moral hazard between the parties that Allen & Lueck (1998) advocate. The result would be allocative inefficiencies for these farms. Bojnec & Latruffe (2013) seem to confirm this result and they argue that allocative efficiency is reduced when farmers resort to external factors of production, i.e. hired land and labour.

An example of this allocative inefficiency of corporate farms is rent. A company that doesn't own land and has to rent the land should view land as an input into production and not a factor of production. This is because firstly they do not own the land and secondly they have to compete in the market place for land. As a result it is suggested that land rent would have an effect on the allocative efficiency, as there is an optimal proportion of the total input cost for land that can be achieved. The same can be said for hired management.

Therefore, if the producers are hired managers and not owners one would expect the manager or agent to maximize his own objectives and not those of the principle. As shown before, this results in a considerable moral hazard between the contracted parties. One of the possible reasons for the low allocative efficiency of input use according to Liefert (2005) is poor decision-making by farm managers, which is complicated by the corporate structures and this limits the flexibility of the managers. This argument is confirmed by Cherchye & Van Puyenbroeck (2007) who found that the managers directly suggesting the wrong input mixes were an important source of inefficiency for East German farms.

It is argued then that all the stages within the cycles, in this case, could generate a moral hazard between the two contracted parties in the various stages of production. It is suspected that it is these moral hazards that have a large impact on the allocative efficiency at which these farms operate. The short stages in this case could be viewed as the symptom and the moral hazards generated the cause of these symptoms. This problem is perpetuated by the difficulty in monitoring any unfavourable behaviour of the agent which generates considerable transaction costs between the two contracted parties which would have a negative impact on the allocative efficiency of these farms.

From the above discussion it can be seen that there are various factors favouring the family owned, or commercial farm in the South African context. The majority of these benefits are derived from the owner-operated farms ability to avoid certain principle agent issues and transaction costs. There are also factors that favour the larger farms and these are mainly derived from the size of the operation, and these extremely large farms are generally thought to be corporate farms. It is important to remember however that it is not the size of the farms that determine the organizational form; it is rather the management structure. Therefore the owner-operated farm that has the ability to take advantage of "economies of size", would be expected to be both technically and allocatively more efficient than a corporate farm.

Chapter 3 describes the data that was used in this thesis, while Chapter 4 serves as the empirical analysis. This empirical analysis will determine both the technical and allocative efficiency with which these farms operate, with the hope of identifying in line with the above literature certain issues inhibiting the corporatization of crop farming.

Chapter 3: Data sources

3 Introduction

Chapter 3 will firstly discuss the Farmsecure Optimized Farming model so as to give the reader a bit of background on the model that is going to be analysed throughout the remainder of the thesis. Secondly the data obtained from the company and used in the thesis will be discussed whereby the various aggregations and statistical tests used will be explained. Lastly the preliminary data analysis will be performed on the data; this preliminary data analysis will then be used in Chapter 4 to determine the allocative, technical and economic efficiency with which the various farms operate at.

3.1 Introducing the Farmsecure Optimized Farming Model

The Farmsecure group is a privately owned company that was founded in 2004 on four operational principles. These were Scientific Farming, Working Capital, Risk Mitigation and Price guarantee (Farmsecure Holdings, 2013). Between 2004 and 2011 the Farmsecure group provided finance to farmers, offering the farmers input finance and using the crop on the land as security for the funds. These farmers were required to take out multi-peril insurance, where the insurance companies would issue a percentage guarantee of the long term yield i.e. if the farmer's long term average yield was 4 tons per hectare and the insurance guarantee was 60% of the long term yield, Farmsecure would thus provide finance up to 2.4 tons per hectare. The grain produced would thus be delivered on behalf of Farmsecure to the Co-op, and Farmsecure would thus generate their income from providing finance as well as the selling of grain.

After the 2010/2011 season the Farmsecure group decided to go into an agreement with selected farmers from the Contract Growers (CG) model into what would be known as the Farmsecure Optimized Farming (FOF) model. The idea behind this new arrangement was that Farmsecure Grains (FG) would mandate certain farmers based on specific selection criteria to conduct farming activities for and on behalf of FG as the principle farmer on the cropland. The company thus decided to move towards primary agriculture so as to be able to fulfill their vision or mission statement which was to be *"a meaningful contributor to securing the world's food supply by creating sustainable and profitable agricultural enterprises, where the process is optimized from 'farm to shelf'"* (Farmsecure Holdings, 2013). With this the contractor (farmer) was to, on the date of commencement, discontinue occupying the land on his own behalf and instead occupy the land on the behalf of FG. These were not forced sales however and the arrangement was entered into willingly by both parties. This sustainability for the farmer was thus derived from the company's ability to obtain discounts on the majority of the farms inputs by owning input companies²⁶.

²⁶ The main input companies under the Farmsecure banner included amongst others Kynoch fertilizers who provided the fertilizer for the farmers as well as Intellichem who provide amongst other things the chemicals for the farmers.

Together with these input companies Farmsecure Holdings owned a grain marketing or trading company known as Farmsecure Global Markets. The company also had other subsidiaries such as Farmsecure Agri Science (FAS) who employed roughly 140 agricultural scientists from eleven different fields including Agronomists and Soil Scientists amongst others (Farmsecure Holdings, 2013). The idea behind the FOF model was thus to optimize each transaction in the value chain as in their mission statement “from farm to shelf”, with the company taking a cut from each link in the chain. These farmers would thus to act as an agent of FG in the sense that the farmers were to carry out the day to day running of these farms on behalf of FG who decided on what was to be produced at what time, and how the produce was to be marketed. The advantage for the farmers was thus to an extent “risk free” production as the company paid for all of the farmers running costs, but not their overhead costs such as machinery finance and so on. They were however remunerated for the usage of their machinery via a contractor’s fee as well as for their land via rental agreements. Lastly the farmers were remunerated for their management via a management fee which will be discussed later on.

Farmsecure in the year of study 2011/2012 rented roughly 90 000ha of crop land from 51 different farmers, and produced grains such as soya-beans, white maize, yellow maize, sunflowers and to a lesser extent peanuts. Farmsecure thus provided an integrated and holistic service with various subsidiaries under the Farmsecure banner. These subsidiaries for the most part operated internally and each made profits one way or another out of the farming operations i.e. FAS would do consulting work for FG and FG would pay FAS for the services. With the high level of expertise within the organization most of the focus was on producing or maximizing output, which does not necessarily relate to or result in profitability which is a common misconception.

The company’s focus was thus put onto the technical aspects of agricultural production, while assuming that the incentives for all of the parties involved would be aligned with the broader goal of the company i.e. if the farmers had the incentive to encourage maximum yield as they got remunerated for doing so, while the input companies also had the incentive to aim for maximum output and thus input usage as they had a name or reputation to build. This was all carried out at the broader expense of the company as in trying to achieve their goals of maximizing output; they neglected the profitability side of their operations. This will be shown later on with the efficiency study of these farms, as it will be shown that the technical efficiency of these farms is relatively high while the allocative and subsequently economic efficiency of these farms is not.

The farmers joining the model could thus to an extent have been considered to be “risk averse” as the majority of the production and marketing risk was absorbed by the company. The financial standing of these farmers prior to the study was unfortunately not known to the Author, however from the discussion of the selection criteria discussed later on it could be assumed that there were a few relatively strong farmers in good financial standing as FG did target the more prosperous farmers in certain regions so as to create a positive stigmatism about the model. This will be discussed later on.

3.2 Farmsecure Optimized Farming Framework Agreement

The selection criteria were to a large extent subjective in the sense that farmers who were identified to be trustworthy, certain farmers were identified by FG based on their ability to work with FG over a longer time frame without intensions of being dishonest thus requiring less supervision, would go over into the new model. The other criteria for selection were based on geographical location, where farmers were chosen that farmed in an area best suited to the crops FG wanted to be grown; mainly maize, soya-beans and sunflowers. Farmsecure Grains also selected a few large farmers as they believed they were prominent members in their communities as well as the broader farming communities. For example, some of these farmers won the SA grain farmer of the year competition; these farmers were assumed to create a positive impression about the group so as to encourage other farmers to join the model.

The farmer however was not appointed by FG as a representative or employee of FG. The agreement was thus not intended to constitute a partnership between FG and the farmer in question. It was structured in such a way that it meant, amongst other things neither party would be liable for another party's debts incurred in any way, other than that specified by the agreement (contract) between FG and the farmer.

With regards to employment and labour on the specific farms, the responsibility of employing suitably qualified and experienced staff to conduct farming activities was placed upon the farmer and, per the contract; the farmer had an obligation to do so. These employees were to remain the responsibility of the farmers and FG would not accept any responsibility for such employees if given orders and or instructions by the farmers. The employees of these farmers were to be paid by the farmer who would then be reimbursed by FG. This in short meant that the farmer would be responsible for the employee's and FG would foot their labour bill, and there was no means of guarding against the over-employment of labour on these farms.

The farmer was thus kept so as to conduct the farming activities on the cropland by applying their skills and expertise. This would be done by applying their farming know how and manage their human resources by applying best farming practices. The agronomical services and advice however was to be carried out by the Agronomical team (FAS) on behalf of FG. The Agronomical team (FAS) together with FG would draw up these production plans by having inputs into each stage of the production. These are as follows:

3.2.1 Planting Season

Farmsecure Grains would have the sole and exclusive right to unilaterally determine which lands would be planted to what, and after these decisions had been made the seasonal production plan as well as the seasonal budget would be amended accordingly.

3.2.1.1 Management and Accounting Procedures

The Farmer's would then meet with a representative of FG on a monthly basis to discuss the management accounts and to compare the seasonal budget with the actual expenditure/income and monitor the progress of the crop in terms of the seasonal production plan and agronomical reports. This was carried out to an extent to monitor the farmer.

3.2.1.2 Best Farming Practices

The Agronomical team was thus appointed to perform agronomical services for and on behalf of FG in accordance with the seasonal production plan; these included but were not limited to:

- The planning of the Planting Season;
- Pre-plant inspection;
- Emergence inspection;
- Progress inspections;
- Pre-harvest inspections; and
- Crop Yield estimates.

The agronomical teams therefore advised the company as to the levels of inputs to be applied and the company applies the levels and types of inputs recommended. The decisions as to the operations of the farms were not given to the farmers rather they were structured in a corporate fashion involving various processes.

3.2.1.3 Marketing and Hedging of Crop

Throughout the season, with regards to pricing, marketing and hedging of the crop, FG had the sole right to and was obliged to determine and establish the price at which the entire Crop was hedged and/or sold at. This right was to be exercised with reasonable care and expertise to ensure that the crop was hedged and/or sold at the best price possible under the current circumstances.

3.2.2 Payment

The payments were to be structured as follows; Farmsecure Grains would pay for the various inputs into production, directly to the suppliers of such inputs, as well as pay rental for land as well as machinery calculated in various ways, this was to be either paid on a monthly or yearly basis. Farmsecure Grains on top of these payments to be made for the inputs would pay the farmers for their efforts in the form of a management fee or contractors profit, for the work he had done on the farm.

The work the farmer was required to do on the farm to earn this management fee and contractors profit was to ensure that the best farming practices were carried out during the season; these included but weren't limited to:

- The timeous preparation of the Cropland for the planting of the Crop;
- The establishment of the Crop in correctly prepared soil with sufficient moisture;
- Clearing the lands of weeds by sufficient spraying and/or hoeing;
- The application of sufficient pest control to safeguard the Crop;
- Assisting Farmsecure Grains and the Agronomical Team with the harvesting of the Crop speedily, adequately and efficiently at the due time;
- Only if directed by Farmsecure Grains, to assist with the delivery the Crop to the silo or storage facility, and
- Any further practices which the Farmsecure Agronomical Services may, in its sole discretion, prescribe from time to time.

The farmer was also obligated to protect the crop against theft, damage, disease, pests, parasites, bacteria and viruses. Below is a discussion and description of calculations made for the various fees and rentals the farmer would receive.

3.2.2.1 Contractors Profit (Management Fee)

The farmer was to receive a “contractor’s profit” or management fees which was a predetermined amount per ton of yield delivered. This amount was predetermined based on the type of crop grown and the amounts for the different crops were as follows;

- Maize: Yellow and White R 300/ton produced,
- Soya beans R 550/ ton
- Sunflowers R 600/ton;

These amounts were to be paid by FG in three installments based on the Long Term Average Yield (LTAY). These payments were structured in such a fashion that there would be two advance payments and one final payment and these payments were calculated on the following basis;

An advance payment of one third would be paid out upon the opening of the season, and this payment was determined according to the LTAY, another advance payment of one third was to be paid out seven days after the crop emergence, this payment was to then be calculated on the actual yield estimated after emergence of the crop, this was amongst other things based on the stand or percentage of the plants that actually germinated, and would be adjusted upwards or downwards to accommodate for any variances between the LTAY and the crop yield estimate.

The remainder of the contractor profit was to be paid thirty days after the harvesting and delivery of the crop and after the actual Yield was determined. This payment was to be calculated on the actual yield, and the amount would be adjusted upwards or downwards to accommodate for variances between the crop yield estimates and the actual yield delivered, this was then adjusted for any under or over payment received by the farmer with regards to the second payment made to them. However if the farmers were over paid so that the value they received after the second payment was more than they should have received after the third payment, i.e. the crop estimates were horribly off, the farmer was not required to pay back the deficit.

3.2.2.2 Profit Sharing

Together with the above mentioned Contractors Profits (management fees), the farmer was entitled to an additional profit sharing, if any, after the completion of the fifth planting season as set out in the contract. These profits according to the contract were to be determined as follows;

By deducting (i) the expenses incurred in terms of the Seasonal Budgets over the first to fifth Planting Seasons; (ii) the contractor’s profits paid out in the description of the management fees above over the first to fifth planting seasons; and (iii) any seasonal losses carried over from planting season to planting season over the first to fifth planting seasons. The farmer and FG would each be entitled to half (50%) of the Additional Profits.

3.2.2.3 Losses

With regards to any losses that might have occurred from season to season, the losses together with accrued interest were to be carried over to the next planting season, and if these losses were incurred the farmer would not be liable for any proportion of such losses, and the farmer would be entitled to have access to the accounting records used to determine the additional profits or losses. In the event of the farmer disputing the additional profits or losses the farmer could at his own expense, be entitled to have it verified by an independent auditor.

3.2.2.4 Rental of the Land

The Cropland was to be let to FG for the purpose of farming activities and the rent of the crop land was to be determined in the following fashion. Should the farmer be held by a current rental agreement with a third party, FG would simply take over this rental contract and pay the amount agreed upon before FG came onto the scene. For the farmer's own land a negotiation process was entered into and a fair rental for both the farmer as well as FG was aimed for. In many instances the rental was market related however in many instances this was a price floor as FG stated that they would not pay less than this. Another method used to calculate a fair rental value was that the rent would equal the amount of monies the farmers would be able to borrow from the bank against this land. For example it was said that the farmer would be able to get finance to the value of 50% of his entire lands value over a ten year period, and FG would thus pay rental equal to the repayment required for such a loan at the prime interest rate, this value however was a price ceiling for land, and FG would have paid some value between these two values for the rental of this land.

This seasonal budget would be revisited by both FG as well as the farmer on a yearly basis, and in the contract it states that the rental may be revisited. In the event of a failure to revise the seasonal budget the rental amount in the last agreed upon seasonal budget would be deemed to be the rental payable until such time that the seasonal budget be revisited between the two parties. The cost of water, electricity and or gas used on the cropland was to be paid directly to whoever provided such services and would be borne by the farmer.

The farmer at his own expense would be responsible for maintaining in good order and condition the infrastructure, and promptly repair or make good any damages to the infrastructure. If the farmer failed to carry out any of his obligations of maintenance and repair in terms of the contract, FG would be entitled to cause the necessary maintenance or repair to be carried out and then recover the reasonable costs from the farmer on demand.

3.2.2.5 Rental of the Equipment

The farmer was appointed by FG as an independent contractor to conduct the farming activities on the croplands to produce the entire crop for FG as well as to manage and operate the croplands. This would be achieved by FG ensuring that the farmer had the necessary equipment to enable the farmer to perform the farming activities by paying the farmer a usage fee for the use of the farmer's equipment.

This usage fee was to be determined in the following fashion; the rental was set at eight percent of the machines value, and five percent of the implements value. This was then paid to the farmers as rental for their equipment. The repairs and maintenance as well as the diesel

for these machines were also paid for by Farmsecure, and so the eight and five percent of value was only paid for the usage of the machines and implements respectively. Also taken into consideration when determining these amounts was the farmers ability to furnish the repayments for such machines, i.e. the values required for hired purchase agreements from banks was also taken into account (HP is over 5 years and the calculations are determined over 10 years thus paying double for the machines) when deciding on a fair value to be paid to the farmer for the usage of his machines.

The duration of this rental agreement would be on a yearly basis after which the contract would be reviewed and renewed thirty days prior to the expiration of the agreement. Once an agreement between the two parties had been reached, the farmer was to discontinue using the equipment on his own behalf, and commence doing so for and on behalf of FG.

The farmer was thus solely responsible for and would bear the full costs of the regular servicing of the equipment per the normal servicing plans. There was however an amount set out in the seasonal budget to be paid by FG for the repairs and maintenance and the farmer was to be, within limits reimbursed for the monies spent on such repairs and maintenance. The farmer was however responsible for and obligated to keep the equipment insured. This was changed later as the farmers misused it.

3.2.2.6 Production Input Costs

Production input costs was for the purpose of the contract mean to be the amount that FG would pay in accordance with the seasonal budget. This budget specified the administrative fees, the contractor's profits (management fees), the maximum production input costs, the amount paid in terms of the equipment usage agreement as well as the amount to be paid in terms of the rental agreement. This budget was to be revised on an annual basis before the opening of every season by the parties concerned.

Farmsecure Grains would during the course of the agreement pay the production input costs set out more fully in the seasonal budget, and the payments were to be paid out on behalf of FG directly to the suppliers of the farmer unless the seasonal budget expressly stated otherwise.

3.2.2.7 Replanting

Should the need for replanting have arisen, the farmer together with a representative from the Farmsecure Agronomic team would jointly decide whether the crop had to be replanted during the course of the season. This decision was still heavily dependent on the decision made by the representative of the Farmsecure Agronomical team, as it stated in the contract that should the decision be given timeously and justified in accordance with the best farming practices in the area by the Farmsecure representative be made not to replant, and the farmer carried on with the replanting of the crop, the farmer would be replanting the crop at his own risk and expense.

3.2.2.8 Rights and Obligations of the Farmer

The farmer had various rights and obligations to FG as will be discussed in this section. With regards to land owned and leased by the farmer, they were to disclose all farming activities

conducted on such land. They also had to offer and make available all of their agricultural properties to FG for the inclusion in the rental agreement as cropland. Farmsecure Grains in their sole discretion was to accept the offer to include such properties as it deemed suitable for the inclusion as cropland. It was also stated in the contract that for the duration of the contract, the farmer would conduct all farming activities on the cropland exclusively with FG. The farmer was thus prohibited from conducting for his own account or in terms of any commercial agreement with a third party, any farming activities that were the same as those conducted in the agreement, on any property for the duration of the agreement.

3.2.2.9 Alienation or Addition of Property

Thus for the duration of the contract between FG and the farmer, the farmer would not be entitled to alienate, dispose or encumber the crop lands and/or equipment in any way by means of mortgage or bond without the written consent of FG. In the event of the farmer wanting to hire additional property for inclusion as cropland, the farmer would need to make a request to FG in writing, and FG would in its sole discretion decide whether to include such additional property as cropland and on what terms and conditions the property would be included.

3.2.2.10 Ownership of Crop

Once this was determined it was established that the ownership of any crop planted by or on behalf of FG on the cropland for the duration of the agreement should pass to FG on severance from the cropland irrespective of how or by whom or on whose behalf it was severed before or after the termination of the contract. The farmer thus had to confirm that upon severance of the crop from the cropland it would hold, receive and take delivery and possession of the crop for and on behalf of FG, and no third party would have a claim on such harvest. Farmsecure Grains would also have the exclusive right to the Cropland during crop resting periods, and the Contractor would not be entitled to allow livestock to feed on the Crop rests without prior written consent of Farmsecure Grains.

3.2.2.11 Harvesting and Delivery

The crop was only to be harvested in the presence, and under supervision of an authorized representative of FG and or the Farmsecure Agronomical team, and FG would ensure that such a representative be available in a timeous fashion to supervise the harvesting of the crop. To monitor the yields it was stated that FG would be entitled to equip all harvesters that are used to harvest the crop with a yield monitor to be installed at the farmer's expense.

The farmer would thus as a representative of FG hold, receive and take delivery and possession of the harvested crop for and on behalf of FG as the owner of the crop. It was also stated that when the farmer received authorization by FG in writing, the farmer would deliver the harvest, or assist in the delivery of the harvest, at the times and places of delivery as directed by FG. This delivery was to take place in the name of FG, and the silo certificates were to strictly be in the name of FG. The farmer was to inform FG without delay of such deliveries, failing which the farmer would be held liable to FG for payment of any additional costs associated with failure to do so. Any payment received by the farmer for and in respect of the delivered crop, was to be immediately paid to FG and any attempt to harvest or deliver the crop in such a way that deprived FG from the benefits of the crop would constitute a

criminal offence. The purpose of this clause in the contract was to oblige the farmer to deliver the tonnage of the entire crop, by trying to limit the capacity for any deviation or unfavorable behavior on the farmer's part.

3.3 Data

The data used in this dissertation was gathered from FG in the form of management accounts, which had detailed financial information on the production for the various farms. This was cross sectional data with 51 farmers spread out in six different areas of the maize belt in South Africa, namely the North West Province, the Eastern, Southern and Western Free-state, Mpumalanga and Northern Natal. The data was measured and recorded in the 2011/2012 production season and the management accounts therefore included only one year's worth of production records, making the data one dimensional.

The next step was to edit the data; this was done so as to remove errors and or outliers that would seriously affect the end results of the efficiency analysis to be performed on the data. This step involved identifying outliers and or errors in the data in the form of either typographical errors, or observations that were unusual. There were not many of these errors however and in total five typographical errors were found and corrected accordingly. Other data editing that took place was that of the aggregation of the various outputs, and in most cases inputs as discussed below.

There were five different types of outputs produced by various farms, these were white maize, yellow maize, sunflowers, soya-beans and in some cases peanuts. The majority of the farms however produced either white and or yellow maize and the other three crops mentioned either made up a small portion of the farming activities or were not produced by the farms at all. Since the amount of farmers that produced Soya-beans, Sunflowers and Peanuts were in such a minority, these outputs were all added using their weights in the form of the total productive area as well as their respective prices, so as to be able to compute one output per farm for all of the farms.

The aggregation of the outputs was made easy by the fact that the management accounts had detailed accounting information for the various quantities of the specific crops harvested as well as the prices received for their respective commodities. That is, there was detailed price and quantity information available so as to be able to combine the value of these products using the output price and quantity vectors respectively and, because of the fact that the data was cross sectional; there was no need to deflate prices. The output was thus calculated in the form of total revenue earned by either the whole farm or on a per hectare basis if the total output was to be divided by the total area of production.

The reason for aggregating these outputs was simply because not all the farms produced all the commodities, and in most cases the largest portion of production for any given farm was the production of either white or yellow maize, or a combination thereof. The aggregation of these various outputs then gave a weighted value of revenue per hectare that the various farms produced, and it was assumed that it would be better and easier to analyze the various farms from the same base. Another important reason for calculating the output in this way was because of the way the management accounts for the inputs were prepared.

The management accounts calculated the value of inputs applied as an overall average value as well as a value per commodity. However in the process of calculating the farm inventories, if there were certain inputs left over after the planting season, the value of the input left over was subtracted from the total value of the input. That is say for example a farm produced 1000 hectares of yellow maize, 200 hectares of soya-beans and 300 hectares of sunflowers and there was 100 tons of fertilizer leftover after the planting season, this amount was subtracted in equal shares as opposed to proportional shares from each enterprise. This then seems to affect the total amount used by each enterprise, as the specific usage of the input then gets “crowded”²⁷ by the total and or final amount reported. This possibly tends to understate the share of the left over inputs of the largest enterprise, while over stating the share of leftover inputs of the smallest enterprise. Although this is an acceptable measure in accounting, this is not a useful measure in efficiency analysis. Therefore by aggregating these values the chances of errors as mentioned above as well as typographical errors was reduced as there was less chance of incorrectly subtracting inventory from any specific enterprise.

The management accounts were therefore very helpful in the sense that they contained detailed information on the area of land hired and planted, as well as the amounts paid for the various inputs applied to this land. That is they contained information on the average level of inputs applied (R/ha) for the production of the total output, and these values per definition took into account both the price paid for the inputs as well as the quantities of the various inputs applied. It was assumed that the difference between the amounts paid for inputs by the various farms could be attributed to the difference in quality of the inputs used, especially for the intermediate inputs such as fertilizer and chemicals. This assumption was safe to make as all the inputs were acquired from input companies owned by Farmsecure, and thus all the prices for the various products would be assumed to be the same, and any difference in price would be as a result of the formulation or quality of the product being applied.

The advantage of working with the data in this form is that you take away the various complications of having many different outputs and variables, which in some cases tend to be collinear, and you combine them into one making the comparisons between the farms possible, as now you are measuring and comparing everything from the same basis. That is for an aggregated output at a Gross Margin per hectare level.

The disadvantage however is that because of the fact that the data is represented in such a manner there is a difficulty in identifying efficient farms from inefficient farms. This is partly because of the fact that the units of measurement become very unspecific as a result of the various varieties of the inputs that are being used. It would thus be suggested that quantities as well as prices be recorded in future so as to be able to identify the inefficient farms, by being able compare both the amounts of inputs used in the production as well as the prices paid for the various inputs in production.

Being that as it may, these variables were then split into the following subsections; Directly Allocatable Variable Inputs and Indirectly Allocatable Variables Inputs. In doing so, it was

²⁷ Crowded in the sense that the true amount of input used to produce that commodity cannot be determined as the leftover inputs are pooled together and subtracted from the total amount of input used, and not in the same proportions as the crops planted.

hoped that it would facilitate the identification of the possible variables to be used firstly in the production function, and then secondly to identify variables that could potentially be used in the Cost Function when trying to establish both Technical Efficiency (te), and secondly Allocative Efficiency (ae), so as to try and identify possible issues with the model. The variables were grouped into the following sub-headings;

- Directly Allocatable Variable Inputs: Chemicals (R/ha), Diesel (R/ha), Fertilizer (R/ha), Seed (R/ha), Precision (R/ha), Labour (R/ha), Land Rent (R/ha), Machinery Rent (R/ha) and Lime Corrections (R/ha).
- Indirectly Allocatable Variable Inputs: Management Fees (R/ha), Hedging Costs (R/ha), Crop Insurance (R/ha), Silo Costs (R/ha), Admin Costs (R/ha), General Expenses (R/ha), Contractors Fee's (R/ha), Repairs and Maintenance (R/ha), Accounting Fee's (R/ha) and lastly Interest (R/ha).

This distinction seemed the best, because of the difficulty in assigning non-directly allocatable variable costs directly to the production of various outputs. It was thus assumed that the production function would be best represented by the directly allocatable variable inputs, which include the original factors of production as well as intermediate inputs into production, simply because without these variables production is not possible, or it is severely diminished.

Similarly for the non-directly allocatable variable costs (Indirect Expenses), such as the management fees paid to the farmers, these costs are just as important to production from the company's perspective, and it is these variables that have a large bearing on the profitability of the model. These variables are thus used together with the directly allocatable variable costs in the determination of the cost function, and later on the determination of allocative efficiency of the farms.

The distinction between the above variables is made because of the fact that in many cases the non-directly allocatable inputs, contributed roughly half of the total costs of production, and it was thus assumed that leaving these costs out of the efficiency analysis of the various farms would be a grave mistake that grossly underestimated the true allocative efficiency of the various farms in question. Although the data from the management accounts, was perhaps not specific enough in certain aspects, such as those of detailed price and quantity information of the intermediate inputs. It could be that these values or hectare amounts of the various inputs could be a better measure to use in the efficiency analysis of Agriculture, especially in the production of field crops, because of the industry specific pre- and co-requisites of the use of certain inputs.

3.4 Inputs used in the Production Function

The inputs to be used in the production function encompassed the original factors of production, which were land in hectares as well as price paid for the land i.e. land rental, and labour. The price paid for the land or the land rental was assumed to be indicative of the market for land in the specific area, as well as a quality adjusted value, as represented by the area in which the farming activities were to take place. That is land in the Eastern Freestate for example was cheaper than land in the Western Freestate, and within districts certain farms

were cheaper than others, and it is because of this fact that it was assumed that the price paid for the land was a good reflection of the market for land, as well as the quality of the land to be hired.

It is important to remember however, that only crop land was to be hired, and thus land that could be too steep to farm, or any other inhibiting factor to crop production was not taken into account, and thus the only differences in quality between the farms would be as a result of differences in soil quality, and not physical aspects of the farms per se. The farms in the broader sense could thus be viewed as being heterogeneous with regards to the soil quality of the specific farms, however they are relatively homogenous in the sense that only crop land was to be hired, and thus all geographical differences between the farms could be to a large extent ignored.

The labour measure used in this case was the amount paid out to the workers on the various farms. This was taken as an amount paid out per hectare, and it encompassed the presence or absence of farm managers, which might not be an ideal measure. However since the type of data was collected from the management accounts, this was the nearest estimate to the amount of labour used in production, and any assumptions made around this fact to try and decompose the labour bill lead to issues in the regression analysis such as multi-collinearity. Data deconstruction with regards to labour was thus to a large extent not possible. That being said, it was still assumed to be a relatively good measure because of the fact that the total value paid out in wages was a quality adjusted value that took into account both general farm workers as well as farm managers. Therefore it was a reflection of the total use of labour into the production of the output, even though the exact distinction between the two different types of labour, i.e. blue or white collar labour was not or could not be determined.

Intermediate inputs into production included inputs such as fertilizer, chemicals, seed, lime corrections and diesel. Diesel was used together with the value paid for the hire of machinery or the use thereof. This was done because of the fact that the use of diesel without machinery is not to a large extent possible, and similarly machinery use without diesel is also not possible. The diesel was used because of the fact that an accurate measure of firstly the kilowatts (KW) or size of the tractor fleet was almost impossible to determine from the available data, and thus it was assumed that the diesel use coupled with the value of machinery rent would be a better and more accurate measure of the machinery used in the production of the outputs.

Another intermediate input used in the analysis of the production function, and subsequently the determination of technical efficiency was that of “precision”. This was a service supplied to the grain farms by one of the mother company Farmsecure subsidiary companies Farmsecure Agri Science. This was taken to be a directly allocatable or intermediate input, because of the fact that the advice offered by these industry specialists was for each productive unit or on per hectare basis. It was therefore assumed that this was a form of specialized labour used in the production of the various crops.

An important point to take into consideration is the use of capital inputs into production, which generally poses a problem. This is because of the fact that capital items generally

represent stocks, while intermediate inputs are flows. Thus it is generally necessary to calculate the service flows that are generated by the capital stocks, and these generally include the depreciation on the capital stock plus the running costs. The problem with assets, and the correct selection of assets to be used and accounted for in the FOF model, is thus either an extremely difficult or easy concept to consider.

It is a difficult concept to consider if one tries to identify, what the actual assets employed are, however if one considers the following it suddenly seems to make the distinction somewhat easier. If the company hires the land as well as machinery from the farmers, and pay different prices for these (one assumes because of quality), the reality is that perhaps the company does not view these investments as assets, rather they view these investments as inputs into production. It was therefore assumed that the difference in price would provide a quality adjusted measure for both the machinery used as well as the land rented. Therefore this measure of “capital” was again measured in an amount per hectare format, and it was this value that was used in the efficiency analysis of the farms.

3.5 Preliminary data Analysis

The variables used in the determination of the production function are summarized in table 1 below. Table 1 shows the maximum, minimum and mean values of the variables for the sample, as well as the standard deviations for the year in question. There is generally plenty of variation between the variables, and this is a positive result as it allows for estimation. The large standard deviation (as measured by a per hectare amount), would tend to indicate a high level of heterogeneity surrounding the production decisions of the various farmers. Therefore when running the analysis, it was also important to keep in mind that there is quite possibly a high level of heterogeneity between the various farms in the model; this is as a result of the farms being in different areas facing different weather conditions and having differing soil characteristics. It is important to remember however, that because of the fact that the data is cross-sectional, panel-data techniques were of little consequence and time was thus assumed to have random effects that produce only variance and not bias, and this is the variance upon which the analysis was done.

Table 1: Summary Statistics for the Production Function variables

Variable	Observations	Mean (R/ha)	Std. Dev. (R/ha)	Min (R/ha)	Max (R/ha)
Output	51	8413.01	3427.33	1619.70	15742.25
Land	51	1046.67	659.46	310.44	3592.36
Labour	51	421.00	179.31	135.14	1017.01
Precision	51	117.26	85.08	0.00	347.99
Fertilizer	51	1984.16	601.18	833.17	3479.61
Seed	51	822.42	292.33	297.53	1578.20
Chemicals	51	647.29	333.51	139.13	1556.64
Machinery	51	757.04	484.64	125.13	2207.31
Diesel	51	835.13	217.02	252.28	1345.40

The large variation between the variables, as well as the relatively large differences between the minimum and maximum values could possibly be as a result of varying weather conditions, between the production areas. This could be expected because of the fact that there is such a vast difference in the areas with which the grains are produced. The Output is measured in R/ha and is simply calculated by dividing the total income the farms received by the area produced on the farm as discussed above. The same can be said for almost every

single other input used in the production function, and as can be seen from table 1, the amounts paid for the various inputs also vary widely from farm to farm, and this could again be as a result of the area these farms are producing in, as well as the types or varieties of the inputs being used in the production by the various farms.

Since the variables are being reported in a value per hectare or R/ha amount it could be assumed that these variables are quality adjusted, as is reflected by the price paid for the labour and land. Other intrinsic differences such as the slope of the land or the quality of the soil might not be a completely reflected in the data, as the price could be indicative of the area that the land is being hired in rather than a true reflection of the quality of the soil.

In the case of FOF however, this could be slightly different, as it was written in the contract that only crop land was to be hired, and secondly an agronomic team was to be used, and thus it was assumed that they could improve the soil quality, maybe not to exact levels as a result of the innate differences between the farms, but improve it none the less. It is therefore safe to assume that the soil qualities of farmers in similar areas would be of a similar standard. Similarly for the use of inputs applied, this was an aggregated measure of different types of inputs, which may vary in quality as well as composition, and thus price. From an agronomic perspective in crop production, this is to be expected, as plants have certain requirements of certain elements at scientifically determined rates, and this is determined by the quality and type of soil being cultivated, this will be discussed later on in the dissertation.

Table 2 below completes this preliminary analysis of the data by reporting the correlation coefficients for the various variables that were to be used in the determination of the production function, and subsequently the determination of the technical efficiency of the various farms in question.

Table 2: Correlation Coefficients for Production Function variables

	ouptut	land	labor	precis~n	fert	seed	chem	machiner	diesel
ouptut	1								
land	0.2687	1							
labor	0.5225	0.0654	1						
precision	-0.1728	0.1719	0.013	1					
fert	0.5437	0.3999	0.2393	-0.1691	1				
seed	0.4174	-0.0195	0.3179	-0.3181	0.4574	1			
chem	0.4505	-0.1337	0.3928	-0.1143	0.3081	0.637	1		
machiner	0.3438	-0.1009	0.3737	0.1282	0.1135	0.1386	0.3134	1	
diesel	0.13	-0.0858	0.0299	-0.2159	0.1148	-0.0227	-0.1555	-0.0345	1

From table 2, it can be seen that the majority of variables are behaving quite well. Variables such as land and labour seem to be behaving in the manner expected, in the sense that they are positively correlated with the output. The only variable that is negatively correlated with output is that of precision. This for the most part does not make sense, as one would expect the precision farming to be enhancing production, not the opposite as is observed. The negative correlation between precision and the other intermediate inputs also makes sense as one would expect the amounts of inputs being used to decrease with an increased use of precision farming. However since this is a service which is supposed to lead to the optimal use of these inputs perhaps the inputs have been reduced too much which would possibly explain the negative correlation with production. The diesel is another variable that is not really behaving, in the sense that it is for the most part negatively correlated with quite a few

variables for which diesel is used to apply, especially seed and chemicals, and more importantly the use of machinery and land. That being as it may for the most part the variables are positively and more importantly correctly correlated with the output. This is what is expected, as it is these fixed factors of production, and various intermediate inputs that one would expect with the production of field crops *per se*.

Cross-sectional data with limited observations however, presents some immediate restrictions or limitations as to the level or types of analysis that can be performed on the data. Tests or inferences made about the effects that time would have on the results cannot be made because of the fact that the estimation of time series is not possible. An option however is to attempt to estimate the production function by estimating the specific year, in the cross-section, for which we have data. This approach however could be hampered because of the fact that the sample size is rather small with only 51 observations.

Keeping that in mind then, the production function is investigated by using the aggregated output measured against the use of both the fixed factors of production as well as certain intermediate inputs, into producing this output. This will hopefully enable the decision between the uses of the functional form that will best describe the production function, i.e. is the data set best described by a linear relationship, such as the restrictive Cobb-Douglas, or is it better described by a more flexible functional form such as the Translog? This will be discussed first, after which the technical efficiency for the various farms will be determined by using both the parametric (Stochastic Frontier Analysis) and non-parametric (Data Envelopment Analysis) approach while discussing the advantages and disadvantages of using both methods, as well as the interpretation their results.

3.5.1 Production Function

Since all the data are recorded for the 2011/2012 production season running from August up until August the next year, it was assumed that no inputs or outputs crossed over into the 2012/2013 season, and therefore it was not necessary to lag any of the variables. It is because of this fact that from the company's perspective, any costs incurred or revenue realized during the production season would be accurately reflected in Gross Margin analysis at the end of the financial year. Keeping this issue in mind the variables that were to be used in the production function are discussed below.

The variables used in the analysis of the various farms' production were a subset of all the variable inputs into the production, because the variables were divided into their respective groups as discussed above. The production function explains a single output with all the important inputs used in the production of this output. Since there are in some cases four outputs, these outputs need to be aggregated as to have a larger number of observations in the sample. The output was thus a combination of all the quantity of output produced multiplied by the price received for the various outputs produced by the farm, this value was then considered to be an aggregate output produced by the farm, and could be calculated back into a per-unit (per hectare) value by simply dividing the aggregated outputs of each farm, by their respective land areas. This is a necessary step in the analysis of the data, as now comparisons are possible across farms, as suddenly the measure of outputs is the same for each of the farms, as this was not the case prior to aggregation.

The variables used in the production function were taken to be the directly allocatable variable costs or what we shall call “productive inputs”, in the sense that they contribute directly to the production of the output. These were assumed to be as follows in-line with agronomic norms and necessities;

- Land Rent (R/ha),
- Labour (R/ha),
- Precision (R/ha),
- Fertilizer (R/ha),
- Seed (R/ha),
- Chemicals (R/ha),
- Machinery Rent (R/ha),
- Diesel (R/ha),

In using the variables this way there was not much construction of the data required save that of aggregating the input as well as the amounts paid to produce a hectare of maize equivalents as discussed earlier on in the chapter, and the correlation between these variables is shown in Table 2.

It is important to note however, that before this analysis was performed, the log of all the variables was taken. The advantages of such an approach are the following; 1) logged models are invariant to the scale of the variables, since they are measuring percentage changes; 2) they give a direct estimate of elasticity of the variables; 3) for models with $y > 0$, the conditional distribution is often heteroskedastic or skewed, while $\ln(y)$ is much less so, and lastly 4) the distribution of $\ln(y)$ is narrower, and this tends to limit the effects that outliers might have even though the data was edited for outliers. For these reasons, throughout the thesis the log of the variables is used in the analysis of the data.

Apart from the advantages of using the logarithms above, this approach was also followed because of the fact that, if these variables are assumed to be linear in logarithms, the coefficients that are then calculated can be interpreted as the elasticities of these variables in producing the output because the units of measurement have been removed. That is if the elasticities or coefficients were to sum up to one, it would imply constant returns to scale, and a one per cent increase in the inputs would *ceterus paribus*, result in a one per cent increase in the output. Another important implication of taking the logarithms of the variables before running the regression is that since production theory limits the range of the output elasticities to be between zero and unity, the t-tests may be taken to be one tailed. As a result if this, the statistical testing, especially that of the t-tests is made less stringent because of the fact you are testing for the possibility of the relationship in one direction and completely disregarding the possibility of a relationship in the other direction.

Keeping this in mind an Ordinary Least Squares Regression (OLS) analysis of the production function and the specific variables was none the less carried out. Table 3 below shows the results obtained from running this regression.

Table 3: OLS regression of Production Function Variables

Source	SS	df	MS		Number of	51
Model	1,061737	8	0,132717		F(8, 42)	5,01
Residual	1,112349	42	0,026484		Prob > F	0,0002
Total	2,174085	50	0,043482		R-squared	0,4884
					Adj R-squared	0,3909
					Root MSE	0,16274
loutput	Coef.	Std. Err.	t	P>t	[95% Conf.Interval]	
lland	0,172791	0,1148928	1,5*	0,14	-0,059072	0,404654
llabour	0,407842	0,1343777	3,04**	0,004	0,1366564	0,6790268
lprecision	-0,02248	0,038501	-0,58	0,563	-0,1001733	0,0552232
lfert	0,342355	0,2260693	1,51*	0,137	-0,1138711	0,7985817
lseed	-0,05051	0,2008876	-0,25	0,803	-0,4559167	0,3548985
lchem	0,218073	0,1481964	1,47*	0,149	-0,0809994	0,5171457
lmachinery	0,067599	0,0973706	0,69	0,491	-0,1289027	0,2641009
ldiesel	0,091644	0,2097201	0,44	0,664	-0,3315885	0,5148761
_cons	0,327706	0,840754	0,39	0,699	-1,369005	2,024416

* significant at 10% level, ** significant at 5% level, *** significant at 1% level

From table 3 it can be seen that the variables as discussed above do not predict or describe the output in a good manner, which is surprising after the establishment of the correlation matrix in table 2. The implication of these results then is that 1) the variables used do not adequately explain the production of the output; this can be seen by looking at the R-squared and adjusted R-squared values of the model. The R-squared value for the model is 0.4884, i.e. 48.9% of the variation between the outputs is explained by the model, the adjusted R-squared is even less at only 0.3909, suggesting that only 39.09% of the variance in the output can be explained by the variables used. This is a better measure than the R^2 because of the fact that it takes the number of variables used in the model into account, while the R^2 does not and would tend to increase as the number of variables used increases. Secondly when looking at the t-statistics for the various variables in explaining their role in the production of the output, these are for the most part statistically insignificant, leaving only land, labour, fertilizer and chemicals being positive and statistically significant between the 1% and 10% level.

After having found these results with little meaning to the exercise particularly because of the low adjusted R^2 , as well as the variables low levels of statistical significance. These results are therefore not in the broader sense sensible. It thus was assumed that it would be better to aggregate the variables together, as the amount of data was already severely limited. The variables thus became the following:

- Y= Logarithm of output, output in this case is the aggregated output as discussed above and is the dependant variable.
- X1=Logarithm of Labour + Precision (LLabprec), Grouped because precision is essentially a consulting service added by FAS and consists of the advice of Skilled Labour.
- X2= Logarithm of Land +Fertilizer (Llandfert), Grouped because fertilizer is used to make up for nutrient shortages in the soil, it is therefore an ameliorant and would act as a function of the land's quality as well as the land's growing potential²⁸.

²⁸ therefore it could be assumed that an increase in land would result in an increase in the application of fertilizer the opposite could be assumed for soil quality, the worse it is the more you apply and *vice versa*.

- $X_3 = \text{Logarithm of Machinery} + \text{Diesel (Lmacdiesel)}$, Grouped because machinery uses diesel in performing its tasks as well. Also older machines would use more diesel and the cost of both renting and operating these machines should strictly speaking be a function of each other.
- $X_4 = \text{Logarithm of Seed} + \text{Chemicals (Lseedchem)}$, Grouped together because seed is used to produce the crop, and chemicals are used to protect the seed's (plants), they are thus complementary.

Below is the correlation matrix for the newly aggregated variables as discussed above;

Table 4: Correlation Matrix for Aggregated Production Function Variables

	loutput	llandfert	llabprec	lseedchem	lmacdiesel
loutput	1				
llandfert	0.459	1			
llabprec	0.464	0.1505	1		
lseedchem	0.4097	0.1965	0.1906	1	
lmacdiesel	0.3196	0.0203	0.3489	0.2193	1

From table 4, it can be seen that the log of the variables are now all positively and quite highly correlated with the output as well as each other. One would expect this because of the nature of agriculture, for example consider the use of all the intermediate inputs into the production of output. Labour, land, fertilizer, seed and chemicals are all an integral part into the production of field crops, without some of these inputs production is either not possible or it severely diminished. Diesel and machinery on the other hand although positively correlated, is not as strongly correlated with output, and other variables except for the labour and precision variable, which is to be expected because of the need for labour when operating machinery.

An interesting point is the lower level of correlation between the variable Lmacdiesel (which is the combination of machinery and diesel) and the output, compared to the correlation of the other variables to the output. This is to an extent to be expected because of the way the machinery variable is constructed, i.e. new machines although more efficient are more expensive, and the "capital" or rental would be higher, however the diesel use and repairs and maintenance would be expected to be lower, the opposite however would be true for older machinery. The difference then between the farms would be as a function of the age and efficiency of the machines, and this information cannot be inferred from the data because of the way in which it is recorded and presented. It is important however that these variables are positively correlated with the output as well as with each other because of their importance in producing output.

These variables would then seem to be a sensible choice, in order to run a regression so as to determine the variables to be used in determining the optimal functional form that will facilitate the efficiency study to be performed on the data. The regression results are shown in table 5, below;

Table 5: OLS Regression of Aggregated Production Function Variables

Source	SS	df	MS		Number of obs =	51
Model	0.997104	4	0.249276		F(4, 46) =	9.74
Residual	1.176981	46	0.025587		Prob > F =	0
Total	2.174085	50	0.043482		R-squared =	0.4586
					Adj R-squared =	0.4116
					Root MSE =	0.15996
loutput1	Coef.	Std. Err.	t	P>t	[95% Conf.Interval]	
llandfert	0.465949	0.144211	3.23***	0.002	0.175667	0.756231
llabprecision	0.37265	0.141307	2.64**	0.011	0.0882125	0.657086
lseedchem	0.319932	0.147711	2.17**	0.036	0.0226049	0.617259
lmacdiesel	0.227609	0.178643	1.27	0.209	-0.1319798	0.587199
cons	-0.46071	0.752962	-0.61	0.544	-1.976345	1.054922

* significant at 10% level, ** significant at 5% level, *** significant at 1% level

From table 5 it can be seen that the majority of the variables are now statistically significant from zero, with two (Llabprec and Lseedchem) out of the four variables being statistically significant at the 5% level, and Llandfert statistically significant at the 1% level which is to be expected. The only variable now that is not statistically significant is that of machinery + Diesel which is also the most liable for miss-measurement, this could be because of the difference between the types and costs of the machines on the various farms, resulting in a large variation between observations. This would suggest then that there is a large variation between the prices paid for the rental of the machines, and this could affect the level of significance this variable has on the output.

Because of the fact that the variables have been assumed linear in their logarithms as discussed above, the coefficient which in turn is the elasticity of 0.46 for Llandfert would suggest that a 1% increase in Llandfert would *ceterus paribus*, increase the output by 0.46% on average. The other variables can also be interpreted in the same way. The sum of the coefficients gives a value of 1.36 which implies increasing returns to scale. It is important to remember however, that because of the lack of data together with the pooling of the data, this high level of increasing returns to scale could be as a result of the data being cross-sectional. This is fairly typical of results for individual years, and it adds to the complication of running regressions and performing statistical tests of such data. This however cannot be avoided as a result of the lack of data, and the implication of this result would be that if the all the inputs were to be increased by 1% there would *ceterus paribus* be an increase of 1.36% in output. This could suggest then that on average these farms are experiencing increasing returns to scale.

The F-statistic shows that jointly the variables have explanatory power over the model, and the adjusted R^2 shows that the above variables explain roughly 41% of the variance in the output. Although R^2 value is only slightly higher than the first model whose results are reported in table 3 its Root MSE value is also lower suggesting a better fit of the model to the data. It is because of these reasons that these variables and this model are preferred to the model obtained or described in table 3.

3.5.2 Choice of Functional Form

Since the above variables are assumed to be linear in logarithms, the production function generated from the analysis was in the form of the Cobb-Douglas (CD) production function.

The advantages of such a model are the ease with which the results are estimated and interpreted. This is as a result of only having to estimate a few parameters of the production function. The disadvantages of the Cobb-Douglas production function however is that it is perhaps an overly simplistic and restrictive functional form. This is because of the fact that the “*elasticity of substitution between any pair of variables is always equal to one or unity*” (Coelli, Rao, O'Donnell, & Battese, 2005)(pg. 19), and the “*output elasticities do not vary with variations in input levels*” (Coelli, Rao, O'Donnell, & Battese, 2005)(pg. 19).

The restrictiveness of the Cobb-Douglas production function then seems to be embedded in the fact that the elasticities of substitution are imposed on the variables, rather than being estimated by the variables. It is therefore necessary to test whether the Cobb-Douglas production function, is an adequate representation of the data as compared with a flexible functional form such as the translog production function, abbreviated from the “transcendental logarithmic production function” as proposed by Christianson, Jorgenson and Lau (1973).

The Translog is less restrictive because of the fact that it adds a squared term for each of the variables to allow for non-linearity between the variables, and cross products which would allow for interaction between the variables. After these additions were made there were an additional four squared terms, and six cross product terms added to the original Cobb-Douglas production function. Because of these two additional terms the Translog production function is quadratic in logs, with the advantages being that it is a more flexible functional form with fewer restrictions on the production elasticities as well as the elasticities of substitution. It is capable of representing any unknown underlying production function. The disadvantages however is that it is firstly more difficult to interpret and it requires the estimation of many more parameters, which could give rise to econometric difficulties such as multi-collinearity.

That being said, it was necessary to perform OLS estimates for the constrained model (Cobb-Douglas) as well as the unconstrained model (Translog) in which the constrained model is nested, so as to be able to test for the functional form that will most adequately represent the data this will be discussed at greater length in Chapter 4. The OLS estimates of the two respective models are therefore defined as follows (Coelli, Rao, O'Donnell, & Battese, 2005, p. 211);

$$\text{Cobb-Douglas: } y_i = \beta_0 \prod_{n=1}^N x_n^{\beta_n} \quad (1)$$

And

$$\text{Translog: } y_i = \exp(\beta_0 + \sum_{n=1}^N \beta_n \ln x_n + \frac{1}{2} \sum_{n=1}^N \sum_{m=1}^M \beta_{nm} \ln x_n \ln x_m) \quad (2)$$

In the above equations y is the dependant variable and is calculated as the logarithm of output. The four independent variables (x_j) are the logarithms of the aggregated variables as discussed above, i.e. they are the logarithms of landfert (land + fertilizer), Labprec (labour +

precision), Seedchem (Seed + Chemicals) and lastly Macdiesel (Machinery +Diesel). The i subscripts represent the individual farmer or the observation within the data set.

Before the OLS estimates were determined the data was mean centred, this involves subtracting the mean from each variable before running an OLS regression model on the data. If this step is not carried out one would have to perform complex calculations, if one were to want to calculate the output elasticities as well as their standard errors. This is because of the fact that if the elasticities are calculated at the sample means, and the means are zero due to mean centring the data for these variables, the output elasticity with regards to the inputs would simply be equal to their first order coefficient (Mkhabela T. , 2011). This step has no effect on the results obtained however, as it simply changes the units of measurement of each variable, but as can be seen the advantages of performing this step are immense.

After having performed these steps of readying the data, the OLS estimates of the parameters from equation one and two were determined using FRONTIER 4.1 (Coelli, Rao, O'Donnell, & Battese, 2005), the results for which are shown in table 6 below.

Table 6: OLS estimation of the Trans Log production Function

Dependant Variable: Output	Translog	Cobb-Douglas
	Loutputmd	Loutput
llandfertmd	0.4127 (2.54)***	0.4659 (3.23)***
llabprecmd	0.3149 (1.96)**	0.3726 (2.64)***
lseedchemmd	0.2844 (1.61)*	0.3199 (2.17)**
lmacdieselmd	0.2686 (1.33)*	0.2276 (1.27)
x1x2	0.0730 (0.08)	
x1x3	-1.7306 (1.20)	
x1x4	-0.3310 (0.23)	
x2x3	0.9914 (0.89)	
x2x4	3.7437 (1.69)**	
x3x4	0.3432 (0.21)	
x12	0.2348 (0.22)	
x22	-1.7023 (2.25)**	
x32	0.6345 (0.84)	
x42	-1.8172 (0.89)	
cons	0.0330 (0.65)	-0.4607 (0.61)
sigma-squared	0,0244	0,0256
Observations	51	51
Adj. R squared	0,4393	0,4116
log likelihood function =	31,22463	23,740392
Absolute value of t-statistic in parentheses		
* significant at 10% level, ** significant at 5% level, *** significant at 1% level		

From table 6, it can be seen that the adjust R^2 value is slightly higher for the Translog than that of the Cobb-Douglas production function. This higher adjusted R^2 would suggest then that a larger proportion of the variance between the dependant variable and independent variables would be explained by the translog model and it suggests that the model possesses significant explanatory power. The adjusted R^2 test is of particular importance in this instance, because of the fact that the adjusted R^2 value penalizes the addition of variables as well as the significance of the variables as a result of the loss of degrees of freedom in performing this test.

As a result of the data being mean differenced as explained above, one is able to estimate the output elasticities for the Cobb-Douglas terms i.e. Llandfert (X_1), Llabprecmd (X_2), Lseedchemmd (X_3) as well as Lmacdiesel (X_4), can be read directly from the coefficients

estimated for these variables within the Translog function. The elasticities in this instance sum to 1.28, which would suggest that a 1% increase in inputs would *ceterus paribus*, result in a 1.28% increase in output. It can thus be seen from the results that on average there is a possibility that these farms are experiencing increasing returns to scale, which could imply that it could be beneficial for the average farm to increase its scale of production.

If one considers the cross product terms, or the interaction terms for the interactions between, Llandfertmd and Lseedchemmd (X_1X_3) and the Llandfertmd and Lmacdieselmd (X_1X_4), variables these do not make much sense. The implication of these interactions would suggest that a 1% increase in the use of input X_1 (Llandfertmd) would, *ceterus paribus*, result in a 1.7% decrease in the use of input X_3 (Lseedchemmd), similar results can be observed with the interaction between the variable X_1 (Llandfertmd) and variable X_4 (Lmacdieselmd) (Boland & Marsh, 2006). These two interaction terms between these four variables do not make much sense; one would rather expect the usage of these inputs to increase with an increase in the amount of input Llandfert (the use of land and fertilizer in production) used. Another odd result is that of Llabprecmd and Lmacdieselmd (X_2X_4) which suggests that these variables are complements for one another. Similar unusual behaviour is observed in the squared terms. It is these terms that would give an indication as to the relationship the variable has with the model, i.e. if the variable has a linear or non-linear relationship with output.

The majority of these variables are also statistically insignificant indicating that they do not significantly differ from zero. The exceptions are the variables X_1 (Llandfertmd), X_2 (Llabprecmd), X_2X_4 (interaction term between Llabprec and Lmacdiesel) and lastly X_2^2 (squared Llabprec term) which is the product term that tests for non-linearity within the data set. If one considers the variable X_2X_4 , this interaction term would suggest that a 1% increase in the use of labour would *ceterus paribus*, increase the use of Lmacdiesel. This could be a counterintuitive result, as it would seem as if an increase in the use of labour should be as a result of a decrease in the use of machinery and *vice versa*. However if one considers the use of machinery and diesel, the only way in which these machines can be used is with labour, and thus it could be assumed that an increase in the use of machinery and diesel would more often than not involve an increase in the use of labour, there thus seems to be a causal issue with this variable as it is hard to determine which causes which. The implication then is that there is a positive and significant association between these variables.

As a result of the majority of the interaction terms and squared variables not being significantly different from zero, it would suggest that this functional form would not accurately represent the fit the data, and it would seem as if the nested Cobb-Douglas functional form would be a better fit. That being said however it is still important to perform the test on which the functional form is chosen, i.e. the generalized likelihood ratio (LR) test. The likelihood ratio test is given by, $\lambda = -2\{(\log(\text{likelihood}(H_0))) - (\log(\text{likelihood}(H_1)))\}$ which has a χ^2_ν distribution with ν being equal to the number of parameters assumed to be zero in the null hypothesis. This produces a value of LR $\chi^2(10) = 14.96$ this value is then compared to the tabulated value or critical value at a 5% significance level which is $\chi^2_{10,0.05} = 18.307$. Since the calculated value is less than the critical value, the null hypothesis

that the Cobb-Douglas is an adequate representation of the data ($H_0: \beta_{ij} = 0, ij = 1, \dots, 4$) is not rejected, and subsequently the translog model is rejected in favour of the more restrictive but simpler Cobb-Douglas model. This conclusion is drawn strictly from the test which indicates that the Cobb-Douglas is a better fit of these data, it is important to note however that the translog model would seem to have better results.

It has thus been determined that the Cobb-Douglas production function best describes the data and this functional form will then be used for the rest of the analysis of the production function, and subsequently the Technical Efficiency with which these farms are operating. Chapter 4 that follows, includes the empirical estimation and analysis of both the production function as well as cost function using both a parametric (SFA) and non-parametric approach (DEA) with the aim of determining the underlying efficiency's, both technical as well as allocative, with which these individual farms in the broader model are operating at.

Chapter 4: Empirical Analysis of the Production and Cost Function

4 Introduction

After having found the functional form that best describes the data, it seems pertinent to discuss the various techniques available to one when trying to determine the efficiency of the various farms, before continuing. This will form part of the theoretical discussion as to the most popular methods and approaches available in the theory used for determining these efficiency measures. These approaches can be either deterministic, where all deviations from the frontier are attributed to inefficiency, or stochastic which allows for the discrimination between random errors and differences in inefficiency (Piesse & Thirtle, 2000). The following chapters purpose then is to discuss these various theoretical approaches so as to be able to proceed to the empirical analysis and estimation of firstly the technical efficiency, and secondly the allocative efficiency of the farms.

In microeconomic theory a production function is defined as the maximum²⁹ output that can be produced from a given set of inputs, using the particular technology available to that firm at that point in time³⁰. Before Farrell's pioneering work done in 1957, the majority of the empirical studies used the least-squares methods to estimate the production functions, which resulted in response or average functions (Battese G. , 1991). These functions began with the estimation of a production function, where producers were assumed to be operating on their production functions therefore maximizing the output obtainable from the inputs they used. The error terms were assumed to be symmetrically distributed with zero means and the only source of departure from the estimated function were assumed to be as a result of statistical noise. There was however a large amount of empirical evidence suggesting that not all producers were always successful in solving their optimization problems (Kumbhakar & Lovell, 2000), and this lead to the notion that it was perhaps better to move away from the traditional production function towards production frontiers³¹ (Kumbhakar & Lovell, 2000).

We will now move on to the Farrell's measure of productive efficiency built on the work of Debreu (1951)³², and Koopmans (1951) in which he showed how to define cost efficiency, and decompose it into its technical and allocative components using distance functions in an empirical application on U.S Agriculture. He did not however use econometric methods, and instead chose those of a linear programming nature. The next section draws on his work, and discusses the implications thereof.

Farrell considered a firm, under constant returns to scale, that used two factors of production (X_1, X_2), to produce a single output (Y) under constant returns to scale to explain his ideas.

²⁹ (Kumbhakar & Lovell, 2000) Page 25-26 suggest that the production function can also be defined as the minimum amount of inputs required to produce any given output vector.

³⁰ Forsund *et al.* (1980:21) state that the "theoretical definition of a production function holds that it gives the maximum possible output which can be produced from given quantities of a set of inputs".

³¹ (Kumbhakar & Lovell, 2000) Page 3-4 defines the production frontier "as the minimum input bundles required to produce various outputs, or the maximum output that is producible with various input bundles and a given technology".

³² (Debreu, 1951) Introduced distance functions as a way of modelling multiple-output technology, as well as a way of measuring the radial distance of a producer from the frontier in an output expanding direction.

He also assumed that the efficient production function, the output that a perfectly efficient firm could obtain from any given combination of inputs, was known. If one has a look at figure one below, inputs X_1 and X_2 are represented on the horizontal and vertical axes respectively.

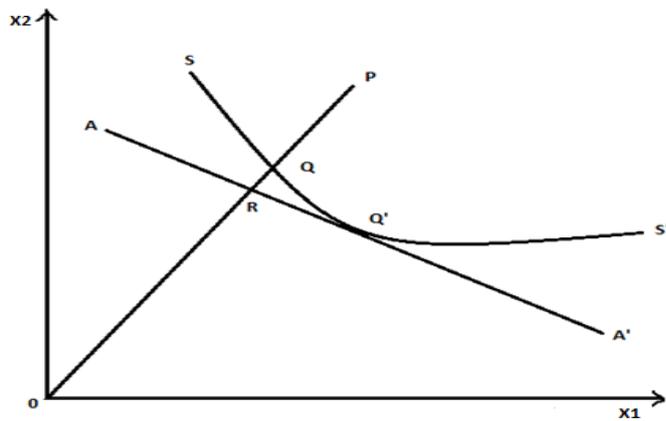


Figure 1: The simple case of Efficiency (Source: (Farrell, 1957) page 254)

The above figure then could be viewed as an isoquant for the industry, this production function is therefore a frontier as this “isoquant” or production function represents the maximum output that is producible from this given input bundle (Aigner & Chu, 1968). The isoquant SS' represents the combination of the two inputs (X_1 and X_2) a perfectly efficient firm would employ in producing a given level of output. Point P on the above figure represents the production of a firm that is producing the same level of output produced that is being produced by say firm Q on the isoquant SS' . The producer at point P then is using higher levels of both factors of production (X_1 and X_2) than say the efficient firm producing at point Q on the isoquant SS' .

Therefore point Q is producing the same level of output as point P, using only a fraction (OQ/OP) as much of each input as point P (Farrell, 1957). Farrell (1957) suggests that point Q can also be thought of as producing (OP/OQ) as much output from the same amounts of inputs, and this would then suggest that (OQ/OP) the Technical Efficiency³³ (TE) of point P would then be equal to the ratio of the distance from point Q to the origin, divided by the distance of the point P to the origin therefore $TE = OQ/OP$.

The assumptions around this example is that technical efficiency would take the value of unity for a perfectly efficient firm, and will become infinitely small if the amounts of inputs used to produce a unit of output become infinitely large. Another important aspect of the above example is that as long as the isoquant SS' has a negative slope, an increase in the unit input per unit output of one of the factors will *ceterus paribus*, imply a lower technical efficiency (Farrell, 1957). This measure therefore adheres to the law of diminishing returns.

³³ (Koopmans, 1951) Provide a definition of technical efficiency: “A producer is technically efficient if, and only if, it is impossible to produce more of any output without producing less of some other output or using more of some input”.

Continuing with the above figure as proposed by Farrell, if there is sufficient information as to the prices for these inputs, then the Allocative Efficiency³⁴, or the ability of the firm to choose these factors of production in optimal proportions, may also be determined. Therefore if there was sufficient price information, then the iso-cost line AA' which has a slope equal to the price ratio of the two factors of production can be determined and drawn tangential to the isoquant SS'.

According to Farrell then point Q' and not Q would be the optimal method of production, because of the fact that, the cost of producing Q' will only be a fraction (OR/OQ) of those at point Q, and therefore the cost of producing (RQ) a unit of output, can be reduced without reducing the level of output. This ratio then is defined as the Allocative Efficiency (AE) in production $AE = (OR/OQ)$ (Farrell, 1957). After having obtained values for the technical as well as allocative efficiencies from the above figure, we can define Economic or Cost Efficiency which is defined as the product of Technical and Allocative Efficiency, i.e. $CE = (OQ/OP)(OR/OQ) = (OR/OP)$.

A producer operating on the frontier was then said to be technically efficient, while a producer operating below the production frontier was said to be technically inefficient. The implication of this shift away from production functions towards production frontiers was that the symmetrically distributed errors with zero means were no longer appropriate when studying producer behavior. These error terms were rather replaced with the "composed" error terms which took the traditional symmetrical random noise component found in the response or average functions, as well as a one-sided inefficiency component into account. It was this addition in 1977 by Aigner, Lovell & Schmidt as well as Meeusen & van Den Broek that led to the development of the Stochastic Frontier Analysis (SFA) which will be discussed later on in the chapter.

Technical, Allocative and Economic or Cost efficiency can be predicted using a non-parametric approach such as Data Envelopment Analysis (DEA) and other linear programming methods or the parametric approaches that follow in the discussion. In the DEA model technical efficiency is calculated using the input-orientated variable returns to scale (VRS) model, and this model based on (Coelli, Rao, O'Donnell, & Battese, 2005) and will be discussed later on in the chapter.

4.1 Deterministic Production Frontier

Farrell's work inspired Aigner & Chu (1968) to argue that the differences between values firms achieved, and an "industry" production function could be as a result of differences in scale of operation, varying organizational structures and other factors that were within the control of the firm. This suggested then that any deviations between the observed output and the industries "best practice" frontier would be as a result of the firm's inability to use the optimal values of the various parameters in the industry resulting in inefficiencies into production (Aigner & Chu, 1968). They considered a parametric frontier production function

³⁴ Price efficiency or allocative efficiency (ae) is the measure of the firm's success in choosing an optimal set of inputs (Farrell, 1957).

of Cobb-Douglas form, using the data on a sample of N firms (Coelli, Rao, O'Donnell, & Battese, 2005). The model was defined by;

$$\ln y_i = x_i \beta - u_i \quad (3)$$

Where $\ln(y_i)$ is the logarithm of the (scalar) output for the i -th firm; x_i is a $(K+1)$ row-vector, whose element is "1" and the remaining elements are logarithms of the K -input quantities used by the i -th firm; $\beta = (\beta_0 + \beta_1, \dots, \beta_k)'$ is a $(k+1)$ column-vector of unknown parameters to be estimated; and u_i is a non-negative random variable, associated with the technical inefficiency in production of the firms in the industry involved (Coelli, Rao, O'Donnell, & Battese, 2005).

The model above is termed a deterministic frontier because of the fact that the function sets a limit as to the range of possible observations. This can be seen by the fact that the error term u_i has a non-positive disturbance. The implication of this then is that since all firms in the model share a common family production function one may only observe points that lie below the frontier, representing firms that produce less than the maximal possible output, and no points lying above the frontier (Forsund, Lovell, & Schmidt, 1980).

This would imply then that any deviations from the frontier relative to the common family frontiers are as a result of inefficiencies that are within the control of the firm and no account is taken of measurement errors. That is given the input vector, x_i the technical efficiency of say firm i , is equal to the ratio between the observed output of firm i , relative to the potential output as given by the frontier (Coelli, Rao, O'Donnell, & Battese, 2005):

$$TE_i = \frac{y_i}{\exp(x_i \beta)} = \frac{\exp(x_i \beta - u_i)}{\exp(x_i \beta)} = \exp(-u_i) \quad (4)$$

This output orientated Farrell measure of technical efficiency, which takes the value between zero and one (Coelli, Rao, O'Donnell, & Battese, 2005) is used to give an indication as to the level of technical efficiency with which the firm is operating, and is determined by estimating the ratio of the observed output y_i , to the estimated value of the frontier output $\exp(x_i \beta)$. In Aigner & Chu's (1968) model the β parameter are estimated using linear programming, where $\sum_{i=1}^N u_i$ is minimized, subject to the constraints that $u_i \geq 0, i = 1, 2, \dots, N$ (Coelli, Rao, O'Donnell, & Battese, 2005).

A serious criticism of the above deterministic frontier model, is that there is no account taken of the possible influences measurement errors or other statistical noise might have upon the frontier, and all deviations from the frontier are assumed to be as a result of technical inefficiency of the firms being considered. This idea of a deterministic frontier shared by all firms ignores the possibility then that a firm's performance could be affected by factors that are entirely out of the firm's control, and rather assumes that all factors are under the control of the firm (Forsund, Lovell, & Schmidt, 1980). This will result in efficiency estimates being lower than those estimated by say a stochastic frontier, because of the fact that it will be estimated in such a fashion that no output values may exceed the frontier, as a result of the non-positive error component as well as the output y_i being bound by the deterministic frontier $\exp(x_i \beta)$ (Coelli, Rao, O'Donnell, & Battese, 2005).

This method of lumping the measurement errors, and other statistical noise together with inefficiency into a one sided error term was unfavorable and as a result an alternative approach to this deterministic frontier was developed simultaneously by Aigner, Lovell & Schmidt (1977) and Meeusen & van Den Broek (1977). Here they suggested that the error term be made up of two components, one normal and the other from a one-sided distribution (Aigner, Lovell, & Schmidt, 1977) it was proposed that this would offer a solution to the majority of the issues with the deterministic approach. Below is a discussion on the stochastic frontier model.

4.2 Stochastic Production Frontier

Aigner, Lovell & Schmidt (1977) and Meeusen & van der Broeck (1977) drew on the assumption that the maximum output may not be obtained because of inefficiency effects as well as random errors outside of the manager's control. They therefore used the same function as Aigner & Chu (1968), the only difference being that they added an extra error term to account for this random error, i.e.;

$$\ln q_i = x_i' \beta + v_i - u_i \quad (5)$$

Here again $\ln(y_i)$ is the logarithm of the (scalar) output for the i -th firm; x_i is a $(K+1)$ row-vector, whose element is "1" and the remaining elements are logarithms of the K -input quantities used by the i -th firm; $\beta = (\beta_0 + \beta_1, \dots, \beta_k)'$ is a $(k+1)$ column-vector of unknown parameters to be estimated; and u_i is a non-negative random variable, associated with the technical inefficiency in production of the firms in the industry involved (Coelli, Rao, O'Donnell, & Battese, 2005).

This addition to the error term as independently proposed by Aigner *et al.* (1977) and Meeusen & van Den Broeck (1977), would mean that since the output values are bounded from above by the stochastic (i.e. random) variable $\exp(x_i' \beta + v_i)$ (Coelli, Rao, O'Donnell, & Battese, 2005). The new error term, $(v_i)^{35}$, as well as a non negative random variable associated with the technical inefficiency (u_i), could then vary about the deterministic part of the model, $\exp(x_i' \beta)$ (Coelli, Rao, O'Donnell, & Battese, 2005) since $(v_i - u_i)$ can be positive or negative there was therefore some specified proportion of the observations that were allowed to lie above the frontier in this new stochastic frontier approach (Aigner, Lovell, & Schmidt, 1977). Fried, Lovell & Schmidt (1993) provide a rather comprehensive survey of these methods and applications.

These important features of the stochastic frontier model are illustrated graphically in figure 9.1 of Coelli *et al* (2005, pg.244). In this case it is assumed that a firm produces output q_i

³⁵ The additional parameter is the parameter, v_i which represents the symmetric component that would account for pure random factors in production as well as any statistical noise within the data set (Battese G. , 1991) these purely random factors of production were assumed to be out of the farmer's control. The statistical noise would arise from any inadvertent omission of relevant variables from the vector x_i as well as from measurement and approximation errors that could be associated with the choice of functional form (Coelli, Rao, O'Donnell, & Battese, 2005).

using only one input x_i i.e. in the case of the Cobb-Douglas stochastic frontier model, the frontier takes the form (Coelli, Rao, O'Donnell, & Battese, 2005);

$$\ln q_i = \beta_0 + \beta_1 \ln x_i + v_i - u_i \quad (6)$$

$$\text{Or } q_i = \exp(\beta_0 + \beta_1 \ln x_i + v_i - u_i) \quad (7)$$

$$\text{Or } q_i = \underbrace{\exp(\beta_0 + \beta_1 \ln x_i)}_{\text{deterministic component}} \times \underbrace{\exp(v_i)}_{\text{noise}} \times \underbrace{\exp(-u_i)}_{\text{inefficiency}} \quad (8)$$

In figure 9.1 of Coelli *et al* (2005, pg. 244), Firm A lies above the deterministic part of the production frontier because of the fact that the noise effect is positive (i.e. $v_A > 0$), while the opposite is true for Firm B where the noise effect is negative (i.e. $v_B < 0$) (Coelli, Rao, O'Donnell, & Battese, 2005). If one considers Firm A it can be seen that the observed output lies below the deterministic part of the frontier, this is because of the fact that the sum of the noise and inefficiency effects is negative i.e. $v_A - u_A < 0$ (Coelli, Rao, O'Donnell, & Battese, 2005). The frontier model therefore identifies firms that represent best practise, and their inefficiencies are explained via Maximum Likelihood Estimates by estimating the unknown parameters, while simultaneously estimating the stochastic frontier and inefficiency effects (Mkhabela T., 2011).

The fundamental difference between the two approaches i.e. the deterministic and stochastic frontier model was then that there was an addition to the error term of a symmetric component that permitted random variation of the frontier across firms. This variation therefore took into account factors such measurement errors, as well as other statistical noise and random shocks that were outside of the manager's control, as well as inefficiency effects (Forsund, Lovell, & Schmidt, 1980). However there were certain issues with this model as proposed by Aigner, Lovell & Schmidt (1977), and these were that the selection of the proportion of the observations that were allowed to lie above the frontier was essentially arbitrary, lacking explicit economic or statistical justification.

Technical efficiency then is calculated as the ratio between the observed output to the corresponding stochastic frontier output (Coelli, Rao, O'Donnell, & Battese, 2005), this gives the measure of technical efficiency as;

$$TE_i = \frac{q_i}{\exp(x_i' \beta + v_i)} = \frac{\exp(x_i' \beta + v_i - u_i)}{\exp(x_i' \beta + v_i)} = \exp(-u_i) \quad (9)$$

Again this measure takes the value between zero and one (Coelli, Rao, O'Donnell, & Battese, 2005), and it again measures the output of the i -th firm relative to the output that could be produced by a fully efficient firm or best practise firm using the same vector of inputs (Coelli, Rao, O'Donnell, & Battese, 2005). The first step in predicting the technical efficiency according to Coelli *et al.* (2005) is to estimate the parameters of the stochastic production frontier (Coelli, Rao, O'Donnell, & Battese, 2005). This is often done using the Maximum Likelihood estimates, which use the Ordinary Least Squares (OLS) results as a starting point.

The use of the MLE in estimating the production frontier however is dependent on the selection of certain distributional assumptions concerning the two error terms of the frontier.

The MLE estimates are preferred over the corrected ordinary least squares (COLS) method because of the fact that they have many desirable large sample (i.e. asymptotic) properties (Coelli, Rao, O'Donnell, & Battese, 2005). Aigner, Lovell & Schmidt (1977) obtained ML estimates under the assumptions (Coelli, Rao, O'Donnell, & Battese, 2005) that the;

$$v_i \sim iidN(\mathbf{0}, \sigma_v^2) \tag{10}$$

And $u_i \sim iidN^+(\mathbf{0}, \sigma_u^2)$ (11)

That is the v_i 's are independently and identically distributed normal random variables with zero means and variances σ_v^2 (Coelli, Rao, O'Donnell, & Battese, 2005), and the, u_i 's are independently and identically distributed half-normal random variables with scale parameter σ_u^2 (Coelli, Rao, O'Donnell, & Battese, 2005). Coelli *et al.* suggest that the finding made by Battese & Cora (1977) who parameterise the log-likelihood in terms of σ^2 and $\gamma = \sigma_u^2/\sigma^2$, is the most appealing because if $\gamma = 0$ then all deviations from the frontier are due to noise, while $\gamma = 1$ means all deviations are due to technical efficiency.

The main criticism against the use of the stochastic frontier is that there is no *a priori* justification for the selection of any particular distributional form for the inefficiency effects or the u_i 's (Coelli, Rao, O'Donnell, & Battese, 2005). That being said, this is still one of the most preferred parametric approaches to determining efficiency with which firms produce. Then next section shows the empirical results obtained from this stochastic frontier analysis.

4.2.1 Estimation of the Production Function and Technical Efficiency using SFA

Table seven below is a summary of the OLS estimates used in deciding which functional form best fits the data. The functional form chosen was the Cobb-Douglas and the Beta coefficients are the same as those defined earlier on in chapter 3. The different coefficients are as follows, Beta 1= Land and fert, Beta 2 =Labour and precision, Beta 3 = seed and chem and Beta 4 = Machinery and diesel. The fact that these values have been logged prior to the analysis, results in the coefficients showing the output elasticity of these variables. That is should the variables all be increased by 1% the output *ceterus paribus*, should increase by 1.08 %.

Table 7: OLS estimates using Stochastic Frontier Analysis (Front. 4.1)

	coefficient	standard-error	t-ratio
beta 0	-0.46	0.75	-0.61
beta 1	0.47	0.14	3.2310199***
beta 2	0.37	0.14	2.6371569**
beta 3	0.32	0.15	2.1659312**
beta 4	0.23	0.18	1.27
sigma-squared	0.03		
log likelihood function =		23.74	

* significant at 10% level, ** significant at 5% level, *** significant at 1% level

These results are important as it is these OLS estimates that are used as a starting point for the Maximum likelihood Estimates (MLE) model. The Log Likelihood function obtained in the OLS estimates are then compared to the Log Likelihood function obtained for the MLE estimates, this comparison will aid in deciding whether the data is better described by a mean response function or a frontier. This is done by testing the hypothesis that the technical

efficiency effects are not simply random errors. The key parameter in this case is $\gamma = \frac{\sigma_u^2}{\sigma^2}$ which lies between zero and one. As found by Battese & Cora (1977), if $\gamma = 0$ then all deviations from the frontier are due to noise, which would indicate that the mean response (OLS) function is an adequate representation of the data, while $\gamma = 1$ means all deviations are due to technical efficiency (Coelli, Rao, O'Donnell, & Battese, 2005) indicating that the data is better represented by the frontier model.

The test for this is then the likelihood ratio test which is given by, $\lambda = -2\{\log(\text{likelihood}(H_0)) - (\log(\text{likelihood}(H_1)))\}$ which has a χ^2_v distribution, with v being equal to the number of parameters assumed to be zero in the null hypothesis. This produces a value of LR $\chi^2(1) = 8.24$ this value is then compared to the tabulated value or critical value at a 5% significance level which is $\chi^2_{1,0.05} = 3.841$. Since the calculated value is higher than the critical value the null hypothesis that the technical efficiency effects are simply random errors ($H_0: \gamma = 0$) is rejected. This result therefore suggests that technical inefficiency is present in the model, and subsequently the Mean Response Function model is rejected in favour of Frontier model. This conclusion drawn, is reaffirmed by the fact that $\gamma = 0.98$ with a t-statistic of 43.48, suggesting that this value is significantly different from zero at the highest confidence level. Since this value is so close to unity, this would indicate that the majority of the deviations are due to technical inefficiency, and the data is therefore best represented by the Frontier model.

Table 8: Final MLE estimates of Stochastic Frontier Analysis (Front. 4.1)

	coefficient	standard-error	t-ratio
beta 0	0.6325	0.5640	1.1215
beta 1	0.5007	0.1032	4.85***
beta 2	0.1095	0.1174	0.9322
beta 3	0.2826	0.1034	2.73***
beta 4	0.1578	0.1248	1.2645
sigma-squared	0.2005	0.2899	0.6917
gamma	0.9842	0.0226	43.4849
log likelihood function =		27.86	
* significant at 10% level, ** significant at 5% level, *** significant at 1% level			

As a result of the variables being logged before being fed into the FRONTIER 4.1 programme, all of the estimated coefficients values represent “share parameters” or elasticities. Looking at the coefficients in table 8 then they can be interpreted in the following fashion, a 1% increase in the use of variable one i.e. land and fertilizer will results in a 0.5% increase in output, and so on for the rest of the variables used. The difficulties of the analysis of these variables lies in the fact that these variables have been aggregated, therefore the proportion of each individual variable within the aggregation cannot be determined.

Therefore it would be better to interpret the sum of the coefficients, which would give an indication as to the scale of production that is increasing, constant or decreasing returns to scale. It can thus be seen that the coefficients given by the MLE estimates as shown in table 8 add up to 1.05. This implies then that a 1% increase in all the inputs would result in a *ceteris paribus*, 1.05% increase in outputs. This would suggest then that the average farm in the sample experiences slight levels of increasing returns to scale, suggesting that there are gains

to be had should the scale of production be increased slightly. Thus for the average farm in the data set, the farm experiences a slight case of increasing returns to scale.

The estimate of γ is 0.98 correct to the second decimal place, and the estimated standard error is 0.04, correct to two significant digits with a t-ratio of 43.48 this would suggest that this value is significantly different from zero at the highest level of confidence. These results indicate that the vast majority of residual variation is due to the inefficiency effect, u_i , and the random error, v_i , is approximately zero (Coelli, Prasada-Rao, & Battese, 1998). The variables used in this analysis are for the most part significantly different from zero as indicated by their t-ratios, suggesting that the variables used in the model would be an accurate representation of the production frontier. This would be expected, as one would expect the fixed factors of production as well as the intermediate inputs into production, to accurately explain the output. We could thus deduce that we have a model that accurately describes the production frontier. This frontier is statistically significant and it can therefore be used in determining the level of technical efficiency for the various farms within the sample. Table 9 below gives an indication as to the levels of technical efficiency with which these farms are operating.

Table 9: Efficiency Estimates from Stochastic Frontier Analysis (Frontier 4.1)

firm	eff.-est.	firm	eff.-est.
1	0.854	27	0.478
2	0.939	28	0.877
3	0.808	29	0.963
4	0.809	30	0.943
5	0.921	31	0.917
6	0.891	32	0.765
7	0.979	33	0.951
8	0.883	34	0.807
9	0.976	35	0.938
10	0.958	36	0.839
11	0.674	37	0.912
12	0.677	38	0.967
13	0.918	39	0.789
14	0.938	40	0.954
15	0.947	41	0.940
16	0.952	42	0.778
17	0.567	43	0.924
18	0.708	44	0.874
19	0.884	45	0.772
20	0.961	46	0.951
21	0.734	47	0.786
22	0.828	48	0.950
23	0.704	49	0.897
24	0.823	50	0.926
25	0.889	51	0.800
26	0.820		
Mean Efficiency = 0.857			

From table 9 it can be seen that for the most part the farms are operating at relatively high levels of technical efficiency. With the high levels of expertise that are being applied to these farms throughout the production cycle, this is to be expected, these high scores also suggest that the production technologies for the various farms are relatively homogenous. It is important to keep in mind however that these efficiency scores are relative to one another, and are not a reflection of the level of technical efficiency of these specific farms relative to the industry as a whole.

The average efficiency can be seen as being nearly 86% this means that the average farm has the propensity to increase efficiency by roughly 14%. This figure of 86% however is reduced as a result of a few outliers, namely farm number 11, 12 and 27. These farms generally have low levels of output relative to what was spent on the inputs; this could have been as a result of drought, poor management or incorrect advice for the production season. That being said however for the most part, these farms all used their inputs well to generate outputs with the best practise farm having a rather limited scope for possible improvement of only 2.1%. There is however some scope for improvement and this could be brought about by reducing certain costs of the inputs used in production. This will be discussed a little bit later on.

The estimation of the stochastic production frontier and the associated technical efficiencies was therefore performed so as to establish the importance of the various inputs used for crop production within the FOF model. The results therefore indicate that the output can indeed be explained by the variables used in this analysis. It is important to note however that the efficiency results obtained can be sensitive to the type of method selected to estimate these efficiency scores.

The two most popular methods used to measure farm efficiency are the Data Envelopment Analysis (DEA) (Charnes, Cooper, & Rhodes, 1978) and Stochastic Frontier Analysis (SFA) (Aigner, Lovell, & Schmidt, 1977) and (Meeusen & van Den Broeck, 1977) as discussed above. The choice of which method is used however has to be determined in every case because it is not always that obvious. The advantage of the DEA approach compared to the SFA approach is that the DEA approach firstly does not require any functional form to be selected, and secondly no behavioural assumptions are needed (Piesse, 1999). The disadvantage of using DEA however is that it is a deterministic approach, which means that the model does not take measurement errors and other statistical noise into account and therefore any deviations from the frontier are assumed to be as a result of inefficiencies (Mkhabela T. , 2011). Below is a discussion of the theory taken from Coelli *et al.* (2005) behind this approach.

4.3 Data Envelopment Analysis (DEA)

Data Envelopment Analysis as proposed by Charnes, Cooper & Rhodes (1978) is both a non-parametric as well as deterministic approach that uses linear programming techniques to construct a piece-wise frontier over the data. Efficiency measures are then calculated as distances between the observed inputs and outputs relative to this frontier as proposed by Farrell (1957) (Coelli, Rao, O'Donnell, & Battese, 2005). The model that Charnes, Cooper and Rhodes (1977) proposed had an input orientation and they assumed constant returns to scale (CRS).

According to Coelli *et al.* (2005) the DEA model can be thought as a ratio of all outputs compared to all inputs, such as $u'q_i/v'x_i$ where u is an $M \times 1$ vector of output weights and v is an $N \times 1$ vector of input weights (Coelli, Rao, O'Donnell, & Battese, 2005). The optimal weights for each farm are then obtained by solving the following mathematical programming problem (Coelli, Rao, O'Donnell, & Battese, 2005):

$$\begin{aligned}
& \max_{u,v} \left(\frac{u'q_i}{v'x_i} \right) \\
\text{st}^{36}. & \frac{u'q_j}{v'x_j} \leq 1, \quad j = 1, 2, \dots, I \\
& u, v \geq 0
\end{aligned} \tag{12}$$

Where q_i is a column vector of M outputs, and x_i is a column vector of N inputs, therefore the Nx1 input matrix, X, and the Mx1 output matrix, Q, represent the data for all I firms. The mathematical programming problem is then to find values for u and v , so that the efficiency measures for each i -th farm is maximised, this is subject to the constraints that all efficiency measures must be less than or equal to one (Coelli, Rao, O'Donnell, & Battese, 2005).

The scale of these weights then gives information about the relevant reference groups (known as benchmarks) for each inefficient farm, with the largest weight being the most appropriate efficient farm for the inefficient farm to be benchmarked against (Mkhabela T. , 2011). The DEA model therefore determines which farms within the sample the inefficient farms can benchmarked against, rather than benchmarking these farms against an average. The problem with the above mathematical programming problem however is that it has an infinite number of solutions, Coelli *et al.* suggest a constraint be imposed so as to limit the amount of possible solutions. Using the preferred envelopment form of this problem it yields the following (Coelli, Rao, O'Donnell, & Battese, 2005);

$$\begin{aligned}
& \min_{\mu, v} \theta, \\
\text{st.} & -q_i + Q\lambda \geq 0 \\
& \theta x_i - X\lambda \geq 0 \\
& \lambda \geq 0
\end{aligned} \tag{13}$$

Where θ a scalar and λ is a $I \times 1$ vector of constants, the linear programming model must therefore be solved I times so that a value of θ is obtained for each farm (Coelli, Rao, O'Donnell, & Battese, 2005). The θ value that is obtained is then the efficiency score for the i -th farm, and it satisfies the property $\theta \leq 1$, with a value of 1 indicating that the farm is on the efficiency frontier, according the Farrell (1957) definition, and is therefore technically efficient. (Coelli, Rao, O'Donnell, & Battese, 2005).

This linear programming problem therefore takes the input vector x_i for the i -th farm, and seeks to radially contract the input vector as much as possible so as to obtain a the minimum input required to produce a given level of outputs for the input orientated measure. For the output orientated measure however measures the maximum amount of output that can be produced from a given level of inputs. According to Coelli *et al.* (2005) This radial contraction therefore generates a projected point $(X\lambda, Q\lambda)$, on the surface of this technology, which is defined by Färe *et al.*(1994) as $T = \{(x, q): q \leq Q\lambda, x \geq X\lambda\}$ and exhibits constant returns to scale and strong disposability.

The use of the above constant returns to scale specification when not all firms are operating at the optimal scale, because of factors such as imperfect competition or constraints on finance etc., however can result in technical efficiency scores that are affected by scale efficiencies

³⁶ The notation “st” stands for subject to.

(Coelli, Rao, O'Donnell, & Battese, 2005). If any of these factors are expected then it is important that the Variable Returns to Scale specification be used, as this specification takes into account any scale efficiency effects. Coelli et al. (2005) show that this Constant Returns to Scale (CRS) linear programming problem can be modified to account for these scale efficiency effects by adding the convexity constraint: $\mathbf{1}'\lambda = 1$ to equation 13 this gives;

$$\begin{aligned}
 & \min_{\theta, \lambda} \theta, \\
 \text{st. } & -q_i + Q\lambda \geq 0 \\
 & \theta x_i - X\lambda \geq 0 \\
 & \mathbf{1}'\lambda = 1 \\
 & \lambda \geq 0
 \end{aligned} \tag{14}$$

Where $\mathbf{1}$ is a 1×1 vector of ones. Coelli *et al.* (2005) suggest then that this approach forms a convex hull of intersecting planes that envelope the data points more tightly than the CRS conical hull, and therefore provides technical efficiency scores that are greater than or equal to those obtained using the CRS model. This convexity constraint ensures then that an efficient farm is only benchmarked against a farm of similar size, as opposed to the CRS model which benchmarks all farms in the sample to each other irrespective of the size of the farm (Coelli, Rao, O'Donnell, & Battese, 2005).

This measure can then be used to determine the scale efficiencies³⁷ of each farm, which result from the differences between the CRS and VRS model, i.e. if there is a difference between these two measures it would indicate then that the firm has scale inefficiency. This example can be illustrated with the use of a figure, which represents a one input one output frontier.

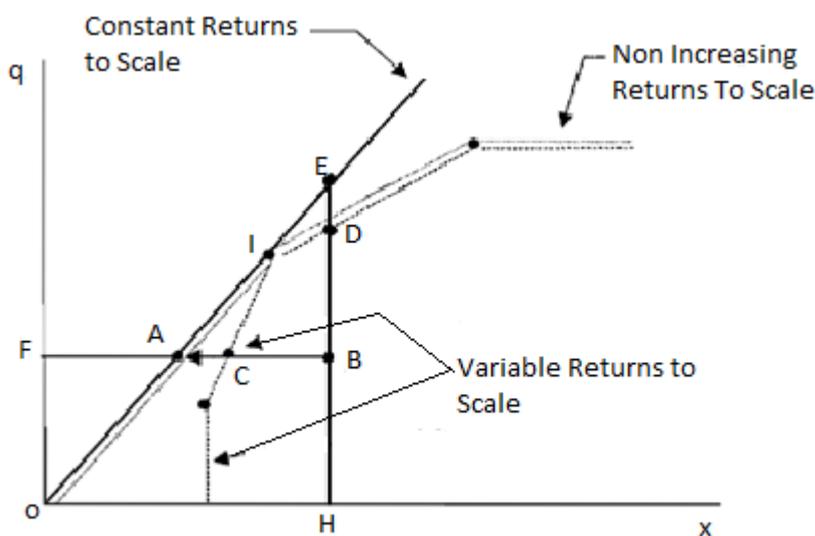


Figure 2: Scale Efficiency Measurement in DEA

Source: Adapted from (Coelli, Rao, O'Donnell, & Battese, 2005, p. 174) and (Mkhabela T. , 2011, p. 119))

³⁷ (Nicholson, 1985, p. 247) Defined returns to scale as: “in intuitive terms, if a proportionate increase in inputs, increase outputs by the same proportion, the production function exhibits CRS. If the output increases less than proportionately, the function exhibits diminishing returns to scale, and if the outputs increase more than proportionately then there are increasing returns to scale”.

As shown by Coelli *et al.* (2005) in figure 2 under CRS, the input-orientated technical efficiency of the point A is the distance AB. Under VRS however, the technical efficiency would be only BC the difference between these two technical efficiency measures, AC then is due to scale efficiency (SE) (Coelli, Rao, O'Donnell, & Battese, 2005). For the output orientated measure of technical efficiency (TE), in the VRS model, the technical efficiency is equal to the ratio of HB/HD and HB/HE in the CRS model, outputs can therefore be expanded by HD/HB in the case of VRS, and HE/HB in the CRS case. According to Coelli *et al.* (2005) these concepts can be expressed in ratios such that;

$TE_{CRS}=FA/FB$ (input-orientated model) and $TE_{CRS}=HB/HD$ (output orientated model)

$TE_{VRS}=FC/FB$ (input-orientated model) and $TE_{VRS}=HB/HE$ (output orientated model)

$SE=FA/FC$ (input orientated model) and $SE = HD/HE$ (output-orientated model)

All of these measures are bounded by zero and one (Coelli, Rao, O'Donnell, & Battese, 2005). The CRS technical efficiency measure is therefore decomposed into “pure” technical efficiency as well as scale efficiency, and this measure can be roughly interpreted as the ratio of the average product of a farm operating at the point C to the average product of a firm operating at a point of (technically) optimal scales (point I) (Coelli, Rao, O'Donnell, & Battese, 2005). A problem with this measure however is that the values obtained do not give an indication whether the firm is operating at increasing or decreasing returns to scale, this issue can be addressed by imposing non-increasing returns to scale, thereby replacing the $I1'\lambda = 1$ restriction with a $I1'\lambda \leq 1$ in equation 14 (Coelli, Rao, O'Donnell, & Battese, 2005).

Coelli *et al.* (2005) suggest then that the nature of the scale inefficiencies can be determined by comparing the technical efficiency scores for the non-increasing returns to scale with the VRS technical efficiency score. If they are unequal, then increasing returns to scale are implied while if they are equal then decreasing returns to scale apply, this constraint insures that the *i*-th firm is not “benchmarked” against firms that are substantially larger than it, but may be compared to farms that are smaller than it (Coelli, Rao, O'Donnell, & Battese, 2005).

It is important to note however that the piece-wise linear form of the non-parametric frontier in DEA can cause a few difficulties in the efficiency measurement. This problem arises as a result of sections of the piece-wise frontier running parallel to the axes (Coelli, Rao, O'Donnell, & Battese, 2005). Consider the following example of producers using two inputs x_1 and x_2 to produce a given level of output, q , taken from Coelli *et al.* (2005);

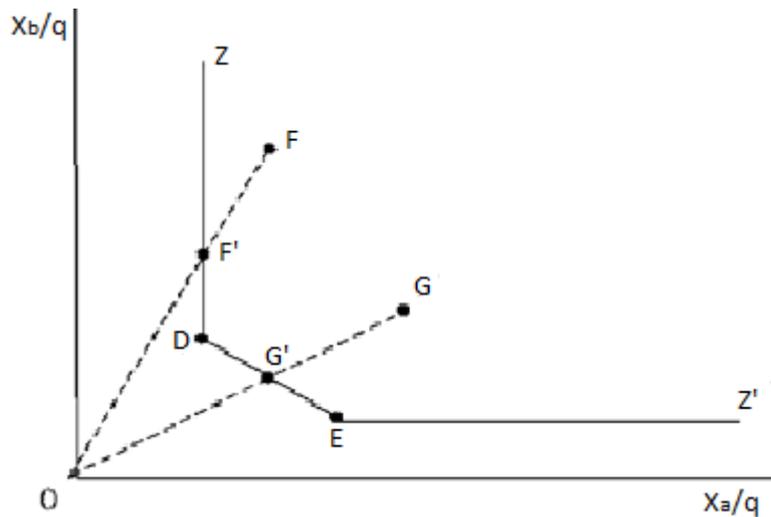


Figure 3: Efficiency Measurement and Input Slacks (Source: (Coelli, Rao, O'Donnell, & Battese, 2005, p. 165))

In the above figure firm using input combinations of D and E are the efficient firms that define the frontier, while firms F and G are inefficient as they are not on the frontier. The Farrell measure gives the efficiency of firms F and G as OF'/OF and OG'/OG respectively. The issue then is that the point F' is still not an efficient point because of the fact that you can reduce the use of input x_b , by the amount DF' and still produce the same amount of output, this is known as the input slack (Coelli, Rao, O'Donnell, & Battese, 2005). If these models contain multiple inputs and/or outputs, the possibility of the output slack can also occur, refer to Coelli *et al.* (2005, pg. 165) for a further discussion. The computer programme used in determining these technical efficiency scores however takes these slacks into account.

Lastly DEA can also be used to determine the Allocative Efficiencies of the various farms, provided that there is price data available as well as a behavioural objective assumed, i.e. either cost minimisation or revenue or profit maximisation (Coelli, Rao, O'Donnell, & Battese, 2005). In this case we will assume that the behavioural assumption employed for this specific data set is that of cost minimisation. For the case of VRS cost minimisation, the input-orientated DEA model given by equation 14, is used to determine the technical efficiency of the i -th firm. The next step is to solve the cost minimising DEA model defined by Coelli *et al.* (2005) as;

$$\begin{aligned}
 & \min_{\lambda, x_i^*} w_i' x_i^*, \\
 & \text{st. } -q_i + Q\lambda \geq 0 \\
 & \quad x_i^* - X\lambda \geq 0 \\
 & \quad \mathbf{1}'\lambda = 1 \\
 & \quad \lambda \geq 0
 \end{aligned} \tag{15}$$

Where w_i is a $N \times 1$ vector of input prices for the i -th farm and x_i^* (which is calculated by the LP) is the cost-minimising vector of input quantities for the i -th firm, given the input prices w_i and the output levels q_i (Coelli, Rao, O'Donnell, & Battese, 2005). According to Coelli *et al.* (2005), the total cost efficiency of the i -th farm is then calculated as $CE = w_i' x_i^* / w_i' x_i$ i.e. the cost efficiency is the ratio of minimum cost to the observed cost, for the i -th farm. The input mix or allocative efficiency is then calculated residually as $AE = CE/TE$, where all three

of these measures take a value between 0 and 1, where a value of 1 indicates full efficiency. This measure implicitly includes any slacks into the allocative efficiency measure, and is often justified on the grounds that slacks reflect inappropriate input mixes (Coelli, Rao, O'Donnell, & Battese, 2005, p. 184).

An important factor to consider when using the DEA approach, is since farms are compared to one another it is important that the input mixes, output mixes as well as production technologies are comparable. This is the case in this study, as the outputs as well as the inputs have been aggregated to form an average income per hectare in monetary terms, and the inputs have been treated in a similar fashion. The DEA model is used in this study because unlike the regressions required for the stochastic frontier analysis, which determines a statistical relationship between the dependant and independent variables at the conditional mean, DEA determines optimal solutions for every observation in a specific data set. This will therefore facilitate the determination of the appropriate benchmarks for the inefficient farms rather than an exogenous source such as the mean (Mkhabela T. , 2011). The following section discusses the results obtained from the DEA model.

4.3.1 Technical Efficiencies using DEA

DEA in this instance could be a better method of measurement because of the fact that there are no statistical trends as a relation to actual happenings. This was as a result of having to construct a large amount of data from the recommendations as well as the management accounts, it would then not seem completely correct to compare the farms to the exogenous mean, but rather to one another using the amounts spent on each input. It therefore seemed safer to assume that everyone was the same, rather than assuming that everyone is different, which could have led to there being a bias in selection. This could be because of the fact that the majority of the decisions that used to be made by the farmer, have now been taken away from the farmer, and are now made by the experts in the field under the same management. The farmer specific attributes then could be taken out of the inefficiency terms, as the majority of their decision powers have been taken away, and their management ability would now have less of a bearing on the final outcome.

The DEA measure can then be used to compare all of the “productive inputs” as established in the data chapter as a high degree of aggregation is not required, which is often the case with the parametric approach as it seeks to employ a functional form that best describes the data (Piesse, 1999). The results obtained are presented in table 10 below. The efficiency scores were determined using both the constant returns to scale as well as variable returns to scale models, and the difference as mentioned above give an indication as to the scale efficiencies with which these farms are operating, i.e. either increasing, decreasing or constant returns to scale.

Table 10: CRS and VRS technical Efficiency Scores using DEA

firm	crste	vrste	scale		firm	crste	vrste	scale	
1	0.973	0.978	0.995	irs	27	0.321	1	0.321	irs
2	0.992	1	0.992	irs	28	0.726	0.812	0.894	irs
3	0.601	1	0.601	irs	29	1	1	1	-
4	0.676	1	0.676	irs	30	1	1	1	-
5	1	1	1	-	31	0.761	0.89	0.855	irs
6	0.766	1	0.766	irs	32	0.716	1	0.716	irs
7	1	1	1	-	33	1	1	1	-
8	0.887	0.9	0.985	drs	34	0.661	0.795	0.832	irs
9	1	1	1	-	35	1	1	1	-
10	1	1	1	-	36	0.73	0.979	0.746	irs
11	0.568	1	0.568	irs	37	1	1	1	-
12	0.416	0.807	0.515	irs	38	1	1	1	-
13	0.879	0.923	0.953	irs	39	0.57	1	0.57	irs
14	1	1	1	-	40	1	1	1	-
15	1	1	1	-	41	1	1	1	-
16	1	1	1	-	42	0.576	1	0.576	irs
17	0.258	0.845	0.306	irs	43	1	1	1	-
18	0.509	1	0.509	irs	44	0.832	0.936	0.889	irs
19	0.794	0.843	0.943	irs	45	0.718	1	0.718	irs
20	1	1	1	-	46	1	1	1	-
21	0.786	1	0.786	irs	47	0.685	0.945	0.725	irs
22	0.703	0.917	0.766	irs	48	0.972	0.992	0.98	irs
23	0.483	1	0.483	irs	49	0.781	0.883	0.884	irs
24	0.683	0.74	0.924	irs	50	0.779	0.8	0.973	irs
25	0.895	1	0.895	irs	51	0.623	1	0.623	irs
26	0.561	1	0.561	irs	mean	0.802	0.96	0.834	

The results show that out of the sample of 51 farms for the 2011/2012 production season there were 18 farms on the efficiency frontier if constant returns are assumed while there are 34 farms that are on the frontier if variable returns to scale are assumed. The farms that defined the frontier would then be the “best practice” farms meaning that they are the most efficient at transforming their inputs into outputs. As a result of these farm being the “best practice” farms within the model, it is these farms then that the DEA³⁸ model would benchmark the inefficient farms against, this will however be discussed a little bit later on.

If one has a look at the actual individual scores obtained when the constant returns to scale model is relaxed it can be seen that the efficiency scores obtained under variable returns to scale model are higher than those obtained from the model in which constant returns to scale are assumed. One could then deduce that there are indeed scale efficiencies or inefficiencies within the sample. More importantly as was observed in the parametric approach, it would seem as if on average these farms are all faced with increasing returns to scale, i.e. there are 32 farms experiencing increasing returns to scale, 18 farms experiencing constant returns to scale and only one farm experiencing decreasing returns to scale, and herein lies the advantage of using the DEA approach to determining these efficiency scores as one can now have a look at each individual and determine what the best course of action would be so as to improve the efficiency of these farms. The conclusion that can be drawn from this then is that the majority of these farms could have considerable gains if they increase the size of their operations.

³⁸ Hockmann and Svetlov (2006) states that “The key idea of DEA is that the location of a firm outside a production frontier indicates that the firm is experiencing a specific problem that does not hamper the activities of firms located on the frontier” (Hockmann & Svetlov, 2006, p. 2)

As can be seen in table 10 the majority of these efficiency scores are rather high with the average efficiency scores obtained under variable returns to scale is roughly 96%, i.e. for the majority or average farm there is only scope to improve efficiency by roughly four percent. This result however is not surprising, as in the majority of case the farms received production advice from specialists in the fields of agronomy and soil science. One could assume then that the advice offered by the technical expert is valuable to the model, and is indeed helping these farms with obtaining these high efficiency levels. Again an important point to keep in mind is that these farms are compared to one another, and not to the entire industry or even to other farms that are outside of the model.

Another advantage of using the DEA method in determining the technical efficiency scores for the various farms, under the input orientation model is that the DEA model uses linear programming to determine by what amount the various inputs can be reduced so as to maintain a given level of output. It does this by firstly determining the amount of radial contraction that is possible, and then determining if there are any slacks in the use of the inputs, refer to the discussion above. Below is a discussion of these slacks followed by a discussion on the summary of input targets generated by the DEAP (Coelli, Rao, O'Donnell, & Battese, 2005) program.

4.3.2 Slacks

Figure 3 can be used to explain slacks for firm F FF' is the radial reduction possible while F'D is the slack. The slack therefore gives an indication as to the amount x_b can be reduced by without reducing the output. It therefore represents the "waste" or portion of redundant input that is being used to generate the output represented by the efficiency frontier ZZ'.

The difficulty in Agriculture and the determination of output maximization, cost reduction, and by definition profit maximization, of an input vector has some serious challenges when determining the input mix or input vector that maximizes output. For example, in maize production there are certain agronomic norms that need to be adhered to in order to sufficiently supply the plants with the nutrients they need in order to successfully grow. If then the production function or vector of inputs that produces outputs is measured in Kg/ha, the input quantities could be reduced to below the level of agronomic norms and this would then change the dynamics of the potential production.

It would thus seem more relevant to calculate these values in the Rand per hectare, especially using DEA since unlogged variables are used, form as a reduction in the input (slacks) could be achieved by simply changing the type³⁹ of fertilizer applied. Therefore a reduction in the use of an input can improve the efficiency with which the farms operate while still satisfying agronomic norms so as to not reduce the level of output which is decided on *ex ante*. This is because of the fact that agronomic norms can be achieved via a large variety of perfectly substitutable goods⁴⁰. This method of measuring the inputs would then seem to be the most

³⁹ For example you could apply a cheaper source of fertilizer, that achieves the agronomic requirements for production, but because the product is cheaper it would account for the slack or radial movement to get onto the isoquant, or production possibility frontier (PPF) for that specific level of output.

⁴⁰ That is the level of nitrogen required to produce one ton of grain in this case is, x , then this level of x , can be achieved by varying combinations of the various formulations q_1x_1, \dots, q_nx_n .

appealing because of the fact that the various levels of inputs required, as given by the level of output being aimed for, can be searched for over a wide range of inputs that satisfy the agronomic norms while at the same time minimize cost. The same can be said for inputs such as seed, chemicals as well as diesel as in most cases a reduction in the total amount applied i.e. Rand per Hectare seems more useful than a reduction in the quantity of the input to be applied.

If these levels of inputs were to be measured in a cost per hectare value, this would seem to quality adjust the input being used, and any slacks that result from the use of this input could then practically be achieved without altering the level of production rendering these observations both pertinent and applicable. Table 11 below gives an indication of these input slack for the various farms, farms 11-39 have been cut out to save space.

Table 11: Summary of Input Slacks using Data Envelopment Analysis (DEAP)

firm input:	Land (R/ha)	Labor (R/ha)	Precision (R/ha)	Fert (R/ha)	Seed (R/ha)	Chem (R/ha)	Machinery (R/ha)	Diesel (R/ha)
1	876.668	0	0	0	218.999	329.535	559.942	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	29.17	991.33	377.75	365.065	0	0
9	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
.
.
40	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0
44	0	8.497	0	19.188	0	183.774	734.649	0
45	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0
47	724.651	0	0	0	63.205	172.247	192.776	0
48	0	0	47.457	0	79.946	0	55.818	0
49	19.401	26.938	0	0	0	0	79.105	0
50	0	0	79.748	0	0	0	90.869	92.711
51	0	0	0	0	0	0	0	0
mean	40.04	13.541	13.353	53.031	28.217	37.32	66.116	8.765

In table 10 it was shown that there were 34 farms that had an efficiency of 1 indicating that they were technically efficient, and it was these farms that defined the frontier and represented the “best practice” farms. Therefore since these farms were on the frontier there was no radial reductions possible, and these farms did not have any slacks.

The remaining 17 farms however had efficiency scores of less than one suggesting that these farms had inefficiencies in the use of some of the inputs, radial reductions were therefore possible, and there were slacks present. The slacks that were common to ten out of the 17 inefficient farms were machinery, precision and seed. This is an interesting point, as this highlights the possibility that these farms are over inflating the values of their machinery fleets, and this is resulting in the company overpaying for the hire of these machines. This is indicative of the model, as the farmer often has the incentive to inflate their costs affirming the suspicion of their existing significant moral hazards within the model. The precision is another interesting slack; this slack would either indicate that these farmers were over charged for the precision services supplied to them or that the precision services supplied to them did not generate any significant difference in the output generated by these farmers. The

seed as a slack could be an indication that the farmers used expensive varieties that did not generate any extra benefit from the use of these varieties.

Therefore from the above table it can be seen that for the most part these farms generally require a reduction in either two or more of the costs spent on the various inputs. For inputs such as seed, chemicals and fertilizer this can be easily achieved without changing the dynamic of production by simply finding a formulation or variety of inputs that still maintains any agronomic norms, but that at the same time reduces the cost of applying and achieving these agronomic norms.

The results obtained from the DEA studies, can therefore be immensely useful for the managing of these various farms because of the fact that management can simply make changes where any inefficiencies exist. These inefficiencies in the use of inputs or the shortfall of outputs produced generate slacks these slacks can then be used to quantify the amount of excess inputs that are being used by that specific farm to produce the same level of output as their peers (Mkhabela T. , 2011). As a result of the DEA model having an input orientation, there were no output slacks; this is because of the fact that the model measures the efficiency of employing those given input levels to produce the measured level of outputs.

Another useful set of results generated by the DEA model is the summary of the input targets. Table 12 gives a summary of these results; farm 11-39 has been cut out of the results so as to save space.

Table 12: Summary of Input targets Data Envelopment Analysis (DEAP)

firm input:	Land (R/ha)	Labor (R/ha)	Precision (R/ha)	Fert (R/ha)	Seed (R/ha)	Chem (R/ha)	Machinery (R/ha)	Diesel (R/ha)
1	1122.447	711.717	51.445	2586.415	1192.631	953.229	802.274	674.706
2	541.004	370.646	0	1622.784	1213.952	1113.021	767.419	1242.086
3	476.013	309.955	18.604	1316.963	708.364	525.531	273.997	620.059
4	359.713	273.322	236.923	1450.256	561.774	893.622	577.773	548.464
5	717.171	458.081	245.046	1104.037	297.527	139.13	791.494	855.094
6	609.03	366.315	40.089	1125.921	520.095	545.173	438.398	1124.122
7	310.438	425.208	0	1956.715	982.44	375.143	603.613	1013.433
8	635.46	433.284	74.734	2026.237	1043.331	760.777	756.407	859.584
9	2200	389.333	113.469	2221.095	725.581	534.536	441.897	939.684
10	1485.776	162.76	195.548	2096.405	464.778	423.496	210.821	746.213
.
.
40	1128.654	586.972	128.249	1982.627	623.209	616.022	1593.014	977.596
41	1092.065	597.577	105.472	2629.971	583.615	731.217	1887.933	1015.883
42	843.478	368.821	119.938	2356.555	613.015	348.074	335.731	661.088
43	490.134	369.258	189.104	2896.275	1415.032	1517.233	1276.222	919.512
44	722.035	368.119	170.568	1785.63	513.112	519.762	825.588	705.815
45	3592.362	567.057	347.985	2013.887	534.501	359.452	573.86	621.036
46	1653.26	234.84	48.2	2121.906	980.639	490.928	942.377	822.596
47	1025.424	201.103	137.588	1903.037	709.547	548.364	523.563	654.678
48	826.985	479.903	97.825	1877.938	804.269	632.977	863.978	677.383
49	1192.502	309.944	129.621	1864.662	606.542	283.423	466.849	752.227
50	400.41	444.176	52.867	1560.37	820.07	528.053	625.147	828.397
51	345.401	221.78	34.634	1058.757	1020.352	348.584	593.93	1071.874

Input targets refer to the desirable level of each input that each farm should use to produce the observed level of output optimally. They would therefore represent the levels of inputs required after the radial reductions and slacks have been subtracted from the values of the various inputs. This would then serve as an indication as to the levels of the inputs that should be used by the various farms so as to bring the various farms onto the frontier. The values can therefore serve as a limit to the amount the company should pay for the various inputs, and this would seem to be a great tool for management.

A useful feature of DEA is that it allows for benchmarking between the various farms. This can be an immensely useful tool for managers and farmers alike. This is because of the fact that farms of similar size and similar technology can be benchmarked against each other, this would then give an indication or a starting point to improving the efficiency with which these farms operate. DEA does this by identifying the actual efficient farm that each inefficient farm can be compared against, rather than some arbitrary average. The identification of these efficient (often called peers) farms then makes it possible for the inefficient farms to observe how to best utilize their inputs to generate outputs. Below is a summary of the top two peers for each of the farms.

Table 13: Summary of Peer Counts from DEA analysis

firm	Peer #1	Peer #2	firm	Peer #1	Peer #2
1	37	33	27	27	
2	2		28	3	35
3	3		29	29	
4	4		30	30	
5	5		31	5	7
6	6		32	32	
7	7		33	33	
8	38	33	34	29	27
9	9		35	35	
10	10		36	7	4
11	11		37	37	
12	25	3	38	38	
13	7	9	39	39	
14	14		40	40	
15	15		41	41	
16	16		42	42	
17	51	29	43	43	
18	18		44	16	5
19	15	7	45	45	
20	20		46	46	
21	21		47	25	10
22	3	38	48	16	25
23	23		49	5	9
24	10	35	50	9	5
25	25		51	51	
26	26				

One can interpret table 13 in the following fashion. If farm 1 is used as an example, farm 37 is its best benchmark to model itself against. In other words farm 1 should emulate farm 37 in the way it structures and conducts its business, including the way in which it applies and uses inputs to generate outputs. This information can therefore be extremely useful to management as it provides a starting point for the various farms to improve the efficiencies with which they operate.

The results obtained from the production frontier, and subsequently the efficiency scores obtained would suggest that for the most part the FOF farms are performing, when it comes to using inputs to generate outputs. If this is the case why then would the model, aside from droughts and unfavorable production conditions be losing money. It appears that this is because of the farms inability to choose inputs in optimal proportions i.e. their allocative efficiencies.

4.4 Cost Function

After having established the technical efficiencies of the various farms within the model, we will now have a look at the allocative efficiencies or inefficiencies with which these farms are operating. DEA will again be used for this. DEA is chosen because of the fact that it seems to allow fixed costs to be taken into account, which is extremely important especially in this case as in the majority of the cases the fixed costs make up roughly half of the total costs into production. The quantities of these fixed costs are hard if not highly improbable to accurately assign to any enterprise on a farm that has more than one enterprise. But by assuming that these fixed costs are applied on a per unit basis (1 unit per hectare), it then seems that these costs would also then be able to be included in the analysis, and these too would affect the allocative efficiency and therefore the economic efficiency of the production. The calculations of allocative efficiencies in this way are not possible with a parametric approach because of issues such as multi-collinearity.

In this instance the linear programming problem is one of minimizing costs, where the total cost efficiency of the i -th firm is calculated as $CE = w_i'x_i^*/w_i'x_i$ i.e. the cost efficiency is given by the ratio of the minimum cost to the observed cost given the output level (Coelli, Rao, O'Donnell, & Battese, 2005). The allocative efficiency is then calculated residually as $AE = TE/CE$, all three of these values take a value between 0 and 1, where 1 indicates a fully efficient farm that is on the frontier, as was discussed in the previous section. Below is the linear programming problem as given by Coelli *et al.* (2005);

$$\begin{aligned}
 & \min_{\lambda, x_i^*} w_i'x_i^*, \\
 & \text{st. } -q_i + Q\lambda \geq 0 \\
 & \quad x_i^* - X\lambda \geq 0 \\
 & \quad \mathbf{1}'\lambda = 1 \\
 & \quad \lambda \geq 0
 \end{aligned} \tag{16}$$

Where w_i is a $N \times 1$ vector of input prices for the i -th farm and x_i^* (which is calculated by the LP) is the cost-minimising vector of input quantities for the i -th firm, given the input prices w_i and the output levels q_i (Coelli, Rao, O'Donnell, & Battese, 2005). This measure implicitly includes any slacks into the allocative efficiency measure, and is often justified on the grounds that slacks reflect inappropriate input mixes (Coelli, Rao, O'Donnell, & Battese, 2005, p. 184).

The use of this approach is then justified by the following. If say for example a level of input x^* based on an agronomic norm was the same for everyone, this level of input can be viewed as a per hectare application. Then the price of that input or the level at which you apply this input would be given by the price of that input multiplied by the quantity of that input, for that specific application that is;

$$C_x = \{(x, w)\}$$

Where C_x is the cost of the input x multiplied by the price vector w .

The assumptions here is that there is a vector of the specific input x together with its vector of prices w . The amount of input applied then is represented by the amount used of that input, x_i

multiplied by the price of that specific input w_i . In the case of fertilizer this is not hard to conceptualize because of the fact that there are various different formulations of fertilizers at various different prices, and thus any difference in the amount applied could be as a result of this, assuming the agronomic norm for production was applied. The next assumption is that of constant returns to scale (CRS), so that any differences between the farms is as a result of the farms ability to efficiently choose a level of input rather than differences in the scale of the various farms.

This could be a better because of the differences in the quality and prices of various inputs therefore it would seem more practical for intermediate inputs such as fertilizer, because you can maintain agronomic norms while still reducing costs by using a different formulation of the input. This can reduce the costs of the inputs to increase the allocative efficiency (AE) and thus per definition the economic efficiency (CE) because you can make changes without changing the dynamic of the production.

If this is true, values like land rent and the management fee cannot be used in Stochastic Frontier Analysis because of issues of multi-collinearity in assigning the quantities of the various inputs and therefore these costs are completely ignored which could have drastic and grave implications on the final analysis. It is assumed for this reason that a non-parametric approach such as that of DEA would be better, as in DEA you are able to use a constant (the level of the input applied based on a per-unit application such as a hectare), to arrive at an allocative efficiency, technical efficiency and economic efficiency score for the various farms.

In this example, this result is shown by correlating the Return on each of the 51 farms with the allocative and economic efficiency scores obtained with the DEA analysis. If this measure can then be used to explain low or negative returns (viz. by a high correlation between AE and Return), then one could assume that returns or profitability could be improved by improving the AE. This is because of the fact that there is a large variety of inputs available in the market, therefore inputs (groups and suppliers) are perfect substitutes for each other and different combinations could be used of the inputs so as to reduce the costs of production while still maintaining critical agronomic norms for plants, which are pre-determined and non-alterable (this would rely on the assumption that the agronomist/consultant/farmer are rational producers and want to maximize output and thus per definition profit). Then any reduction in value is reflected by the allocative efficiency score of the farm in producing the pre-determined level of output, or the output to which the field technician is going to apply inputs for.

The disadvantage of this measure however, is that 1) it is not a statistically sound measure, as a result on the measure relying on the use of the non-parametric approach DEA, and 2) it does not take any scale effects into account, as constant returns to scale are assumed. This last point could not be as serious because one could assume that this measure is taken from a view of the production being in the short run, and thus it would assume that none of the variables are “variable” and thus any scale effects cannot be considered.

These allocative efficiency scores were therefore determined by comparing the output (R/farm) to the entire range of inputs used into the production of the output i.e. they contained all 18 inputs ranging from land rent to accountants fees. The quantities of the intermediate inputs into production such as the fertilizer, diesel and seed were given by the management accounts and agronomists recommendations together with their respective prices. For all other inputs whose quantities and prices were not available, it was assumed that these were applied on a per hectare basis, as discussed above, and their prices were the amounts that were paid towards the total costs of production, i.e. their total costs.

The advantage of this method like mentioned above is that one is able to use all of the costs into production to determine the allocative and economic efficiency, and any reductions required can be achieved by reductions in the amounts paid for each of the inputs. The technical efficiency scores in the figure below can largely be ignored, as the scores obtained in table 2 would be a better representation of the true efficiency scores although these efficiency scores are very close to one another, we are therefore only interested in the allocative efficiency scores from table 15 below.

Table 14 below gives an indication as to the levels of allocative efficiency being achieved by the various farms. It is important to again remember that these levels obtained are relevant to the farms included in the analysis, and are not a comparison to the industry norms.

Table 14: Allocative Efficiency Scores using DEA

Firm	te	ae	ce	Firm	te	ae	ce
1	1	0.826	0.826	27	0.709	0.24	0.17
2	0.85	0.69	0.586	28	0.847	0.757	0.641
3	0.684	0.582	0.398	29	0.799	0.63	0.504
4	0.727	0.525	0.382	30	1	0.824	0.824
5	0.912	0.535	0.488	31	0.757	0.645	0.488
6	0.684	0.588	0.402	32	0.846	0.543	0.46
7	0.96	0.86	0.825	33	1	0.813	0.813
8	0.976	0.705	0.688	34	0.868	0.483	0.419
9	1	1	1	35	1	0.739	0.739
10	0.906	0.723	0.656	36	0.715	0.629	0.45
11	0.827	0.41	0.339	37	1	0.924	0.924
12	0.802	0.437	0.35	38	1	0.767	0.767
13	0.905	0.69	0.624	39	0.677	0.482	0.327
14	0.924	0.718	0.664	40	0.989	0.822	0.813
15	1	0.674	0.674	41	1	0.789	0.789
16	0.965	0.648	0.625	42	0.82	0.425	0.349
17	0.725	0.245	0.177	43	0.952	0.833	0.793
18	0.738	0.381	0.281	44	0.789	0.651	0.513
19	0.719	0.624	0.448	45	0.884	0.531	0.47
20	0.977	0.926	0.904	46	0.937	0.817	0.766
21	0.797	0.473	0.377	47	0.886	0.575	0.509
22	0.888	0.605	0.537	48	0.934	0.788	0.736
23	0.677	0.372	0.252	49	0.896	0.605	0.542
24	0.827	0.672	0.556	50	0.918	0.619	0.568
25	1	0.504	0.504	51	0.812	0.414	0.336
26	0.725	0.469	0.34	mean	0.867	0.632	0.561

If one considers how these scores relate to the industry in which Farmsecure grains were operating in for the 2011/2012 season, these scores were not to a large extent impressive. The mean Allocative efficiency of the farms was sitting at 63.2%, i.e. the average FOF farm lies

quite some distance from the production frontier as discussed above, suggesting that there are sufficient gains to be had should this allocative efficiency be improved. The low allocative efficiency score could be as a result miss-allocation of resources, which could present themselves as a result of moral hazards within and around the model. The above inference can be made because of the fact that if one considers the marketing aspect of the 2011/2012 production season one of the highest prices for maize was recorded in the history of South Africa. This should mean then that a low price could not be a factor in these low allocative efficiency scores.

Together with this fact is the fact that the level with which the farms operated at from a technical efficiency perspective was rather impressive, as this was between 83 and 90% depending on the models with which these scores were determined. These scores were calculated in such a way that the “quantities” of these inputs used were of a Rand per hectare amount. This makes the reduction or increasing of certain inputs possible, as this would allow a combination of a different formulation at a different price to be used so as to satisfy any agronomical norms, as well as satisfy the reduction of the cost of the said input. This would indicate that although there was room for improvement with regards to the reduction in the usage of certain inputs to generate outputs, they were generally efficient with only one or two outliers dragging the average score for the group down, the farms for the most part were producing at near an optimal level when comparing them between one another. This is to be expected, as a result of the level of expertise provided for these farms throughout the production season.

The allocative efficiency scores obtained in table 14 are correlated against the returns these farms made using Pearson’s Correlation Coefficient. This was calculated as a percentage that is total income less expenses, divided by the expenses. Table 15 gives an indication of the results obtained using Pearson’s Correlation Coefficient.

Table 15: Pearson's Correlation Coefficient between Allocative Efficiency and Return.

Farmer	AE Score	Return	Farmer	AE Score	Return
1	6	17	27	51	50
2	19	24	28	14	4
3	33	35	29	26	29
4	38	40	30	7	32
5	36	21	31	25	36
6	32	39	32	35	8
7	4	3	33	10	14
8	18	30	34	40	10
9	1	18	35	15	7
10	16	15	36	27	13
11	47	51	37	3	12
12	44	47	38	13	28
13	20	37	39	41	45
14	17	9	40	8	22
15	21	25	41	11	11
16	24	27	42	45	26
17	50	48	43	5	6
18	48	43	44	23	2
19	28	31	45	37	49
20	2	1	46	9	23
21	42	34	47	34	33
22	30	20	48	12	42
23	49	46	49	31	5
24	22	38	50	29	16
25	39	19	51	46	44
26	43	41			
62.4%					

From table 15 it can be seen that there is a 62.4% correlation between the Allocative Efficiency scores and the percentage return. The t-ratio for Pearson's correlation coefficient is given by $t = \frac{r}{\sqrt{(1-r^2) \div (N-2)}}$ where N is the size of the sample, and r is the Pearson's product moment Correlation Coefficient. The calculated t-ratio is then 5.59 with 49 degrees of freedom. The tabulated t-value is at a 1% significance level is 2.68, since the calculated value is greater than the tabulated value we can conclude that the Pearson's Correlation Coefficient is significantly different from zero at a 1% level of significance. The interpretation of the above results are then that there is a 62.4% chance of having a low return if there is a low allocative efficiency score.

That would suggest then that an increase in Allocative Efficiency would result in increased returns for the various farms. It is important to note in this instance however that the exact level of Allocative Efficiencies could not be determined as a result of the fact that the data was not in a suitable format (quantities and prices) for the various statistical models. This however does give some statistical evidence that these two are correlated, and it could be viewed as a perfectly acceptable method of determining these scores, as this measure uses linear programming and considers all of the costs into production from the company's perspective so as to maximize profits. This would therefore give an accurate representation to the true underlying cause of the low and in most cases negative returns achieved by the farms.

The next section of the dissertation will then discuss the findings of both the technical and allocative efficiencies, and what impacts these results have on the model. It will also consider the implications of the above findings on the model. These findings will be used to try and identify possible principle agent issues that present themselves as moral hazards within the model. The incentives the farmers are faced with will also be scrutinized to possibly identify

how these incentives might be encouraging these moral hazards. Lastly using the findings in the above analysis as well as those found by Van Zyl (1996) will be used to discuss Allen & Lueck (1998) findings on the smaller family farm and the inability to corporatize because of the inability to specialize., this will be done with the help of Sender & Johnston (2004) paper on Land Reform in Africa where they argue against the Inverse Relationship, as a reason for Land Redistribution in Africa.

Chapter 5: Discussion

5 Discussion

After having performed the empirical analysis in the previous chapter it was determined that these farms operate at high levels of technical efficiency, while for the most part the allocative efficiency with which these farms operate is rather poor. The identification of factors that lower this allocative efficiency is of utmost importance in trying to find viable solutions to the issues hampering these farms. It is therefore important to study both the technical as well as allocative efficiency as these are both pre- and co-requisites for economic efficiency. The technical efficiency with which these firms operate is according to Allen & Lueck (1998) expected to be low because the production cycles of these farms are characterized by few cycles, with many stages i.e. crop farming.

Contrary to Allen & Lueck (1998) argument and rationalization, the technical efficiency of these farms was found to be on average 96%⁴¹. This high level of technical efficiency would suggest that the production technologies were relatively homogenous for these farms. This finding was expected because of the fact that the majority of these farmers used technical field agents, which specialized in fields such as Agronomy and Soil Science, for the production as well as Trading and Hedging for the marketing of the crop. These specialists were hired by the company and organized in a hierarchical fashion and provided extension services to the farmer. Therefore the farmer only had to supply his management skills to the farm by making production and timing decisions for the general management of the farm.

5.1 Technical Efficiency and Transaction Costs

The way in which the farming model was set up was such that individual farmers would partner up with Farmsecure. This would suggest that all farms in the model would have the ability to take advantage of being large and therefore have “economies of size” to their advantage. The benefits of being larger than a certain size lay in the concept of “economies of size” as discussed in the literature review. These benefits imply that the farms have the ability to reduce their transaction costs by reducing several costs which include the costs of finance as well as the cost of inputs by receiving certain discounts on purchased inputs for these farms.

An equally important benefit of being larger than a certain size is the ability of these farms to take advantage of the various technologies available in the agricultural industry in the present day. Machinery is an important part of the technology of the modern day farmer and is often given as a reason for the increase in yields of these farms. This is said to be largely as a result of the advent of Global Positioning Systems (GPS), which gives the farmer the tools to monitor and reduce input costs as well as identify other problematic areas of the production stages such as soil deficiencies⁴².

⁴¹ This was determined using the DEA VRS method while the SFA method gave an average efficiency of 85.7%, please see chapter 4 for an explanation of the advantages and disadvantages of the various methods used.

⁴² These Soil deficiencies can be identified through yield maps, they do however need to be examined by an industry specialist to determine the cause. The GPS technology therefore supplements the specialist’s advice.

Machinery alone however does not imply increased yields rather it is the combination and management of all production process that increase yields. The improvement in the mechanical technology concerned with this, is the ability to monitor the machines and their efficiencies with which they are operating. It could be argued then that the manager has excess time, for example time that used to be devoted to fixing and monitoring machines, which can now be devoted to another task. If each task in production is stream lined and made efficient, then the farmer will have all his time to just manage and delegate tasks. Therefore one could say that the manager with the aid of technology and services can now specialize in the day to day planning and general management of his/her business.

Another important benefit of being larger than a certain size is that these farms could access the services of industry specialists in both the production as well as marketing phases of their production cycles, to such an extent that these farmers can hire specialist's services from the market place for all the tasks that might require certain specialist knowledge. However for the most part it would be these larger farms that would be able to take advantage of their size, such that their transaction costs in obtaining and making use of technological developments and specialists within agriculture would be reduced. Throughout the literature this is an often argued point against the existence of there being an "Inverse Relationship" between farm size and efficiency.

The benefits that "economies of size" infer for these farmers are an important explanation for the often noticed trend of increasing farm size. Perhaps Balmann (1999) notion of their existing a path dependence in agriculture such that the larger farms will continue to grow larger while the smaller farms will continue to decrease in size would be an appealing explanation except for the fact that this notion does not take managerial ability into account. Management's ability would seem to have an impact on the negative effect of random shocks, such that superior managers would have the ability to better prepare for random shocks while less competent managers would not. The result would be that the farmer's management ability to account for these shocks would result in the size of the farm increasing. Within the literature it is argued that this is as a result of the farmers desires to earn an income that is comparable to incomes from off-farm activities.

It is argued then that if the level of the Technical Efficiency (TE) with which the farms produce at is high, one could conclude that some form of specialization must have been attained either in the management of the cycles or the stages. This is because of the fact that many of the stages in production can be hired out to specialists in the market place. The findings would then suggest that contrary to Allen & Leuck (1998) argument for the lack of ability of the farmer to specialize, with sufficient market access these farmers would have the ability to specialize⁴³. As such, one could argue that it is not the technical efficiency (TE) which was 96%, that would encourage the form of organization chosen rather it is the Allocative Efficiency (AE) and economic efficiency (CE), which was 63.2% and 56.1% respectively, that would have a larger bearing on the organizational form chosen. Throughout

⁴³ Specialization in this sense would refer to the farmer's ability to specialize in the management processes and decisions on his farm, due to the fact that he can hire industry specialists from the market place to advise and maximise production on his farm.

the literature it is suggested that this dominant organizational form is the owner-operated farm. A widely discussed reason for this is that the family owned farm avoids the moral hazard as the family are the residual claimants to profit and would not have any incentives to shirk.

The moral hazard as argued by Allen & Lueck (1998) would still be present in the sense that the behaviour of the contracted parties would respond to various incentives created by the contract between them. This moral hazard could be as a result of adverse selection, in the sense that the parties had information not known by the other party which would have an impact on the outcome of the contract. This incentive to misrepresent information and shirk according to Liefert (2005) resulted in poor decision making by the managers and subsequently lowered the allocative efficiency of the Russian corporate style farms. The reason given for this was that the objectives of the farm managers were to achieve mandated output targets and not maximize profit. The success of the corporate organization in the production of grain then seems to be hampered by certain increased costs which manifest in the form of principle agent issues resulting in there being an incentive compatibility issues between the principle and agent. These issues will be discussed next.

5.2 Allocative Inefficiency and Agency Theory Approach

When uncertainty and complexity of the production process increase so too does the difficulty of predicting what performance will be desirable and contracting becomes a very complicated process (Roberts & Milgrom, 1992). The complexity in structuring these contracts could possibly be the result of a principle agent issues in the form of a moral hazard between the two parties, in the sense that the owner (principle) cannot determine if the manager (agent) is maximizing their own self interests. This post contractual opportunism could be lowering the allocative efficiency scores and would arise because of the fact that the contracts between the parties are incomplete. This contractual incompleteness is perpetuated by the complexity and uncertainty in the production of these field crops⁴⁴.

The level of completeness of these contracts involves the tradeoff between *ex-ante* costs of crafting more detailed contracts and the *ex-post* costs of inefficiencies (Chiappori & Salanié, 2002). These *ex-ante* costs could arise in situations of incomplete information, the detection of which is complicated and reduced by uncertainty and complexity of the process involved. The *ex-post* costs of inefficiencies on the other hand would increase with the likelihood of opportunistic behavior. These *ex-post* costs of inefficiencies are influenced by the nature of the production and the inability to detect amoral behavior by the agent.

The Agency theory in this situation is used to explain the negative impact this amoral and opportunistic behavior has on the incentives for the farmers, which could have negative effects on the efficiency with which these farms operate at. While the technical efficiency scores were high, the economic efficiency scores were rather poor. This economic efficiency score is calculated as the product of the technical efficiency and allocative efficiency scores. It is therefore these allocative efficiency scores that would therefore have a larger bearing on

⁴⁴ Grain farming especially in dry land production is filled with this uncertainty in the form of random weather shocks, while at the same time it is an extremely complex production system that relies on the simultaneous interaction between many different aspects.

the profitability of these farms. This was shown by the high level of correlation between the allocative efficiency and the return of these farms from the company's perspective.

When one considers the return and variables to include in the calculation of the return it could be assumed that the construction thereof is a lot easier for a company renting land than for an individual that owns the land. This is because of the fact that the company does not view variables like land as an asset rather it views it as an input into production. Therefore the company finds certain characteristics in certain districts and chooses the farmers that match their requirements, consider the land for example. The company pays rent under all circumstances; the only aspect that differs is the amount of rent that is paid, as well as the area rented.

While the organization makes use of the local managers, they do not allow these farmers autonomy in the implementation of these production plans and the local managers are in many instances required to just oversee the various operations. This is because of the fact that the majority of the production and marketing decisions are made by the company and the specialists the company employs. As such, there are various instances where there are considerable incentives for the farmer or agent to fulfill his own self-interests above those of the company. These incentives for the most part are as a result of the complexity and unpredictability of the production process, which reduces the ability to monitor and subsequently reward or punish unfaithful partners. There is thus a need for formal mechanisms to enforce these agreements between the company or principle and agent or farm owner in this instance.

These counter-productive or negative incentives in this instance are thought to arise from pre-contractual opportunism of the farmers in the sense that there is adverse selection, and secondly in the form of post contractual opportunism in the form of a moral hazard between the principle (company) and the agent (farmer). These two phenomena are both thought to have an effect on the allocative efficiency with which these farms operate at from the company's perspective. An appealing way to consider this is that since the company hires both the land and general management from the farmer as well as pays for all of the inputs used in production one could consider these as inputs into production which would suggest that there is an optimal proportion of the input required such that the output is maximized⁴⁵.

There are various moral hazards that seem to dominate the model, and for the most part these are thought to be as a result of there being adverse selection in the screening process for these farms. Below is a discussion of firstly this adverse selection followed by a discussion of a few of the most important moral hazards and incentive issues these farmers face.

5.2.1 Adverse Selection: Farmers in the Model

The adverse selection in this sense would be related to the quality of firstly the land the farmer owns and secondly the management ability of the farmer joining the model. If there was adverse selection one would expect the land quality to have a positive and somewhat large correlation to the price paid for the rental of the land. However this is not the case and it

⁴⁵ Refer to the motivation for the use of the cost function used in the calculation of the Allocative Efficiency using the program DEA in Chapter 4.

could therefore be assumed that there are other factors guiding the company in choosing farmers for their model, and this is thought to result in adverse selection. This adverse selection is initiated by the company through their desire to farm in any specific area because of geographical risk, with a specific farmer possibly because of the prestige of having the farmer in the model or alternatively the company's belief in forging a beneficial relationship with the said farmers.

This is an argument that can be made because unlike farmers who have a fixed and given resource the company chooses whether or not to rent any specific piece of land. The price the company is willing to accept is just as much a function of their willingness or desire to farm in a specific area with a specific farmer as it is to get good quality land in their model. While both of these factors, i.e. obtaining good "quality land" or good "quality farmers", could generate the adverse selection the one that carries the most weight in the decision is the one generating the adverse selection. This can be seen from table 16 below which shows the correlation between the prices paid for land, as well as the correlation between the size of the farm and the rental paid. If the potential yield that is obtainable for a given piece of land is a measure of the quality of the land, then one would expect farms with higher Long Term Average Yield's (LTAY's) to have higher rents as a result of the assumption that the quality of the land is superior to that of a farm with a lower LTAY's.

If one looks at table 16 it can be seen that using Pearson's Correlation Co-efficient this is not the case. There is only a 2.79% correlation between LTAY and rent paid for the land. Rather there seems to be a larger correlation between the farm size and the rental paid (17.09%) which would seem to indicate that it is not the LTAY that drives the price of rent, rather other factors such as those mentioned before. This would suggest then that the contracts are given out endogenously as opposed to exogenously as often assumed throughout the literature. An interesting point in table 16 is that the yield is positively related to size. This could be either because of the fact that one could assume that better manager would be on larger farms through evolution. However these farmers are all under the same management teams and it is therefore more likely that these farmers use more advanced technology which they have access to because of their size.

Table 16: Pearson’s Correlation between Rent, Yield and Size

Provi	District	Farmer ID	Size Rank	Yield Rank	Rent Rank	Province	District	Farmer ID	Size Rank	Yield Rank	Rent Rank						
WF	Sasolburg.	23	1	40	12	EF	Bethlehem.	6	25	12	36						
NW	Schweizer-Reneke.	37	2	7	9	WF	Bultfontein.	10	26	24	22						
NW	Schweizer-Reneke.	27	3	14	44	WF	Hoopstad.	43	27	19	19						
NW	Vryburg.	12	4	16	24	WF	Welkom.	38	28	36	46						
EF	Frankfort.	47	5	42	8	WF	Hoopstad.	8	29	18	23						
NW	Vryburg.	15	6	20	18	WF	Bultfontein.	9	30	28	47						
NW	Wolmaransstad.	44	7	5	40	EF	Frankfort.	46	31	37	39						
EF	Vrede.	25	8	34	6	WF	Wesselsbron.	31	32	32	27						
NW	Lichtenburg.	35	9	45	26	WF	Wesselsbron.	45	33	30	34						
NW	Schweizer-Reneke.	13	10	21	7	WF	Marquard.	3	34	46	13						
MP	Ermelo.	2	11	13	37	EF	Reitz.	36	35	33	41						
MP	Balfour.	7	12	4	2	WF	Bultfontein.	41	36	25	11						
WF	Vijjoenskroon.	30	13	6	21	EF	Reitz.	21	37	43	33						
WF	Ficksburg.	5	14	35	15	WF	Koppies.	29	38	17	31						
NW	Lichtenburg.	1	15	41	28	EF	Bethlehem.	17	39	38	42						
MP	Middelburg.	39	16	15	16	EF	Frankfort.	18	40	39	1						
WF	Hoopstad.	11	17	23	3	MP	Vryheid.	34	41	10	38						
MP	Bethal.	4	18	31	43	MP	Carolina.	33	42	9	17						
WF	Winburg.	16	19	47	20	WF	Bothaville.	32	43	22	4						
WF	Clocolan.	24	20	44	45	WF	Wesselsbron.	20	44	26	30						
WF	Hoopstad.	14	21	27	14	MP	Ermelo.	40	45	1	29						
MP	Balfour.	22	22	8	5	WF	Hoopstad.	19	46	29	10						
MP	Middelburg.	26	23	3	25	EF	Harrismith.	28	47	11	35						
WF	Hoopstad.	42	24	2	32												
Pearsons Correlation Co-efficient																	
Yield and Rent			2,79%			Size and Rent			17,08%			Size and Yield			19,21%		

The low correlation between the yield and rent or the size and the rent, it would seem to suggest that perhaps yield was not the most important factor in choosing these farmers. It would rather seem as if the size of the farm, where the farm was and who the farmer was would have an influence on the farmers being chosen for the model. Therefore one could assume that the company’s desire to farm in a specific area with a specific farmer suggests firstly the contracts are given out heterogeneously and secondly there is adverse selection in choosing these farmers. This adverse selection would therefore contradicts the conclusion that the contracts are given out randomly, rather they are given out based on the company’s belief that they can maximize their profit from that given relationship.

Imperfect information of the farmers however limits the ability to choose these partners by sending false signals to the company. Figure 3 depicts a scenario where farmers have been assigned to various quadrants according to their soil quality’s and their management abilities. For simplicity this figure draws on the assumption that there are two types of soil and two types of farmers within a farming district, and these are divided equally throughout the district. The second assumption is that farmers in quadrant one are assumed to be more risk neutral, while farmers in quadrants two to four are assumed to be risk averse such that they would seek arrangements that would minimize the variability of their income.

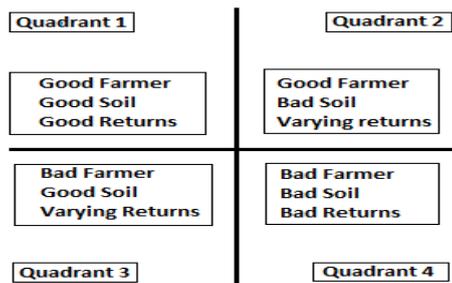


Figure 4: Farms and Farmers within any given district

If for simplicity these farmers and soil qualities are assumed to be in equal share, i.e. 50 % good and bad farmers and 50% good and bad soil, so there would be a situation in which there are;

- 25% in Quadrant 1,
- 25% in Quadrant 2,
- 25% in Quadrant 3,
- 25% in Quadrant 4,

Assuming the farmers all have the equal incentive to join the model, statistically one would have a 75% chance of getting farmers from quadrants two to four in the model and only 25% chance of getting farmers from quadrant one in the model.

This has been shown in the calculations carried out by the DEA program. It was shown that there are 32 farmers with increasing returns to scale (farmers from Quadrants two or three) the increasing returns to scale. This could suggest that the managers are good as they have applied the right amounts of inputs, but have not kept up with technological trends, even though their soil quality does lend itself to this level of technological commitment. The other possibility is that the farmers have good soil quality, but are using too little inputs as a result of poor management. There is one farm with decreasing returns to scale and this farmer is likely to be in quadrant four as he has either over capitalized in technology, as a result of poor soil, as well as applied to many inputs as a result of their poor management abilities. Lastly there are 18 farms with constant returns to scale, suggesting these farmers have applied the right level of inputs as well as adopted the right level of technology as a result of their management abilities as well as soil qualities. This result would not vindicate that these farmers are from quadrant one because it is equally likely that farmers from quadrants two and three could have favourable conditions in the year studied.

Rather the incentives for joining the model would be related to the farmer's belief in their ability to do better with or without the model, stated in another way a function of the farmer's attitude towards risk. That is if the farmer believes he can do better on his own, as is the case with the farmers in the first quadrant, they will have a less of an incentive to join the model. Should these farmer's join the model the company would most likely find that it is paying too much to these farmers, as they would want to receive more from the model than they could on their own. This is as a result of the assumption that individuals are profit maximizing.

Should this be the case it would be safe to assume that the company is either paying too much for the land in cases where farmers have poor land quality, the farmers in this quadrant would have the incentive to overstate the quality of their land so as to be accepted into the model. Or the farmers would inflate their management ability which would mean that the company is paying too much for the farmer's management, as in the cases where the managers of the farms are poor. Or lastly they are over paying for both land and management in the case of farmers lying in the last quadrant. Although the company have tried to give the contracts out randomly there has possibly been unintentional adverse selection as a result of the unobservable imperfect information these farmers have prior to joining the model.

A possible solution would be to offer a fixed level of land rent per unit of output produced. This value would have to be high enough to allow for farmers in quadrants 2 and 3 to join into the model, as it would seem in either of these cases either the negative effects caused by either land quality or management ability could to a certain extent be ameliorated by the high level of technical ability within the company. The price should also be low enough so as to be able to exclude the farmers in the quadrant four, as these farmers would generally not be beneficial for the company. Farmers in quadrant one, like mentioned before might be willing to join the model, and this would be a reflection of that farmer's belief in his abilities. The price set per unit output should not be planned around attracting those farmers to the model, for the obvious dangers of paying too much to the farmer.

This method of land rent would then seem to act as a quality adjusted value for paying the rent, and the best land would then cost the most therefore the rent would be determined on the productive capacity of the land, and not the district in which the land is situated in per se. Because of its allocation of risk, the model would suggest that farmers in Quadrants two to four would most likely join the model, as they are then suddenly guaranteed constant returns while the company carries the possibility of varying returns. Therefore the company is effectively taking the risk away from the farmers, and placing it upon itself which could lead to a sub-optimal outcome for the company resulting in an almost unavoidable moral hazard.

5.2.2 Agency Theory

It would seem then that it is these costs that would have a large bearing on the model, as in many cases the means with which these payments are determined as well as structures that are put into place result in a moral hazard. It was shown that the farmer has the incentive to overstate the quality of his land by means of falsely reporting his Long Term Average Yield (LTAY), as well as his fleet of machines and the costs thereof. It is also in the farmers best interests to overstate firstly his costs with regards to amounts payable directly to him viz. labour and other inputs that FOF does not have direct control over, such as diesel. All of these factors are extremely difficult to monitor, and would therefore result in large monitoring costs for the FOF model, as was the case with the Bonanza farms mentioned in the introduction.

5.2.2.1 Moral Hazard: The Case of Inputs

As a result of these difficulties in monitoring the farmers there are often incomplete and unenforceable contracts. This occurred in this case and resulted in a moral hazard between the principle which is the company and the agent or the farmer. This moral hazard could stem

from the selection process in the form of imperfect information that the farmers have about their land quality as well as their management ability, the price and quantities to be announced would therefore be based on the planners incorrect estimate. The result is then that there is a possibility of self-interested misbehaviour that generates the moral hazard problem which according to Roberts & Milgrom (1992) limits the contracts that can be written and enforced between the principle and the agent..

Throughout the literature it is argued that the use of prices to co-ordinate behaviour avoids any loss on account of imperfect cost estimates. In other words the fixing of prices performs better than fixing quantities. This is an interesting point with regards to the FOF model, which is often guided by the LTAY as the desired level of output quantity per hectare produced. This resulted in a similar situation as those of the soviet farms (Liefert (2005) and Roberts & Milgrom (1992)) in which the farmers jobs were made easy by adopting wasteful production plans.

5.2.2.1.1 Management Fee

In order to motivate the farmers to achieve this level of output the company used a management fee per ton of grain produced from a given piece of land. No matter what the production was that was generated from the farm, a fixed amount was to be paid out on the expected yield which was based on the LTAY for that farmer⁴⁶. The moral hazard was then imbedded in the fact that these farmers would overstate their management ability and use excessive amounts of inputs to produce these outputs. This moral hazard would then seem to have a direct impact on the allocative efficiency as a result of the wrong proportions of inputs being used.

If the farmer had *ex ante* imperfect information on the quality of his land as well as his management abilities such that he misrepresented his LTAY, *ex post* there will be a situation in which the farmer has the incentive for self-interested misbehaviour in the sense that any under production could be blamed on a number of factors that are extremely difficult to monitor. There thus seems to be little motivation to produce more than the LTAY and the management fee in this instance could be creating an incentive to miss-represent the farms LTAY. However it is also likely that the management fee structured in this way has a disincentive for excess effort.

This could be the case when high rents are being paid to the farmers for soil and equipment, as the level of profit that they could be expecting from a hectare of land could already be exceeded (exceeding their utility curves) with the rents they receive. They would therefore be indifferent to the income generated from a 7 ton yield as opposed to a 6 ton yield while this is very much the opposite for FOF.

However these management fees are beneficial to both the farmer and the company, especially in the sense that they firstly attract farmers to the model suggesting that better

⁴⁶ This management fee was structured in such a way that 2/3 of the management fee was paid out prior to harvesting. In the event of the farmer producing less than the management fee owed to him because of a poor yield the company had no recourse against him and could not demand the excess monies back, they would however not pay the final third over to the farmer.

managers with better soils and higher beliefs in their abilities would join the model and secondly they can create an incentive to produce more profitably. How these management fees are structured and paid out however could be the most important factor affecting the different incentives these farmers are faced with. The incentives for the farmers to produce could be paid out in a sliding scale format, i.e. if they make x% profit then they receive y% of the profit as a management fee or a bonus so that the higher the level of production the higher the level of reward. As such, it would seem to be better to make this incremental increase in payment to be in line with profits rather than production, as it is the profits at the end of the day that are important to the company.

Management fees that would reward and motivate the farmers for higher yields and punish farmers for unprofitable production will create a positive incentive for the farmers to monitor their input costs as well as generate higher yields and profits. This could greatly improve the profitability of the model. If the management fees do not act as a disincentive to using excess levels of inputs, as was the case during this study, there will be a situation in which the farmers overuse inputs to produce mandated levels of outputs. This is discussed in the following section with help of the on farm employment as an example.

5.2.2.1.2 On Farm Employment

A possible explanation for the farms poor allocative efficiency scores could be as result of over paying on certain fixed costs of the model, viz. Labour, Management Fee, Land Rental etc. it would seem then that it is these costs, which are possibly generated by moral hazards of the principle agent nature⁴⁷, that are hampering the profitability of the FOF model. In some instances it would seem, with the fortunate power of hindsight, as if the incentives for the farmer to produce as well as operate within the model could be counterproductive with regards to the ideals of FOF, in achieving both sustainability and profitability in agriculture.

Let us consider labour, the same can be said for the majority of the fixed costs for the company such as rent etc., as an example of this statement. Let us assume that the labour multiplier⁴⁸ is 0.01 people per hectare, and the average farm laborers wage is at R 2500 per month, the per hectare cost of labour would be R300⁴⁹ per hectare regardless of the size of the farm. If one then considers the section of the contract devoted to the employment of labour. The employees of these farmers were to be paid by the farmer who would then be reimbursed by FG. This in short meant that the farmer would be responsible for the employee's and FG would foot their labour bill.

⁴⁷ Refers to situations in which one individual (the agent) acts on behalf of another (the principle) and is supposed to advance the principles goals. The moral hazard problem arises when agent and principle have differing individual objectives and the principle cannot easily determine whether the agent's reports and actions are being taken in pursuit of the principles goals or are self-interested behaviour.

⁴⁸ (Bureau for Food and Agricultural Policy (BFAP), 2011, p. 88).

⁴⁹ R 2500/ month = R113.63/ day well above the minimum wage. Then the per hectare cost would be equal to $(R2500 \times 12) \times 0.01 = R300 /ha$.

Table 17: Actual Spending on Labour (R/ha)

Farmer ID	Actual (R/ha)	Farmer ID	Actual (R/ha)	Farmer ID	Actual (R/ha)
1	R 727.81	18	R 563.20	35	R 371.51
2	R 370.65	19	R 288.56	36	R 370.43
3	R 309.96	20	R 407.38	37	R 1 017.00
4	R 273.32	21	R 354.44	38	R 691.52
5	R 458.08	22	R 456.28	39	R 214.37
6	R 366.31	23	R 384.03	40	R 586.97
7	R 425.21	24	R 511.81	41	R 597.58
8	R 481.19	25	R 408.23	42	R 368.82
9	R 389.33	26	R 270.71	43	R 369.26
10	R 162.76	27	R 135.14	44	R 402.42
11	R 143.80	28	R 567.15	45	R 567.06
12	R 393.12	29	R 237.83	46	R 234.84
13	R 737.82	30	R 767.32	47	R 212.73
14	R 676.88	31	R 503.76	48	R 483.93
15	R 187.47	32	R 391.04	49	R 381.32
16	R 556.71	33	R 323.75	50	R 555.03
17	R 317.58	34	R 275.83	51	R 221.78

The moral hazard that presents itself would have a large bearing on the costs for these various farms. In the worst case, if one considers the possibility that the farmer is dishonest he will have the incentive to overstate his labour bill on the farm thus acting as a broker to FOF in the whole situation and making a direct profit for brokering labour to FG. The alternative and more likely scenario would be that such farmers would have an incentive to have labour intensive enterprises on the farm such as dairies, feedlots or even cattle⁵⁰ enterprises. If this is the case the value of labour that is normally spent on these other enterprises is now received at no cost, as FG bears the labour costs as well as the risk. The per unit costs for each farmer to the company is now higher, as he has hired labour to such an extent that the marginal cost of producing that “private unit” has effectively been driven to zero. This is indicative of most of these costs that are difficult to monitor, and therefore present themselves as moral hazards within and around the FOF model.

There is this increased incentive to shirk because the benefits from shirking are higher than the benefits of not shirking⁵¹. This is because of the fact that the chance of being caught is low because of the need for high monitoring and transaction costs, the contract between the parties is therefore for these reasons difficult to enforce. The smaller family owned farms on the other hand rely on family contracts, and one could therefore conclude that they are not under the same constraints. It is for these reasons one would expect the allocative efficiency scores to be higher for the family owned farms as the owner operated farm is often not faced with these same incentive issues and moral hazards.

⁵⁰ The BFAP labour multiplier for a cattle enterprise is roughly 0.015 (Bureau for Food and Agricultural Policy (BFAP), 2011, p. 88), this would mean a per hectare cost, using the same reasoning as above of R 450/ha, that is an increased overall cost to the model of R 15 000 000.

⁵¹ For example if managers were to hire additional land on behalf of say a company, if the farmer gets rewarded for the level of land farmed. Due to the moral hazard between the principle and agent in this instance one would not expect the manager to hire the best land as it is in their interests to hire any available land as they receive additional benefits for doing so.

5.2.2.1.3 Horizontal Integration

An argument for these corporate farms is their ability to horizontally integrate in the sense that the company, because of its size, has the ability to own amongst other things input companies so that they can supply the farms with the necessary inputs. This is thought to be beneficial because of the fact that these farms could now receive and use these inputs at a discounted price, and have the specialist knowledge and services that come with these inputs. Therefore by owning these input companies, each stage of production is organized as a separate firm and the transactions between the stages are intermediated by the market (Roberts & Milgrom, 1992).

This is happening but company seems like it is trying to manipulate the market to suite themselves⁵² thus the stages between production are not being intermediated by the market. Rather they are being controlled by the company and the company with the strongest will, will survive and dominate the other companies. The “economic activity” within the company is thus approaching the extreme where all transactions are made at an arms-length basis. While this is true for the inputs, this is not the case for the outputs and here the company faces significant competition. This is because the company does not produce a large enough amount of maize so as to have an influence on the market.

It would seem as if there is a significant moral hazard for the company and its subsidiaries. On the input side the input specialists such as the area specialists have the incentive to sell expensive inputs to the farmer who does not have a choice but to use the inputs offered to him. This happens as a result of making one decision maker and taking away farm level market forces that are driven by price. Therefore co-ordination and any benefits derived from the free market in co-ordinating the firm is lost.

Consider the following argument. If you make the farmers buy inputs from your input companies, you firstly lose price competition and secondly you lose cost considerations as neither the farmers nor the agronomical team is co-ordinated nor motivated to maximise FG interests rather they are going to maximise their own interests, as now they are not co-ordinated through market forces, nor price but rather their own self-interests either in their personal capacity, fees the farmers receive. These farmers are not given the incentive to produce profitability rather they are given the incentive to produce maximally and this could result in the over use of inputs by the farmers.

The subsidiaries and the specialists have a reputation to build and uphold, and this could have resulted in them using inputs that negatively affect the allocative efficiency of the company, for example supplying unnecessarily expensive inputs to these farmers. If on the other hand these specialists had the incentives to over sell fertilizer to the farms because of sales incentives and kick-backs the moral hazard is obvious. With regards to the outputs the company had to trade in the open market and did not have an ability to affect or manipulate

⁵² By removing any competition via contractual obligations, the company is trying to act as a monopoly to their own farmers within the model.

the market⁵³. The result was that they to a large extent received for their maize what the normal commercial farmer receives for his grain.

This problem was perpetuated by a subsidiary that knew very little about farming and relied on the honest opinions and recommendations from their “partner’s” specialists. Because the final decision rested with the primary production subsidiary, this decision was made upon imperfect information that was fraught with moral hazard. This moral hazard in the production and decision making process resulted in these farms being allocatively inefficient.

5.2.3 Property Rights and Profit Sharing

From the data it can be gathered that the non-productive inputs (management fees, admin fees, rent (land and equipment), etc.) outweigh the productive inputs (fertilizer, chemicals etc.) by more than 100%. That is a farm with /ha input costs of R 11 500, will have “productive input” costs of R 5 100 and “non-productive input” costs of R 6 400. This is tantamount to fixed and overhead costs of 50% of the total income assuming the LTAY is 6 tons, and the maize price is R 2000, this situation gets worse if the yields and prices change. The proportions of these costs that are paid out to the farmer are of great concern, as this could have to some extent become the level at which these farmer would want to be compensated at in order for them to remain in the model.

A reduction in these costs is imperative especially since these costs for the most part are not coupled to output nor prices received for the output. They therefore pose a grave threat to the sustainability of the model, in situations of either low prices or low yields such as in cases of drought. The difficulty in this arrangement is firstly the risk and the reward for risk and secondly the issue of property rights in the sense that the farmer owns the pre-requisite to production and the only fixed assets. Even though the company takes all the risks of production by hiring the fixed factors of production and paying for all of the intermediate inputs, the company is not the residual claimant to profit because they do not own any of the fixed factors of production. This type of fixed rent production contract in this sense does not seem to attract equal rewards for risk and a type of share crop or profit share arrangement might work better.

Profit sharing would to an extent reduce these costs. However the costs such as land and machinery rent cannot be ignored, and would have to be paid to the farmer. If one were to view these costs as the contribution being made by the farmers to the costs of producing the output, this would propose an equitable means to the costs incurred by both sides and therefore risks, which would require an equal level of compensation, incurred by both sides. That is say for example the inputs cost R 6000, and the rent amounted to R 900 (150 x 6), and the machinery rent was R2000/ha, then the total costs for producing a hectare of maize would be (R 8900).

The farmers contribution towards the production could then be the rent of the land as well as the rent of the machinery towards the production of the output (i.e. in this case R 2900/R8900), and that is the share of the profits the farmer should receive as a reward for his risk

⁵³ They produced less than 5% of the country’s maize crop. This is assuming that the countries maize crop was at 12 million tons.

in producing. The management fee to be paid on the sliding scale of incentives then could be determined by calculating the farmer's percentage contribution towards production, and this percentage value could be used to calculate the management fee to be paid to the farmer as a part of his incentives to produce. The exact level of the contribution towards the total costs would need to be determined, and the profit to be shared then should ideally be the level at which the contributions are made towards the total costs. Therefore an equitable arrangement could be achieved between the two parties concerned. Below is an example;

If the farmer were to contribute the value of his machinery say at R2000 per hectare, then his contribution towards the total costs would amount to 36% of the total costs of production (2000/9000). This value could then be paid out to him as his share of the profits, which are R 3200 after all the costs have been, subtracted (Inputs – R6000). This would result in a total amount of R 3117 being paid out to the farmer ($8.5\% \times R 3100 + R900 + R2000$), and a total amount of R 2883 being paid out to Farmsecure per hectare. Therefore the farmer makes a slightly higher profit than Farmsecure, this deficit from Farmsecure perspective could easily be made up in savings on the costs of certain inputs. The farmer on the other hand has more than an incentive to join the model, as he is in most cases receiving a more than adequate amount per hectare (R 2900 per hectare per season), and he has an incentive to produce larger outputs, as the benefit he gains from doing so would become greater and greater, one could assume that the farmer would want to increase his efforts so as to increase production, that he can reap higher rewards for doing so.

Within the theory, if the firm uses a production contract it should not try an intermediate the various stages of production as this results in increased transaction costs and moral hazards because of the difficulty and expense of monitoring the agent's actions. Therefore if the model were to follow the above means, it would be suggested that the ultimate decisions as to which types of inputs to be applied as well as at what cost should be made by the farmer. These "options" of which inputs should be used should be made by specialists, as they have the correct technical skills to make such suggestions. It would thus be recommended that the specialists recommend various options to the farmer who then has the option, under cost consideration, to choose which one is to be used in the production process.

It is recommended in this fashion because of the fact that the farmer now has the incentive to maximize profits, and it would be assumed that they would then limit the spending on unnecessary inputs. They would thus act as the policemen in the whole scenario and this would in turn reduce the transaction costs incurred by the company to monitor all these steps into the production process. One would also assume that since the farmers have been on the farms for such a length of time these farmers would be the most qualified on their specific farms to make such decisions. This would also seem to reduce the chances of a moral hazard presenting itself between the farmers and the company.

Chapter 6: Conclusion

6 Conclusion

As was determined using empirical analysis using both deterministic as well as stochastic measurements the technical efficiency with which these farms operated at was relatively high which contrary to Allen & Lueck (1998) argument suggests that these farms have been able to specialize. If one considers the changes in technology since 1998 this inability to specialize (Allen & Lueck, 1998), might no longer be in place to the same magnitude they once were. In present times there are means and methods of tracking and recording almost every single aspect of production, and these are almost all accessible in the market place. One could deduce that the larger the owner-operated farm is the better access the farmer has to the market place, which would imply that the opposite might be true. This would be because of the fact that these larger egalitarian farms would benefit from aspect such as discounted transactions and better and cheaper access to credit. What results is a manager that has the ability to specialize in the production and operation of the farm, with the ability to make use of the services of industry specialists to specialize and advise on the use of certain inputs, this farm would have “economies of size”. Economies of size therefore seems to be an important factor in the modern day setting, and it can be argued then that commercial farmers who have the ability to access and make use of these technologies and markets can greatly improve their technical efficiency, and therefore productivity in producing outputs.

This argument is often found in the literature as a major benefit of the larger company over owner-operated farms. To such an extent that because of the size of some of these companies they have the ability to horizontally integrate which limits they need for perfect contracts as argued by Deininger & Byerlee (2012). Apart from the ability to horizontally integrate, because of the sizes of corporate farms they generally have the ability to access these markets and hire much of the work requiring specialist attention out to specialists in the field. This would suggest and was indeed shown that these larger corporate farms with their ability to adopt the latest technology have high technical efficiency scores such that there were not significant gains to be had by improving their technical efficiency. This was thought to be the case because by having agronomists and other field specialists under the company’s employment it was assumed that they would form part of the company and thus principles.

Rather it was the allocative efficiency and subsequently the economic efficiency with which these farms operated at that seemed to have a larger bearing on the profitability of the model. The owner-operated farm however does not suffer from this, as has been shown in numerous studies, simply because the owner-operated farms firstly have autonomous decision making rights and secondly they are residual claimants to profits. They will therefore not have the incentive to shirk or behave in an amoral fashion. The corporate, production contract farming model for grain farms on the other hand is fraught with opportunities for amoral and opportunistic behavior.

This is because of the adverse selection in obtaining farmers for the model and it was argued that there is an affinity for the company to attract farmers who seek to diminish their risk by

creating a situation in which they earn fixed incomes. The level of income the farmer desires as well as the amount the farmer would demand not to farm, would according to Stigler (1976) be a function of these farmers utility. That is some farmers would require more to give up their autonomous management rights on their farms, while other farmers would only require a certain level of income and not be to perturbed by giving up their autonomous management rights. It is this adverse selection then that opens the possibility for post-contractual opportunism in the form of moral hazards.

This was shown by the case of the rent where the farmers have the incentive to overstate both the quality of their land as well as management ability which resulted in many cases where the company were paying rents way above the soils productive capacity. If rent is viewed purely as an input into production⁵⁴ for these corporate farms then one could assume that there could be optimal proportions of land used in the production of outputs as such the rent being paid out would have a negative impact on the allocative efficiency if this amount is too high. These moral hazards seem to be imbedded in the fact that the agent and his utility function will have pre-contractual imperfect information as to their true expectations from and motivations for joining the model.

These moral hazards were perpetuated by the difficulty in effectively monitoring costs⁵⁵ and amoral behaviour. These moral hazards were highlighted throughout the discussion particularly in the examples of the on farm employment and the management fee. It was also argued that the specialists could have had the incentive for opportunistic behaviour. The already complicated process fraught with moral hazard and incentive issues is made even more complicated by property rights and the reward to risk. The result for these farms was therefore low allocative efficiency and subsequently economic efficiency scores which greatly reduced the returns for these farms and therefore for the company. This was shown using Spearman's Correlation Co-efficient, indicating that it is this allocative efficiency in the form of fixed costs to the company that limits the returns and therefore metamorphosis of owner-operated farms into corporations, and not the inability to specialize as argued by Allen & Lueck (1998).

The commercial farmer is not faced with these moral hazards and is therefore assumed to have the incentive to maximize profit by being allocatively efficient. While this data set did not contain any owner-operated private farms, it is believed that with economies of size these commercial farmers have the ability to access the market and latest technology which would increase their technical efficiency. Because of the allocative efficiency the increase in their technical efficiency would imply an increase in their economic efficiency, productivity and profitability. This could be because it would allow the various specific farmers the ability to "specialize" on their own farms where they would essentially act as specialist farm managers as such truly using their own farming management abilities. The continuous growth in size of

⁵⁴ It could be viewed as an input into production because the company can choose how much rent is to be paid and which farms they prefer, as is the case with fertilizer and other intermediate inputs where you can change the proportions and formulations.

⁵⁵ This difficulty in monitoring the actions and behaviour of the farmer as argued by Allen and Lueck (1998) is as a result of the influence of both random shocks and weather shocks and this results in the farms not being able to specialize in any aspect of their farming.

these farms could therefore be as a result of “economies of size” and the desire for these farmers to attain these economies of size such that the manager or owner maximizes their utility. In other words the good managers grow larger while the bad managers grow smaller and exit the industry, Deininger (2011) argues that this is because of the off-farm wage rate implying that utility is mainly derived from money and a monthly income.

Based on these results it would seem then that these farms with “economies of size” being a pre-requisite, do have the abilities to specialize in the production of these field crops which is an argument used for the owner-operated farm in Allen & Lueck (1998) study. Rather the difficulties of the model come into play with the motivational aspects of corporate farming which can be seen by the low allocative efficiency scores. In grain production autonomous decision making is of utmost importance because of the short cycles involved, this autonomous decision making in the corporate setting however is often limited by lengthy processes and applications and therefore struggles to alter input and output mixes with signals from the market. These stem from moral hazards between the principle and the agent and result in low allocative efficiencies for these farms. It is therefore argued that it is these inefficiencies that determine the organizational form chosen and not the ability or lack in ability of the farmer to specialize.

There are various limitations to this study, the majority of which stem from the data that was used. As a result of the data being collected for management purposes and decisions, the data was collected for financial reasons and not for the analysis of efficiency and much more information could have been gathered had the data been gathered specifically for these purposes. Another important issue with the data was that as a result of the data being only one dimensional, the year studied could have been a particularly dry or wet year which could have an effect on the results as no time trends can be observed so as to definitively establish trends and relationships, which would make the analysis less meaningful. The decision to use the data set however was made so as to perhaps find issues with the model, and was therefore making the best out of what was offered. Future research might want to include time series data as well as data from individual private farms and corporate farms to try and reliably replicate these findings and arguments.

This study is useful as it could be used as a background for studying these various relationships and their effects on the tendency for farming to remain in the owner-operated organizational form. Future research using a more complete data set containing time series could study firstly the relationship between allocative and technical efficiency and land ownership of these corporate farms, i.e. does the ownership of land reduce this adverse selection and moral hazards enough to improve these farms efficiency? Secondly to what extent these “economies of size” affect the farms ability to partake in the market place and the effects this has on firstly the technical efficiency of these farms and secondly the implications this has on the arguments for the Inverse Relationship? Lastly further research might want to analyze the impact of partnerships on economic (and allocative) efficiency, i.e. the farmer’s ability to choose optimal levels of inputs or outputs (cost minimizing or profit maximizing) for given prices?

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